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Sensory and Consumer Research for a Sustainable Food System

Edited by

Antti Knaapila

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Cover image courtesy of Antti Knaapila

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About the Editor

Antti Knaapila

Antti Knaapila, PhD, is a food scientist experienced in sensory and consumer research. He works as a University Researcher at the Department of Food and Nutrition, University of Helsinki, Finland. He completed his MSc (Food Chemistry) in 2004 and PhD (Sensory Food Science) in 2008, both at the University of Helsinki. After completing his PhD, he first worked as a postdoc for 2.5 years at Monell Chemical Senses Center (Philadelphia, USA), and then for 5 years at the University of Turku (Turku, Finland). Since autumn 2016, Dr. Knaapila has again been worked at the University of Helsinki, first as a University Lecturer, and recently as a University Researcher. His research interests include the chemosensory perception, eating behavior, and sensory evaluation of foods. His PhD and postdoc research related to smell and taste perceptions, as well as food neophobia; however, in recent years he has focused on sensory analyses of foods. Currently, Dr. Knaapila is involved in projects studying sensory properties and the consumer acceptance of novel plant-based alternatives to conventional animal-based foods (e.g., meat analogs). He also contributes to the teaching of Sensory Food Science and supervises students working towards their theses in the field.

Preface to "Sensory and Consumer Research for a Sustainable Food System"

In the future, the global food system must provide more food for the growing population. However, the contemporary food system has considerable environmental impacts due to the land and water use and greenhouse gas emissions driving climate change and biodiversity loss. To become sustainable, the food system needs changes not only in primary production, but also in food industry and consumer behavior. In the end, consumers have the key role: through their food choices, they direct the demand, and further, the supply for foods. Although availability and price sometimes limit food consumption to certain options, at other times, sensory properties (e.g., taste and texture) have a strong effect on food choice. Consumers'attitudes, values, knowledge, skills, and previous experiences on foods also influence eating behavior. Changing the food system will also require engaging consumers in changing their diets.

This book, reprinted from the articles published in the Special Issue "Sensory and Consumer Research for a Sustainable Food System"of the journal *Foods*, shows how sensory and consumer research can contribute to the development of a sustainable food system. In this book, the 18 original research articles of the Special Issue are presented first, followed by the 2 review articles. Within the research articles, those including sensory evaluation are presented first, followed by articles using survey or interview methods.

Environmental challenges such as the climate change and biodiversity loss are global and follow no borders. These problems also are best solved by global collaboration. The scientific community is used to everyday international collaboration, which is also displayed in this Special Issue. The authors of the articles, totaling 90, work at research institutes from over twenty countries, representing Africa, Asia, Australia, Europe, and North America.

I thank all the authors for their contributions and the reviewers for helping the authors to make their papers even better. I extend my acknowledgements to the personnel of the Editorial Office of *Foods* for the smooth process in compiling this Special Issue and this reprinted book.

Antti Knaapila
Editor

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Editorial

Sensory and Consumer Research Has a Role in Supporting Sustainability of the Food System

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How can sensory and consumer research contribute to the sustainability of a food system? This question was discussed in this Special Issue of *Foods* with its 20 articles, including 18 original research articles and 2 reviews. These articles showcase recent sensory and consumer research on the topic in a versatile way. We learn what kind of food ingredients and products have been of interest, which questions have been studied, which methods have been applied, and what were the results and conclusions. The contributions by more than 90 authors show not only progress in the field but also propose future directions.

The sustainability of a food system can be improved by many ways. A variety of approaches were investigated in the articles of this issue. One of the main topics was the sensory quality and consumer responses to novel alternatives to conventional animal-based foods. For example, plant-based meat and dairy analogues may help omnivores to reduce their consumption of animal-based food (i.e., to become flexitarians) and thus eat more sustainably, since plant-based foods are generally regarded as more sustainable than animal-based ones. The novel products covered in this issue include plant-based and insect-based meat analogues [1–3], plant-based cheeses [4], plant-based dairy alternatives [5], and beverages made of pea protein as the main ingredient [6].

Several articles of this Special Issue also studied novel aspects that can make conventional plant-based foods contribute to sustainability and biodiversity. These studies addressed sensory properties and/or consumer acceptance of fortified lentils [7], extruded snacks made of legume flour and bran [8], white vs. brown rice [9], heritage cereals such as spelt and emmer wheat [10], and non-thermally processed fruit and vegetable products [11].

Consumers' attitudes to various sustainable foods were investigated in several survey studies. Some of the studies focused on plant-based [2] or plant- and insect-based alternatives to meat [3], whereas others explored a wide range of sustainable foods and ingredients [12]. Modelling of data from consumer surveys was also used to study purchase intention for organic food in a discount setting [13] and the role of various factors on convenience food choice [14].

Consumers' actual food choices/liking were also studied in experimental settings with foods to be tasted or eaten. In one study, consumers' actual food choices and consumption were studied in an experimental lunch buffet in a multisensory environment [15]. Another study explored the impact of a "Mountain pasture product" claim on liking for cheese [16].

Minimizing food waste is another means to increase the sustainability of a food system. This aspect was addressed in studies on the acceptance of suboptimal citrus fruits [17] and unexploited, low-commercial-value fish species [18].

Topics of the articles in this Special Issue extend from foods to food packaging. One study explored consumers' perspectives on sustainable paper-based packaging in a qualitative study using focus groups [19], whereas another study investigated sensory characteristics and consumer preferences of the conventional vs. sustainable packaging [20].

A wide variety of research techniques were applied in the studies. Of the 18 original articles, nine (50%) reported studies that included sensory analysis (i.e., at least one sense was used to evaluate the samples) [5–9,15,16,18,20], seven (~40%) were survey studies based on paper-and-pencil or online questionnaires [2,3,10,12–14,17], and two (~10%) used qualitative focus group interview approaches [11,19]. Furthermore, of the nine studies that included sensory analysis, two studies exclusively applied analytical sensory evaluation techniques using trained or semi-trained sensory panels [6,18], six studies employed hedonic tests to assess acceptability using non-trained panels (consumers) [5,7–9,15,16], while only one study used both [20]. Methods used in the studies demonstrate that the usual techniques of sensory and consumer research are also applicable to research on sustainable foods.

Analytical sensory techniques were used in studies that aimed to characterize the sensory properties of the samples as objectively as possible. Cosson et al. [6] compared three different sensory profiling methods (static block profiling, mono-intake temporal dominance of sensations (TDS) profiling, and multi-intake TDS profiling) for studying pea-protein-based beverages, especially for their beany, bitter, and astringent notes. Their results showed that the different profiling methods provided complementary information on the sensory properties of the beverages. Of the used methods, the multi-intake TDS profiling resembled real-life consumption and thus could provide additional information about how consumers perceive foods.

Silva et al. [18] studied sensory properties of unexploited fish species from the Portuguese coast during a year using check-all-that-apply (CATA) methods tailored to each species. The authors found seasonal influence on sensory attributes in four out of the five studied species and made conclusions on what time of the year would be most favorable for catching a specific fish species in sensory quality's point of view.

Hedonic sensory tests were used in several studies. Oduro et al. [5] studied liking for a set of different plant-based milk analogues blending three plant beverages. They concluded that the multi-blend approach can be useful for improving sensory appeal and nutrient profiles as well as reducing over-reliance on a single plant material.

The fortification of plant-based foods for some nutrients may be beneficial for followers of vegetarian diets. Podder et al. [7] studied the effects of fortification with iron and zinc on liking for red and yellow lentils as uncooked and cooked among lentil consumers in Bangladesh, where the consumption of lentils is high. The authors concluded that, in general, the fortification decreased liking for the uncooked lentils, but not the cooked ones.

Proserpio et al. [8] studied liking for extruded snacks prepared with different ratios of pea and chickpea flours/brans blended with rice flour. In addition to hedonic value (measured using the Labeled Affective Scale, LAM) the consumer panel evaluated the samples using a CATA questionnaire with 23 sensory attributes. Using the combined data, the authors were able to conduct a penalty-lift analysis and show which sensory attributes significantly influenced overall liking. Moreover, the authors found that food neophobia was associated with lower liking for the novel snack products, particularly in women.

Gondal et al. [9] used a nine-point hedonic scale and just-about-right (JAR) scale to study consumer acceptability of brown and white rice varieties. The authors found that white rice varieties were preferred over their brown counterparts and that texture was the most important sensory attribute explaining the differences in liking.

Hoppu et al. [15] applied a sophisticated multisensory experimental setting for a lunch buffet to study effects of the eating environment to amount of food intake and emotions evoked. Compared to the control condition, the multisensory eating environment was rated as more pleasant and evoked more positive emotions, while no difference in food intake was found between the conditions.

Endrizzi et al. [16] studied the impact of external information, specifically a product claim "Mountain pasture product", on the overall liking for tasted cheeses (nine-point hedonic scale). The authors found that the effect of the labeling information on the liking was positive and associated with consumers' positive opinions with mountain pasture practices.

Lignou and Oloyede [20] used both analytical (trained panel) and hedonic (consumers) sensory analysis in their study on food packages. They employed several methods to study the sensory profile and consumer acceptability of sustainable paper-based packaging for two product categories (biscuit and meat). Both categories studied included a conventional plastic package and two or three paper-based prototypes. The authors concluded that while consumers were open to sustainable propositions, the design and size of the package were more important factors influencing consumer choice than the sustainable character of the packaging material.

Survey techniques were applied in several studies. These studies focused on revealing consumers' attitudes and responses to foods using questionnaires (without tasting). Wendin et al. [10] conducted an online survey to investigate different consumer groups' awareness, attitudes, and preferences toward heritage cereals such as spelt and emmer wheat in Sweden. Almost all respondents were aware of spelt, whereas the other heritage cereals (e.g., einkorn, emmer, Oland and Kamut wheat) were known by less than a half of the participants. Nevertheless, over 90% of the respondents expressed willingness to purchase bread made of heritage cereal.

Knaapila et al. [2] investigated millennials' attitudes toward plant-based meat alternatives using an online survey in Finland. The authors classified the respondents to six consumer segments based on the hedonic tone of their first associations to meat and plant-based meat alternatives. While the extreme segments strongly preferred either meat or alternatives to meat, the middle segments had positive or neutral attitude to both. These segments were concluded to be flexitarians or prospective flexitarians and the best targets for future interventions designed to reduce meat consumption.

De Koning et al. [3] conducted a large survey on consumers' attitudes toward and willingness to try and buy plant- and insect-based proteins in nine countries (Brazil, China, Dominican Republic, France, the Netherlands, New Zealand, Spain, the UK, and the USA, totaling 3091 responses) and analyzed the data using structural equation modelling (SEM). They concluded that behavioral intentions towards meat alternatives are inhibited by food neophobia but augmented by the perceived suitability and benefits of the protein (such as environmental impact, healthiness, nutritional importance, and sensory attributes).

Lundén et al. [12] conducted two online surveys to reveal consumers' perspectives on a variety of novel, and partly traditional but marginally utilized, ingredients and foods in Finland. The results showed that plant-based ingredients are preferred over raw materials of animal origin, including insects. The authors concluded that Finnish consumers are not ready to adopt insects into their diet and that consumers need more knowledge and experience on cultivated meat and 3D food to accept them in their daily diets.

Katt and Meixner [13] ran a survey in the USA to examine the factors that influence discount grocery shoppers' purchase intention for organic food, that is, usually premium priced compared to non-organic options. This study also employed SEM for data analysis. The results indicated that while price consciousness exhibited a negative relationship with the purchase intention, the impact of environmental concern, health consciousness, and hedonic shopping value was greater on the purchase intention of organic food than that of price consciousness (even in the discount setting).

Imtiyaz et al. [14] investigated the extent to which sensory appeal, nutritional quality, safety, and health determinants influence purchase intention, consumption, and satisfaction of consumers towards convenience food in India. Here, a purposive sampling method was used to recruit consumers of convenience foods. SEM was again used for data analysis. The authors concluded that, in emerging economies such as India, consumers give more importance to sensory appeal as compared with quality, safety, and health attributes during the purchase and consumption of convenience food.

Huang et al. [17] addressed an interesting question on consumer preferences for suboptimal foods in Taiwan. The authors studied effects of appearance, freshness (harvesting/packaging date), certification, and price discount on preferred choice of citrus fruit (ponkan, *Citrus poonensis*). Of the suboptimal citrus fruit certification attributes, the most important was the freshness indicator, followed by appearance, traceability certifications, price discounts, and finally size. That is, consumers were willing to compromise with fruit size but not with appearance or freshness. It would be interesting to see whether the same applies for other products or populations.

Focus group interviews (qualitative approach) were used in two studies [11,19]. Song et al. [11] investigated consumers' perception and attitudes towards non-thermally processed fruit and vegetable products using focus groups (total 94 participants) in six European countries (Denmark, Germany, Italy, Serbia, Spain, and the Netherlands). They concluded that due to a lack of knowledge and trustworthy information sources, consumers had difficulties in assessing relevant benefits and risks in non-thermally processed fruit and vegetable products. The authors also recommended targeted communication (especially for middle-aged consumers) that could explicitly and efficiently reveal benefits and risks.

Oloyede and Lignou [19] conducted a qualitative study investigating consumers' expectations and opinions of sustainable paper-based packaging materials using focus groups (total 60 participants) in the UK. The authors concluded that while the participants were concerned about the negative impact of the unsustainable packages on the environment, price and quality remained the key driving forces for consumers' purchase intent—consumers may not be willing to pay more for a sustainable package.

Two review articles were published in this Special Issue. Fiorentini et al. [1] reviewed 14 studies on sensory properties and sensory-based consumer acceptance of plant-based meat analogues (12 studies) and meat extenders (2 studies). The authors found that, in terms of increasing consumer acceptance, studies have focused on ingredients and processing methods to improve especially the color, flavor, and texture of meat analogs. Regarding methodology, Fiorentini et al. stated what is generally applicable not only to meat analogs but all foods: "A combination of hedonic testing and descriptive analysis provides a more holistic understanding and an ideal approach to evaluate the sensory profile of meat analogs while also being able to identify the strategies to increase consumer acceptance of these novel foods". However, only 1 of the 14 reviewed studies employed both analytic and hedonic sensory techniques.

Short et al. [4] made a systematic review on sensory studies on plant-based cheeses. The authors identified and reviewed 12 articles reporting sensory evaluation of (fully) plant-based cheese analogs. Most of the studied samples were soft (spreadable) and made of soy, either exclusively or blended with other plant-based ingredients. All of the studies applied a hedonic sensory method, while four of them also used a descriptive method. Short et al. noted that several studies had limitations in their methodology for sensory testing, such as a small number of participants and the use of trained panelists in hedonic testing. This review, especially the section Review of the Sensory Methods, provides helpful "dos and don'ts" for sensory evaluation of plant-based cheese analogs (and foods in general) for those who are not experts in sensory science but plan to use sensory techniques in their studies.

In conclusion, sensory and consumer research can support the development of food systems towards sustainability in many ways. Research in the field can help develop successful new products (such as meat and dairy analogs) and foster the use of existing sustainable options. Demand for more sustainable food drives change in food supply on the market, but consumer acceptance of new products cannot be taken for granted. Survey studies are essential for understanding various consumer segments in their needs, attitudes, and preferences. Sensory studies are needed to reveal the sensory properties of foods (qualitatively and quantitatively) and consumers' hedonic responses to them. However, as Fiorentini et al. [1] and Short et al. [4] noted in their reviews, many previous sensory studies on meat and cheese analogs had limitations in their methodology, such as in the number of panelists, their training, and the statistical analysis of the data. Furthermore, both analytical and hedonic sensory techniques were employed jointly only in few studies. Sensory evaluation could also be utilized as combined with survey studies and chemical and physical analysis of the samples, to provide a more comprehensive understanding on factors influencing the sensory characteristics and consumer acceptance of the studied products. I hope that this Special Issue inspires readers for future studies in sensory and consumer research to support sustainability of the food system.

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Conflicts of Interest: The author declare no conflict of interest.

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Article

Using Multiple Sensory Profiling Methods to Gain Insight into Temporal Perceptions of Pea Protein-Based Formulated Foods

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Abstract: The food industry is focused on creating plant-based foods that incorporate pea protein isolates. However, pea protein isolates are often described as having persistent beany, bitter, and astringent notes that can decrease the desirability of the resulting foods and make static sensory profiling difficult. To obtain more realistic descriptions of the sensory experiences associated with this category of products, researchers should consider using temporal methods and multi-intake methods, which allow consumers to evaluate whole food portions. This study aimed to understand better how product composition affected the sensory perception of pea protein-based beverages using three different sensory profiling methods. Particular focus was placed on beany, bitter, and astringent notes. Twelve pea protein-based beverages were formulated; they varied in pea protein type (pellet vs. isolate) and their content of gellan gum, salt, sunflower oil, sugar, and soy lecithin. They were evaluated by 16 trained panelists using three sensory profiling methods: static block profiling, mono-intake temporal dominance of sensations (TDS) profiling, and multi-intake TDS profiling. The static block and mono-intake TDS profiling methods yielded complementary results about the impact of beverage composition on attribute perceptions. Static block profiling revealed that beaniness was mainly affected by gellan gum and oil content and that bitterness and astringency were mainly affected by protein type and gellan gum content. Mono-intake TDS profiling highlighted the dynamics of beaniness and the strong persistence of astringency, and its results suggested that higher gellan gum and salt contents could limit this persistence. Multi-intake TDS profiling found that, throughout the consumption of a full product portion, beaniness and bitterness decreased, indicating an adaptation effect, while fattiness increased, indicating a build-up effect. This study has increased the understanding of how pea protein-based beverages are perceived under conditions that more closely resemble those associated with real-life consumption. It has also revealed how product formulation can reduce bitterness and astringency.

Keywords: formulation; legume; profile; TDS; multi-intake; bitter; beany; astringent

1. Introduction

Consumers are increasingly seeking out healthy, ethically produced, and eco-friendly foods. In this context, plant proteins are proving to be a great success. Yellow field pea (*Pisum sativum L.*) is becoming a common ingredient in plant-based foods [1] because it has a low level of allergenicity and high nutritional value. It also helps ensure the nutritional balance of amino acids in grain-based diets. Yellow field pea isolates also have desirable functional properties: they have excellent emulsification, foaming, gelation, and whipping capacities [2,3]. They are used in the formulation of many types of foods, including dietary supplements, bakery and confectionery products, beverages, yogurts, ice creams, meat products, and alternatives to meat and dairy products.

That said, consumers usually describe pea protein-based foods as having strong beany, bitter, and astringent notes, which can decrease desirability. These attributes have different chemical origins. Indeed, beaniness is the complex flavor perception associated with bean products [4] and results from the complex composition of volatile aroma compounds found in pulses [5]. Bitterness arises from the interaction of bitter compounds (e.g., amino acids, phenolics) with the TAS2R family of receptors, which are found on the apical membranes of taste receptor cells [6,7]. Finally, astringency is produced by "the complex sensations due to shrinking, drawing, or puckering of the epithelium," and it results from interactions between phenolic compounds and saliva proteins [8,9].

To develop novel products with less pronounced beany, bitter, and astringent notes, food production companies combine pea proteins with several other ingredients (e.g., fat, salt, sugar, flavoring agents, and/or texturizing agents). However, successfully formulating new products from combinations of these ingredients can be challenging and requires a great deal of trial and error. Sensory profiling is a valuable tool in this context: it can be used to explore the impact of food composition on the perceived sensory characteristics of formulated foods, and thus, allows target food products to be obtained more quickly. Many studies have used static block sensory profiling to examine how formulation affects sensory perceptions, the physico-chemical interactions between the different constituents of the food matrix, and the interactions between perceptions of texture, sapidity, and flavor [10–18].

However, static methods cannot quantify the dynamic mechanisms that play an essential role in how consumers experience foods. Indeed, the oral processing of food includes mastication, salivation, and tongue movements, leading to a complete transformation of food in the mouth. Food transformation has major consequences on food perception and perception persistence [19]. Retronasal aroma perception is affected by interactions among volatile compounds, and the levels of salivary compounds are not constant throughout food consumption [20,21]. Sensations of astringency and bitterness often go hand in hand [22] and slowly develop in the mouth after ingestion. They also increase following repeated exposure [23].

Temporal sensory profiling methods are increasingly being used to take these phenomena into account and to obtain a more realistic picture of the sensory experiences elicited by food products. One widely adopted approach is the temporal dominance of sensations (TDS) method. It yields information on the sequence and duration of dominant sensations [24]. The dominant sensations to occur are those that attract the most attention from consumers [25]. The TDS method has been used in tandem with static sensory profiling to evaluate different types of products, making it possible to identify sensory characteristics that are not picked up by one method alone. For example, this combined approach has proven to be useful for studying the persistence of gel containing odorants [26]; interactions between texture and aroma in model candies [27]; solid foods with contrasting textural layers (i.e., fish sticks) [28]; interactions between olive oil composition and pureed beans and tomatoes [29]; the influence of aroma on taste and texture in an apple matrix [30]; and the key flavors perceived in strawberries [31].

Typically, the TDS method is applied to a single instance of food intake (i.e., one bite of solid food or one sip of a beverage). However, in real life, food consumption involves a series of instances of food intake. Several studies have shown that repeated intake of a product can change the perception of product attributes due to sensory adaptation and/or perception persistence [32–34]. The multi-intake TDS method can provide a sensory profile for a full portion of food. It has recently proven its utility in studies evaluating the influence of wine on cheese perception [35] and in studies characterizing the sensory properties of an oral nutritional supplement [36], fat-free strawberry yogurts [37], and yogurts with granola [38].

This study aimed to understand better how product composition affected the sensory perception of pea protein-based beverages using three different sensory profiling methods. Particular focus was placed on the perception of beany, bitter, and astringent notes. Trained panelists analyzed lab-formulated beverages using three sensory profiling methods: static block profiling, mono-intake TDS profiling, and multi-intake TDS profiling. Analyses were centered on the effects of food composition (protein type, gellan gum content, salt content, and oil content) on texture, sapidity, and aroma, as well as on the sensory interactions of flavor with taste and texture. Finally, the usefulness of a combined sensory profiling approach was discussed.

2. Materials and Methods

2.1. Materials

Water (Evian, France), gellan gum (Texturas Ferran Adria, Spain), salt (Auchan, France), sunflower oil (Auchan, France), sugar (Daddy, France), soy lecithin (Louis Francois, France), and commercial pea protein isolates were the ingredients used to formulate the beverages. Two Thermomix® TM5™ appliances (Vorwerk, Germany) were employed to standardize product preparation.

2.2. Product Preparation

In this study, different pea protein-based beverages were created in the lab. Two mixture designs were used to produce a wide range of plant-beverages from different ingredients while being realistic in terms of ingredient concentrations. The first mixture design was formulated with pea protein isolates and had three independent variables with two levels: sunflower oil concentration (0% or 1.5%), gellan gum concentration (0.12% or 0.5%), and salt concentration (0.08% or 0.12%). The second mixture design was formulated with pea pellets and also had two independent variables: the protein, sunflower oil concentration (0% or 1.5%), and two levels of gellan gum concentration (0.12% or 0.5%). Thus, the total number of trials was 12 (composition and ingredient concentrations are in Table 1).

Table 1. Composition (ingredient concentrations [w/w %]) of the pea protein-based beverages used in this study. Abbreviations: I = isolate, P = pellet, F+ = 1.5% oil, F− = 0% oil, G+ = 0.5% gellan gum, G− = 0.12% gellan gum, S+ = 0.12% salt, and S− = 0.08% salt.

Product Name	Protein Type	Sunflower Oil (%)	Soy Lecithin (%)	Gellan Gum (%)	Salt (%)	Sugar (%)	Pea Protein (%)	Water (%)
	(*P or I*)	(*F+ or F−*)		(*G+ or G−*)	(*S+ or S−*)			
I/F−/G−/S−	Isolate	**0.00**	**0.00**	0.12	0.08	1.00	7.00	91.80
I/F−/G−/S+	Isolate	**0.00**	**0.00**	0.12	**0.12**	1.00	7.00	91.76
I/F−/G+/S−	Isolate	**0.00**	**0.00**	**0.50**	0.08	1.00	7.00	91.42
I/F−/G+/S+	Isolate	**0.00**	**0.00**	**0.50**	**0.12**	1.00	7.00	91.38
I/F+/G−/S−	Isolate	1.50	0.10	0.12	0.08	1.00	7.00	90.20
I/F+/G−/S+	Isolate	1.50	0.10	0.12	**0.12**	1.00	7.00	90.16
I/F+/G+/S−	Isolate	1.50	0.10	**0.50**	0.08	1.00	7.00	89.82
I/F+/G+/S+	Isolate	1.50	0.10	**0.50**	**0.12**	1.00	7.00	89.78
P/F−/G−/S−	**Pellet**	**0.00**	**0.00**	0.12	0.08	1.00	7.00	91.80
P/F−/G+/S−	**Pellet**	**0.00**	**0.00**	**0.50**	0.08	1.00	7.00	91.42
P/F+/G−/S−	**Pellet**	1.50	0.10	0.12	0.08	1.00	7.00	90.20
P/F+/G+/S−	**Pellet**	1.50	0.10	**0.50**	0.08	1.00	7.00	89.82

First, pea protein pellets were obtained as follows: water and pea protein isolates were slowly mixed together (96% [w/w] water, 4% [w/w] pea protein isolate), and then left to hydrate for 60 min at

4 °C under stirring. The pellet and supernatant were separated via centrifugation at 6000 rpm at 4 °C for 10 min. The pellet was stored at 4 °C for a maximum of 2 h before the beverages were made.

Second, the beverages were created using the following method: the water was mixed and heated (3 min, 50 °C, a speed setting of 2.5) in one of the Thermomix appliances. The sugar, salt, pea protein (isolate or pellet), and gellan gum were then gradually mixed into the water (30 min, 50 °C, a speed setting of 4.5). Simultaneously, the sunflower oil was heated (1 min, 65 °C, speed setting of 1.5) in the second Thermomix. The soy lecithin was then mixed into the sunflower oil (3 min, 65 °C, a speed setting of 2). The contents of the first Thermomix were added to the contents of the second Thermomix and combined without heating (5 min, speed setting of 5). After this step, the overall mixture was heated (6 min, 90 °C, a speed setting of 3.5). Immediately after preparation, the beverages were stored at 4 °C until they were used in the sensory profiling sessions. The Thermomix appliances were cleaned by filling them with a mixture of 2 L of water, 100 mL of white vinegar, and 5 mL of dishwashing liquid, which was then heated (5 min, 70 °C, a speed setting of 1). The appliances were subsequently thoroughly rinsed with hot water and stored at 4 °C until they were used next in order to prevent any bacterial growth.

Rheological tests were performed on each beverage to verify repeatability, and the microbial safety of the products was tested by a certified external laboratory (Eurofins Scientific, France). The products were served to the panelists at room temperature (20 °C) in transparent cups (29.5 mL) identified with three-digit codes.

2.3. Experimental Conditions

Sixteen panelists (15 women and 1 man, 18–39 years in age) were recruited based on their desire and availability to participate in a long-term study. Two of the panelists had participated in a study that focused on the sensory characterization of pea protein solutions the year before. The other panelists had no prior experience with pea protein-based products. The panelists were told the overall aim of the experiment. They gave their free and informed consent to participate in the study and received compensation for their participation. They were asked not to eat, drink, or smoke for at least 1 h before the training sessions and evaluation sessions. Panelists performed the sensory evaluations in individual booths under white light in an air-conditioned room (20 °C).

Panelists had to analyze the beverages using three different sensory profiling methods: a static block method [39], a mono-intake TDS method, and a multi-intake TDS (multi-TDS) method. To account for the order in which the beverages were experienced and any potential carry-over effects, beverage order was balanced across panelists using a Latin square.

A palate-cleansing protocol was used between beverages to reduce sensation build-up: panelists had to consume an apple slice, drink water, and wait for 40 s before consuming the following beverage [39]. As some beverages were viscous, participants were instructed to intake beverages with spoons, instead of sipping for the three profiling methods.

Sensory analysis was managed using Fizz Acquisition software (v. 2.51, Biosystemes, France).

2.4. Attribute Selection and Panelist Training

Panelists were asked to complete a check-all-that-apply (CATA) questionnaire. It listed 30 attributes, and panelists could add more. For the final list and the validation process with the panelists, we retained the attributes that were mentioned most of the time, and that allowed the products to be clearly distinguished. These 11 attributes were salty, bitter, astringent, sweet, fat, pea, almond, nuts, broth, mouthfeel, and overall aromatic intensity (Table 2). As the study was conducted in French, the terms used in French, as well as their translation into English, are presented.

Table 2. Definition of the sensory attributes evaluated by the panelists.

Attributes	Attributes in French	Definition
Salty	*Salé*	A fundamental taste—sodium chloride is a typical example
Bitter	*Amer*	The fundamental taste associated with a caffeine solution
Astringent	*Astringent*	A sensation of drying out, roughening, and/or puckering that is felt in the mouth, like when consuming red wine or unripe fruit
Sweet	*Sucré*	A fundamental taste—sucrose is a typical example
Fat	*Gras*	Property relative to the perception of the quantity of fat in the product
Mouthfeel	*Epais*	The way a food feels in the mouth in relation to its viscosity
Overall aromatic intensity	*Intensité aromatique globale*	Total aroma impressions created by the product in the mouth
Pea	*Pois*	The flavor characteristic of beans and bean-based foods
Almond	*Amande*	The flavor associated with almonds
Nuts	*Noix*	The flavor associated with nuts, like walnuts or hazelnuts
Broth	*Bouillon*	The flavor associated with boiled vegetables, soup, or stock

The panelists were trained to evaluate the intensity of these attributes along an unstructured scale (range: 0–10) using external references. Training took place over 10 sessions that each lasted 45 min. Afterward, panelist performance was evaluated and verified. Overall performance was assessed using ANOVAs with three independent variables (product type, panelist ID, and replicate) and their first-order interactions. There was a product effect, indicating that panelists distinguished among the different beverages ($p < 0.05$). The significance of various interactions revealed whether the panelists consistently scored attributes across replicates (panelist*replicate), whether there was consistency in scoring among panelists (product type*panelist ID), and whether panelists scored products consistently across replicates (product type*replicate). The performance of individual panelists was also evaluated based on their ability to discriminate among beverages and on repeatability criteria.

2.5. Static Block Profiling

Panelists were asked to score the attributes of the 12 beverages using a static block profiling method adapted from the technique used in Cosson et al. [39]. They had to evaluate six different beverages per session and were unaware of beverage identity. They were exposed to four replicates of each product. In total, the panelists evaluated the products over 8 different sensory sessions during four weeks of evaluation. For two replicates, sapidity and texture were evaluated using a nose-clip, and aroma attributes were evaluated without using a nose-clip. For two replicates, all the attributes were evaluated without the nose-clip (Figure 1). The panelists were asked to evaluate attribute intensity as during the training process (along an unstructured scale ranging from 0 to 10). Attributes were assessed in blocks of 4, 5, and 6. First, the panelists had to evaluate sapidity and texture. Second, they had to evaluate aroma. Third, they had to evaluate attribute persistence (using a shorter list of attributes).

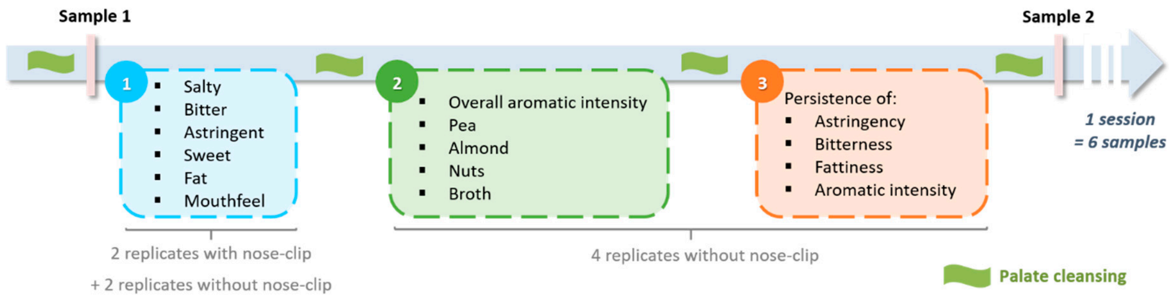

Figure 1. Schematic representation of the static block profiling method used in this study.

2.6. Mono-intake Temporal Dominance of Sensations Profiling

Panelists were asked to evaluate the 12 beverages using a mono-intake TDS method—where they evaluated the change in attribute intensity for 120 s after taking a sip of a given beverage. Panelists were exposed to two replicates of each beverage, and they evaluated six beverages per session. In total, the panelists evaluated the products over 4 different sensory sessions during two weeks of evaluation. The attributes were the same as in the static block profiling method except for overall aromatic intensity, which was removed because it was not relevant in this method. Watery was added as an attribute, and it was described to panelists as being the opposite of the fat attribute. Another attribute was also added: “I swallowed.” All the attributes were presented simultaneously on the computer screen. Attribute order was the same for each panelist for all the mono-intake TDS sessions but was randomly assigned and balanced among panelists.

The evaluation process started as soon as the panelists took a sip of the beverage. The panelists then had to click on the attribute that they perceived as dominant, which was defined for them as “the attribute that draws the most attention.” When this dominant attribute changed, the subject had to click on the new dominant attribute. The panelist was free to choose the same dominant attribute several times or, conversely, to never select a dominant attribute. The panelists also had to click on the button “I swallowed” each time they swallowed the beverage or their saliva.

For each panelist and each beverage, the following data were collected: the time at which an attribute was selected as dominant, the specific attribute, the time that had elapsed before the panelist clicked on “I swallowed” for the first time (i.e., the panelist had largely consumed the product), and the number of times that the panelist clicked on the button “I swallowed.”

2.7. Multi-intake Temporal Dominance of Sensations Profiling

Panelists were asked to evaluate two beverages using a multi-intake TDS method. These two beverages were chosen based on the static block profiling results, and the mono-intake TDS profiling results. They contained different protein types (isolate vs. pellet), had a low level of astringency persistence, and displayed different temporal sensory profiles despite having the same gellan gum, salt, and oil contents. The multi-intake TDS profiling method can be used to evaluate changes in attribute perceptions as people consume a full portion of a product (Figure 2). Here, a portion was defined as 120 mL, which is equivalent to an entire ready-to-drink beverage or a serving of yogurt. First, the panelists had to cleanse their palates. Throughout the session, they were not allowed to consume anything except the beverage to allow for the possible cumulative effects of persistent sensations. Second, the panelists evaluated the beverages using the same general approach as in the mono-intake TDS profiling method, except that a given beverage was evaluated at three time points. The first evaluation took place after the first spoonful of the beverage was consumed (hereafter, first spoonful). The second evaluation took place after panelists had consumed 60 mL of the beverage (~half the portion); they then had to evaluate a second spoonful of the beverage (hereafter, second spoonful). The third evaluation took place after panelists had consumed the remaining 60 mL of the beverage, and they then had to evaluate a final spoonful of the beverage (hereafter, third spoonful). Thus, we obtained three sets of data reflecting the shift in sensations from the beginning to the end of beverage consumption. No time limits were placed on this process. Panelists were exposed to two replicates of each product. One replicate of one product was evaluated per session, resulting in a total of four sessions.

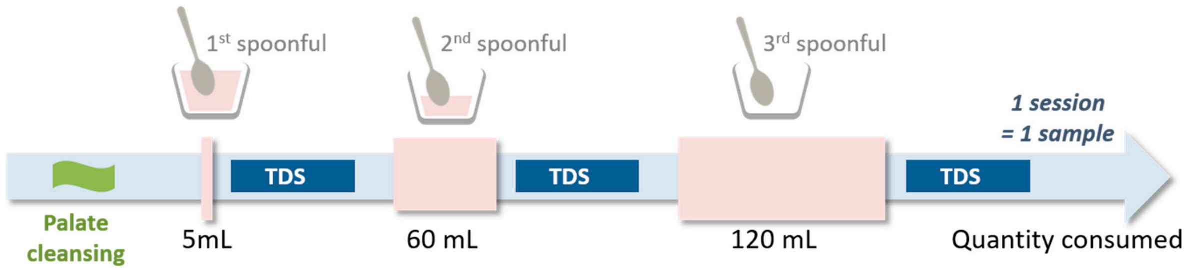

Figure 2. Schematic representation of the multi-intake temporal dominance of sensations (TDS) method used in this study.

2.8. Statistical Analysis

The data were automatically acquired using Fizz Acquisition software (v. 2.51; Biosystemes, 1990). Data analysis was performed using XLSTAT (Addinsoft, 2017, Paris, France) and R (R Core Team, 2019). The threshold for statistical significance was $\alpha = 0.05$.

The static block profiling data were analyzed using ANOVAs. To assess panelist performance, ANOVAs were carried out in which product type, panelist ID, and replicate were fixed effects, and there were first-order interactions. Post-hoc comparisons were then performed to interpret the specific effect of product type (Newman-Keuls method). To analyze the effect of beverage composition on attribute perception, ANOVAs were performed in which panelist ID, protein type, gellan gum content, salt content, oil content, and nose-clip use were fixed effects, and there were first-order interactions.

In the case of the mono-intake TDS profiling analyses, the time to the first instance of swallowing and the total duration of the evaluation period were extracted from the data collected during the sessions. ANOVAs were performed in which product type, panelist ID, and replicate were fixed effects, and there were first-order interactions. For the multi-intake TDS profiling data, the ANOVAs had product type, panelist ID, replicate, and spoonful ID as fixed effects and included first-order interactions.

Relative attribute dominance (i.e., the percentage of panelists who perceived a given attribute as dominant) was determined for each beverage at each time point, and the TDS curves were graphed. As suggested by Pineau et al. [24], two lines were drawn on the TDS graph: one line representing the relative dominance an attribute could achieve by chance alone when considering all the attributes evaluated and one line representing the minimum relative dominance an attribute must obtain for the result to be significantly different from that expected by chance alone (binomial distribution, $\alpha = 0.05$).

3. Results

3.1. Panelist Performance

The static block profiling data were used to examine how consistent panelists were in their scoring of attribute intensity (three-way ANOVAs; Table 3). Product type was significant for 15/15 attributes, so the panelists were able to distinguish among the beverages. The interactions between replicate and product type were not significant for 10/15 attributes (except for sweet, mouthfeel, the persistence of bitterness, persistence of fattiness, and persistence of overall aromatic intensity). Replicate was not significant for 12/15 attributes (except for salty, pea, and persistence of overall aromatic intensity), but the interaction between panelist ID and replicate was significant for 11/15 attributes (all except bitter, mouthfeel, pea, and broth). However, in the latter case, the F-values were low compared to the F-values for the product effects. Panelist ID and the interaction between panelist ID and product type were significant for 15/15 attributes. Such interactions are common when sensory attributes are evaluated using unstructured scales, and they are difficult to control even when panelists have undergone extensive training [40,41]. These results nonetheless suggest that the panelists' scoring was consistent (repeatable and homogeneous) for the majority of attributes. For three attributes (bitter, pea, and almond), there was some inconsistency between panelists, which was taken into account in the analysis of the results.

Table 3. Results of the three-way ANOVAs (panelist ID, replicate, and product type as fixed effects + their first-order interactions) examining consistency in panelist performance (total degrees of freedom: 739; residual degrees of freedom: 681). Significant *p*-values are in bold (α = 0.05). Abbreviations: Astringent-P = persistence of astringency; Bitter-P = persistence of bitterness; Fat-P = persistence of fattiness; and Aromatic intensity-P = persistence of overall aromatic intensity.

	Panelist ID		Replicate		Product Type		Panelist ID * Replicate		Panelist ID * Product Type		Replicate * Product Type	
	F	*p*-Value	F	*p*-Value	F	*p*-Value	F	*p*-Value	F	*p*-Value	F	*p*-Value
Salty	29.47	**<0.01**	5.71	**0.02**	61.90	**<0.01**	4.42	**<0.01**	1.78	**<0.01**	1.34	0.21
Bitter	34.83	**<0.01**	0.01	0.92	8.44	**<0.01**	1.22	0.25	2.49	**<0.01**	0.43	0.93
Astringent	26.94	**<0.01**	0.95	0.33	5.71	**<0.01**	3.23	**<0.01**	1.78	**<0.01**	0.25	0.99
Sweet	23.09	**<0.01**	0.92	0.34	8.14	**<0.01**	2.60	**<0.01**	1.64	**<0.01**	2.03	**0.03**
Fat	10.11	**<0.01**	0.49	0.49	62.77	**<0.01**	1.98	**0.02**	2.38	**<0.01**	0.91	0.53
Mouthfeel	13.79	**<0.01**	1.07	0.30	358.24	**<0.01**	1.58	0.07	2.00	**<0.01**	3.77	**<0.01**
Overall aromatic intensity	9.17	**<0.01**	0.17	0.68	14.71	**< 0.01**	2.55	**< 0.01**	1.93	**< 0.01**	0.87	0.57
Pea	29.85	**<0.01**	4.82	**0.03**	2.44	**0.01**	1.48	0.11	2.47	**<0.01**	1.03	0.42
Almond	32.78	**<0.01**	0.16	0.69	2.57	**<0.01**	2.61	**<0.01**	1.60	**<0.01**	0.29	0.98
Nuts	27.21	**<0.01**	3.69	0.06	5.72	**<0.01**	2.84	**<0.01**	2.60	**<0.01**	0.84	0.59
Broth	25.34	**<0.01**	0.04	0.83	41.96	**<0.01**	1.01	0.45	1.76	**<0.01**	0.21	1.00
Astringent-P	52.86	**<0.01**	1.41	0.23	9.47	**<0.01**	3.54	**<0.01**	1.86	**<0.01**	1.38	0.19
Bitter-P	34.61	**<0.01**	0.02	0.89	2.88	**<0.01**	2.93	**<0.01**	1.71	**<0.01**	1.91	**0.04**
Fat-P	79.46	**<0.01**	3.19	0.07	26.28	**<0.01**	1.90	**0.02**	2.89	**<0.01**	1.90	**0.04**
Aromatic intensity-P	57.42	**<0.01**	11.22	**0.00**	4.71	**<0.01**	1.90	**0.02**	1.35	**0.01**	1.97	**0.03**

* corresponds to the interaction between replicate and product type.

3.2. *Impact of Beverage Composition on Perceived Attribute Intensity*

The static block profiling data were also used to examine the effects of beverage composition on attribute intensity (five-way ANOVAs; Table 4). The mean attribute intensities (across replicates and panelists) for the different beverages and the differences among groups (Newman–Keuls post-hoc analysis) are shown in Figure 3.

Sensory interactions between taste and flavor and between texture and flavor were examined. When panelists were wearing the nose-clip, they perceived the bitter and salty notes as more intense (F = 14.71 and F = 4.17, respectively) than when they were not wearing the nose-clip (4.00 vs. 3.45 and 3.98 vs. 3.70, respectively).

Protein type influenced the perception of 14/15 attributes (not almond). The most affected attributes were salty (F = 241.07), mouthfeel (F = 233.58), and broth (F = 142.49). Compared to isolate-based beverages, pellet-based beverages were perceived as more bitter and fatty with a more pronounced mouthfeel and more persistent astringency and bitterness; they were also perceived as less salty, sweet, and aromatically intense with less persistent overall aromatic intensity.

Table 4. Results of the five-way ANOVAs (panelist ID, nose-clip use, oil content, gellan gum content, salt content, and protein type as fixed effects + their first-order interactions) examining the effects of beverage composition on attribute perception using the static block profiling data (total degrees of freedom: 739; residual degrees of freedom: 716). Significant p-values are in bold ($\alpha = 0.05$). Abbreviations: Astringent-P = persistence of astringency; Bitter-P = persistence of bitterness; Fat-P = persistence of fattiness; and Aromatic intensity-P = persistence of overall aromatic intensity.

	Panelist ID		Nose-clip Use		Oil Content		Gellan Gum Content		Salt Content		Protein Type		Oil * Gellan Gum		Gellan gum * Salt		Gellan gum * Protein Type	
	F	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value
Salty	25.39	**<0.01**	4.17	**0.04**	0.24	0.62	27.96	**<0.01**	49.64	**<0.01**	241,07	**<0.01**	0,73	0,39	15,56	**<0.01**	1,15	0,28
Bitter	26.64	**<0.01**	14.71	**<0.01**	1.30	0.26	0.65	0.42	1.69	0.19	34.38	**<0.01**	0.00	0.99	1.20	0.27	0.11	0.74
Astringent	22.23	**<0.01**	0.86	0.35	2.39	0.12	14.33	**<0.01**	2.00	0.16	5.32	**0.02**	2.76	0.10	0.88	0.35	0.05	0.83
Sweet	21.44	**<0.01**	0.88	0.35	1.24	0.27	1.73	0.19	1.36	0.24	55.21	**<0.01**	0.00	0.95	2.89	0.09	1.09	0.30
Fat	7.71	**<0.01**	2.53	0.11	6.45	**0.01**	247.75	**<0.01**	13.13	**0.00**	46.78	**<0.01**	0.33	0.57	8.18	**<0.01**	14.18	**<0.01**
Mouthfeel	11.39	**<0.01**	0.52	0.47	19.10	**<0.01**	1769.43	**<0.01**	82.71	**<0.01**	233.58	**<0.01**	2.03	0.15	39.03	**<0.01**	23.56	**<0.01**
Overall aromatic intensity	7.24	**<0.01**	3.07	0.08	7.39	**0.01**	15.19	**0.00**	2.07	0.15	55.03	**<0.01**	6.78	**0.01**	0.41	0.52	5.41	**0.02**
Pea	23.19	**<0.01**	1.95	0.16	0.01	0.94	0.90	0.34	0.00	0.99	10.48	**<0.01**	0.36	0.55	0.98	0.32	0.47	0.49
Almond	29.31	**<0.01**	1.67	0.20	9.88	**<0.01**	6.57	**0.01**	0.14	0.71	1.71	0.19	0.98	0.32	0.02	0.88	0.17	0.68
Nuts	20.15	**<0.01**	1.86	0.17	12.40	**<0.01**	0.99	0.32	0.69	0.41	8.99	**<0.01**	6.09	**0.01**	1.10	0.29	3.41	0.07
Broth	23.17	**<0.01**	0.82	0.36	1.10	0.29	21.10	**<0.01**	31.06	**<0.01**	142.49	**<0.01**	0.65	0.42	0.16	0.69	11.41	**0.00**
Astringent-P	39.99	**<0.01**	0.68	0.41	0.03	0.87	16.27	**<0.01**	1.36	0.24	17.26	**<0.01**	0.00	0.97	3.59	0.06	5.01	**0.03**
Bitter-P	29.24	**<0.01**	0.04	0.84	2.47	0.12	0.06	0.80	0.83	0.36	8.16	**<0.01**	0.08	0.78	3.07	0.08	0.01	0.90
Fat-P	54.04	**<0.01**	3.77	0.05	1.91	0.17	118.24	**<0.01**	14.35	**<0.01**	21.24	**<0.01**	0.00	0.96	6.11	**0.01**	0.02	0.89
Aromatic intensity-P	51.62	**<0.01**	2.82	0.09	16.59	**<0.01**	0.15	0.70	1.25	0.26	9.73	**<0.01**	2.12	0.15	4.00	0.05	0.52	0.47

* corresponds to the interaction between replicate and product type.

Figure 3. *Cont.*

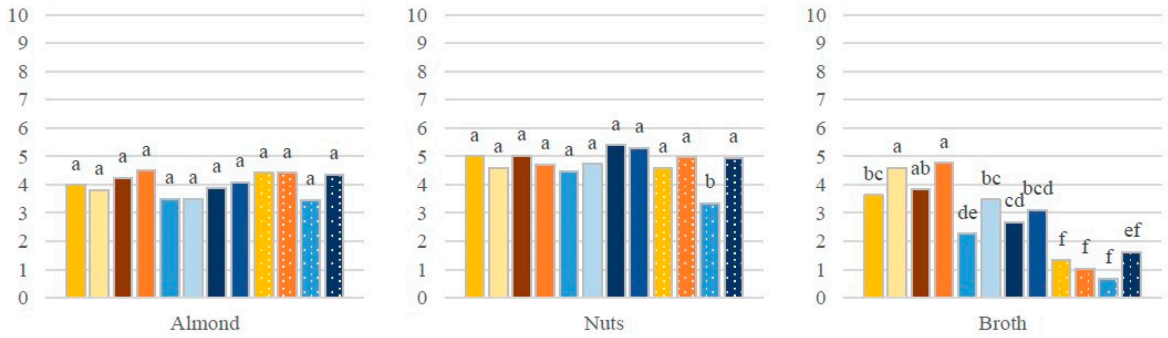

Figure 3. Mean attribute intensities (across replicates and panelists) of the 12 beverages containing different levels of the same ingredients as evaluated using static block profiling (differences in letters indicate significant differences among groups as revealed by the Newman–Keuls post-hoc analysis). Intensity scores could range from 0 to 10. Abbreviations: I = protein from isolate (*solid color*), P = protein from pellet (*dotted color*), F+ = 1.5% oil content (*dark color*), F− = 0% oil content, G+ = 0.5% gellan gum content (*blue*), G- = 0.12% gellan gum content (*orange*), S+ = 0.12% salt content (*light color*), and S− =0.08% salt content.

Gellan gum content (0.5% vs. 0.12%) influenced the perception of 9/15 attributes (not bitter, sweet, pea, nuts, the persistence of bitterness, or the persistence of overall aromatic intensity). The most affected attributes were mouthfeel (F = 1769.43) and fat (F = 118.24). Beverages with 0.5% gellan gum content were perceived as fattier with a more pronounced mouthfeel; the persistence of fattiness was also greater. These beverages were also perceived as less salty and astringent with a lower overall aromatic intensity and less persistent astringency. Their almond and broth notes were also less-pronounced.

Salt content (0.08% vs. 0.12%) influenced the perception of 5/15 attributes (salty, fat, mouthfeel, broth, and the persistence of fattiness). Interestingly, the most affected attributes were mouthfeel (F = 82.71) and salty (F = 49.64). Unsurprisingly, beverages with 0.12% salt content were perceived as saltier, and they were also perceived as fattier and brothier with a more pronounced mouthfeel.

Oil content (1.5% vs. 0%) influenced the perception of 6/15 attributes (fat, mouthfeel, overall aromatic intensity, almond, nuts, and the persistence of overall aromatic intensity). The most affected attribute was the mouthfeel (F = 19.10). Consequently, oil content appeared to have more moderate effects than protein type, gellan gum content, and salt content. Compared to beverages without oil, beverages with oil were perceived as fattier with a more pronounced mouthfeel. They were also perceived as having greater overall aromatic intensity, more persistent overall aromatic intensity, and stronger notes of almond and nuts.

Except in the case of protein type, beverage composition did not significantly affect the perception of bitterness. Only protein type and gellan gum content influenced the perception of astringency.

There were interactions between protein type and gellan gum content that significantly impacted 5/15 attributes (fat, mouthfeel, overall aromatic intensity, broth, and the persistence of astringency). When a beverage was made with pellet-based protein and contained 0.5% gellan gum, its fattiness and mouthfeel were perceived as more intense, whereas its overall aromatic intensity and brothiness were perceived as less intense. When the gellan gum content was lower (0.12%), the persistence of astringency was perceived as lower. There were also interactions between gellan gum content and salt content, which affected 4/15 attributes (salty, fat, mouthfeel, and the persistence of fattiness). Beverages containing 0.12% gellan gum and 0.12% salt were perceived as saltier and fattier with a more pronounced mouthfeel and more persistent fattiness. The interaction between gellan gum content and oil content significantly impacted 2/15 attributes (nuts and overall aromatic intensity). Beverages containing 0.5% gellan gum and 1.5% oil were perceived as nuttier and as having greater overall aromatic intensity. The other interactions were not significant.

For the four attributes whose persistence was evaluated (bitter, fat, astringent, and overall aromatic intensity), the mean intensity of attribute persistence was around 2/10, which was lower than the mean intensity of the stand-alone attributes during beverage evaluation. Consequently, static block profiling appears to provide limited information about attribute persistence, at least for the attributes tested. Furthermore, the intensities for the stand-alone attributes (blocks 1 and 2, Figure 1) were correlated strongly with the intensities for attribute persistence (block 3, Figure 1) (R^2 = 0.84 for astringent and the persistence of astringency; R^2 = 0.81 for bitter and the persistence of bitterness; R^2 = 0.95 for fat and the persistence of fattiness; R^2 = 0.79 for overall aromatic intensity and the persistence of overall aromatic intensity). Thus, temporal sensory profiling is needed to provide better-quality information on attribute persistence.

3.3. *Results of Mono-intake Temporal Dominance of Sensations Profiling*

The perceived dominant attributes of the beverages across the consumption period can be seen in Figure 4.

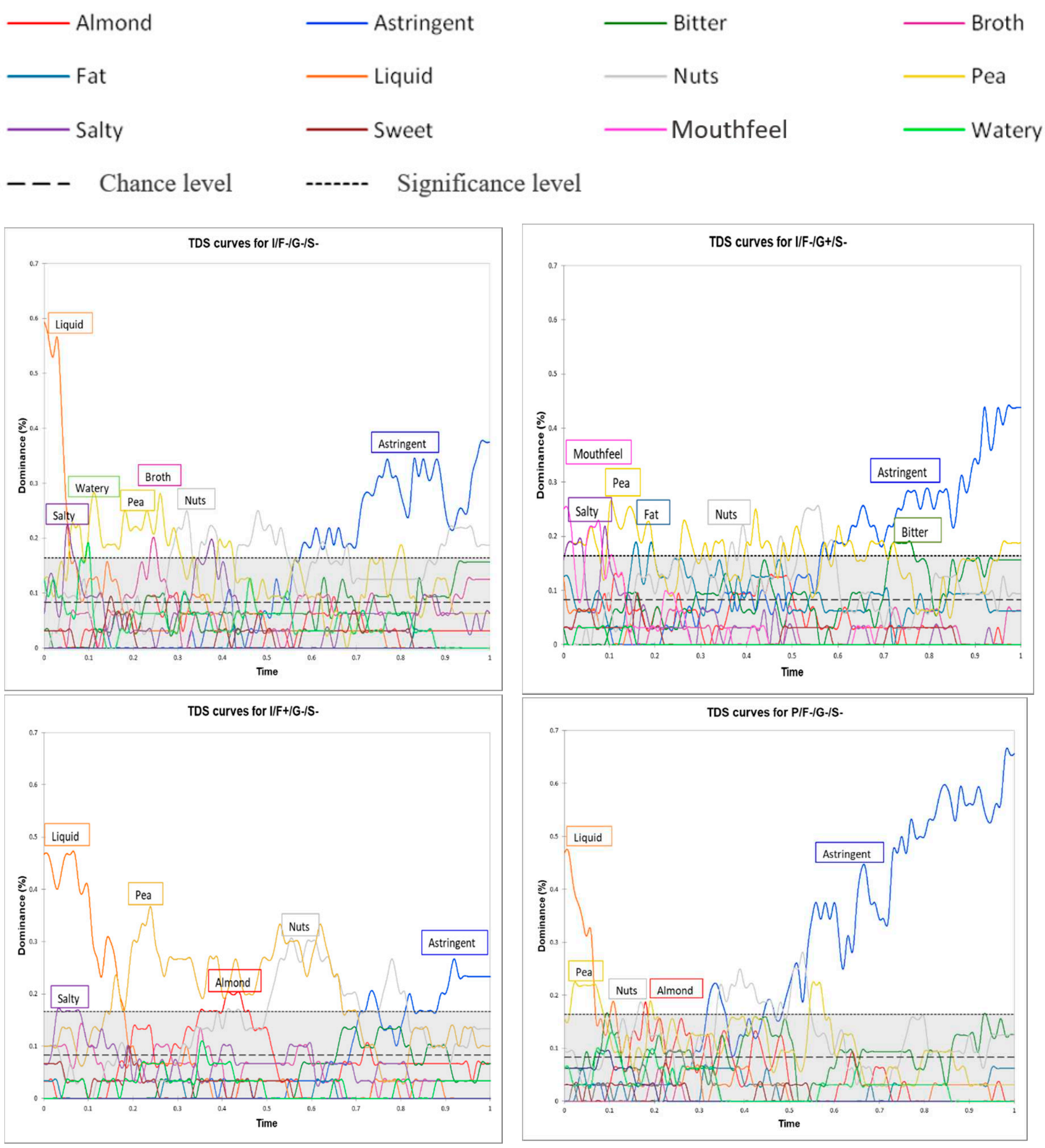

Figure 4. *Cont.*

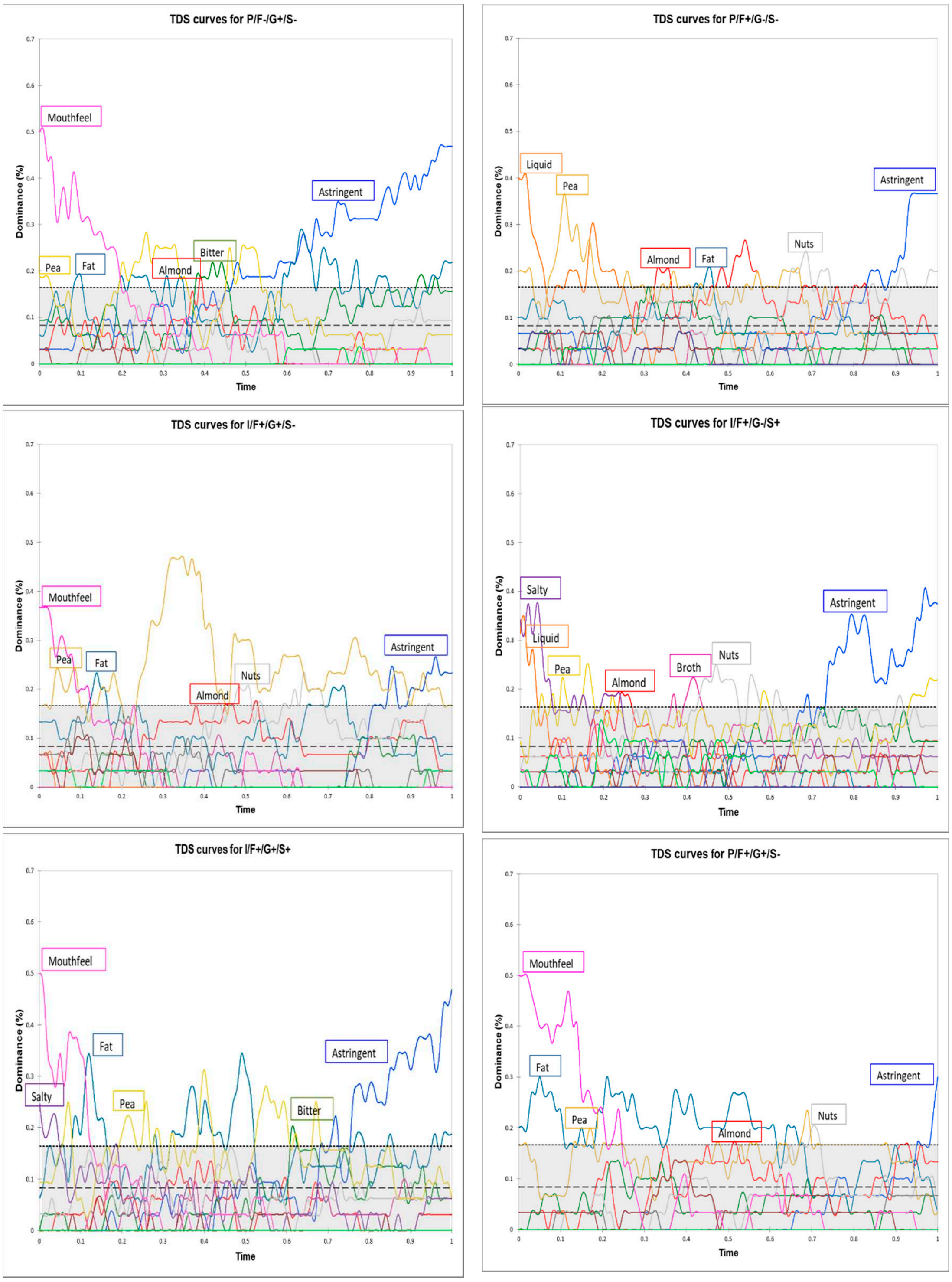

Figure 4. *Cont.*

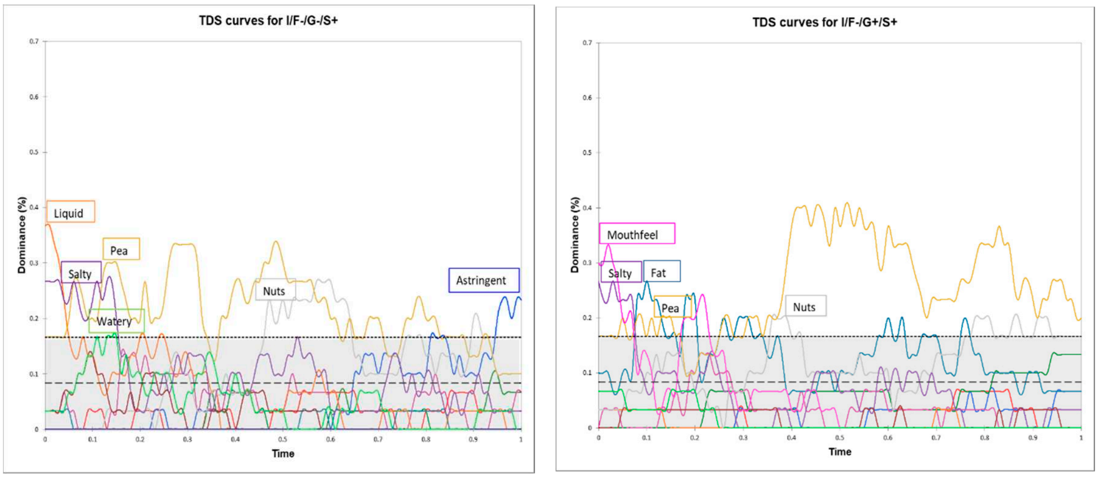

Figure 4. Standardized (mono-intake temporal dominance of sensations) TDS curves for the 12 pea protein-based beverages used in this study. The curves depict attribute dominance over time. The two horizontal lines indicate the relative dominance an attribute could achieve by chance alone (chance level) and the minimum relative dominance an attribute needed to obtain for the result to be significantly different from that expected by chance alone (significance level). Abbreviations: I = isolate, P = pellet, F+ = 1.5% oil, F− = 0% oil, G+ = 0.5% gellan gum, G- = 0.12% gellan gum, S+ = 0.12% salt, and S− = 0.08% salt.

The first instance of swallowing is not indicated because it always occurred at the very beginning of the evaluation period (within 4.32–7.90 s of starting the 120-s period), which underscores the effect of the aftertaste on attribute dominance. Beverage composition affected the time to the first instance of swallowing and total evaluation duration (three-way ANOVAs; Table 5). Differences in both these dependent variables (F = 3.43 and F = 6.51, respectively) were observed among beverages. Beverages with the least pronounced mouthfeel were swallowed the fastest (I/F−/G−/S−, I/F+/G−/S+, I/F−/G−/S+, and I/F+/G−/S− were first swallowed within 4.32–4.93 s). The beverage with the most pronounced mouthfeel was swallowed the slowest (I/F+/G+/S+ product was first swallowed within 7.90 s), and its evaluation duration was the longest. There were also marked differences among panelists in both variables (time to first swallow: range: 0–42.25 s, mean: 30.48 ± 5.11 s, and F=35.82; evaluation duration: range: 10.75–120 s, mean: 24.49 ± 5.90 s, and F = 158.70). The interactions between product type and panelist ID were also significant (time to first swallow: F = 1.40 and evaluation duration: F = 1.98). The pronounced variability in both variables reflected the prominent differences in food oral processing among panelists.

During the evaluation period, panelists described the 12 beverages using at least five attributes. Specific sensory phases were also identified. In the first part of the evaluation period, for all beverages, the dominant attributes were those associated with texture and sapidity (liquid, mouthfeel, and salty). Then, depending on the specific beverage, the attributes related to aroma (almond, pea, and broth), texture (fat, watery), and sapidity (salty, bitter) were simultaneously dominant. Finally, in the last part of the evaluation period, astringency was dominant for all the beverages.

When the beverages were examined separately, the results were consistent with those obtained using static block profiling, as illustrated by the high RV coefficient of 0.796 between static and TDS profiling data (multiple factor analysis). For the pellet-based beverages versus the isolate-based beverages, the attributes fat, mouthfeel, and astringent remained dominant for a longer period, while the attributes salty, almond, pea, and broth remained dominant for a shorter period. The dominance of the attributes fat and mouthfeel lasted longer in beverages containing 0.5% gellan gum than in beverages containing 0.12% gellan gum. Unsurprisingly, the dominance of the attribute salty lasted longer in beverages containing 0.12% salt than in beverages containing 0.08% salt. Similarly, the dominance of the attribute fat persisted for longer in the beverages containing oil (1.5%) than in the beverages without any oil.

Table 5. Results of the three-way ANOVAs (panelist ID, replicate, and product type as fixed effects + their first-order interactions) examining the effects of beverage type (all 12 beverages) on the time to the first instance of swallowing and the total duration of evaluation using the mono-intake TDS profiling data (total degrees of freedom: 359; residual degrees of freedom: 154). Significant *p*-values are in bold (α = 0.05).

	Panelist ID		Replicate		Product Type		Panelist ID * Replicate		Panelist ID * Product Type		Replicate * Product Type	
	F	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value	*F*	*p*-Value
Time to first swallow	35.82	**<0.01**	0.01	0.90	3.43	**0.00**	0.46	0.95	1.40	**0.02**	0.71	0.73
Total duration of evaluation	158.70	**<0.01**	1.03	0.31	6.51	**<0.01**	0.84	0.63	1.98	**<0.01**	2.31	**0.01**

* corresponds to the interaction between replicate and product type.

However, mono-intake TDS results also provided additional information, notably with regards to bitterness and astringency. Panelists seemed to barely perceive astringency in the beverages containing 0% oil and 0.12% salt (I/F−/G−/S+ and I/F−/G+/S+). This attribute was also much less dominant in beverages containing 1.5% oil and 0.08% salt (P/F+/G+/S−, I/F+/G+/S−, I/F+/G−/S−, and P/F+/G−/S−). The attribute bitter was rarely perceived as dominant, and when it was, it was only in the three beverages containing the higher percentage (0.5%) of gellan gum (P/F−/G+/S−, I/F−/G+/S−, and I/F+/G+/S+).

Based on these results, two beverages (I/F+/G+/S− and P/F+/G+/S−) were selected for evaluation with the multi-intake TDS method because they displayed weakly persistent astringency and different temporal profiles for the attribute pea (a contributor to beaniness).

3.4. Results of Multi-intake Temporal Dominance of Sensations Profiling

In the multi-intake TDS method, panelists had to evaluate attribute dominance at three time points. Once after consuming the first spoonful of beverage, once after consuming 60 mL (half) of the beverage, and once after consuming 120 mL (all) of the beverage.

Product type affected the time to the first instance of swallowing and total evaluation duration (four-way ANOVAs; Table 6). Beverages differed in the time to the first swallow (F = 4.70). The beverage with the less pronounced mouthfeel was swallowed faster (I/F+/G+/S−: 5.87 s) than the beverage with the more pronounced mouthfeel (P/F+/G+/S−: 6.73 s). There were differences in both variables among the evaluation time points (time to first swallow: F = 11.48 and evaluation duration: F = 7.10). Time to the first swallow was longest after the first spoonful, regardless of product type (1st spoonful: 7.55 s; second spoonful: 6.12 s; third spoonful: 5.23 s), as was the length of the evaluation period (1st spoonful: 48.11 s; second spoonful: 44.39 s; and third spoonful: 41.82 s). These results likely reflect panelist fatigue and adaptation effects.

Table 6. Results of the four-way ANOVAs (panelist ID, product type, spoonful ID, and replicate as fixed effects + their first-order interactions) examining the effects of beverage type (only I/F+/G+/S− and P/F+/G+/S−) on the time to the first instance of swallowing and the total duration of evaluation using the multi-intake TDS profiling data (total degrees of freedom: 191; residual degrees of freedom: 107). Significant p-values are in bold ($\alpha = 0.05$). Abbreviations: I = isolate, P = pellet, F+ = 1.5% oil, G+ = 0.5% gellan gum, and S− = 0.08% salt.

	Panelist ID		**Product Type**		**Spoonful ID**		**Replicate**		**Panelist ID * Product Type**		**Panelist ID * Spoonful ID**		**Panelist ID * Replicate**		**Product Type * Spoonful ID**		**Product Type * Replicate**		**Spoonful ID * Replicate**	
	F	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**	***F***	***p*-Value**
Time to first swallow	33.07	**<0.01**	4.70	0.03	11.48	**<0.01**	0.06	0.81	4.29	**<0.01**	0.85	0.68	2.98	**<0.01**	1.94	0.15	1.06	0.31	1.24	0.29
Total duration of evaluation	61.87	**<0.01**	2.74	0.10	7.10	**<0.01**	10.54	0.00	2.15	0.01	1.81	0.02	3.42	**<0.01**	0.76	0.47	0.10	0.76	0.26	0.77

* corresponds to the interaction between replicate and product type.

Attribute dominance over time for the two beverages is shown in Figure 5. These two beverages were selected from the evaluation with the multi-intake TDS method because they displayed weakly persistent astringency and different temporal profiles for the attribute pea. As in the results for the mono-intake TDS method, panelists described the beverages as having at least five different attributes. The sequence of dominant attributes was also similar. In the first part of the evaluation period, the dominant attributes for I/F+/G+/S− were mouthfeel and pea; for P/F+/G+/S−, they were mouthfeel and fat. Then, the attributes of fat, pea, nuts, and almond were more dominant, but their relative ranks were dependent on product type and spoonful ID. In the last part of the evaluation period, the attributes astringent and bitter were dominant for I/F+/G+/S−, and the attributes astringent and fat were dominant for P/F+/G+/S−.

Figure 5. *Cont.*

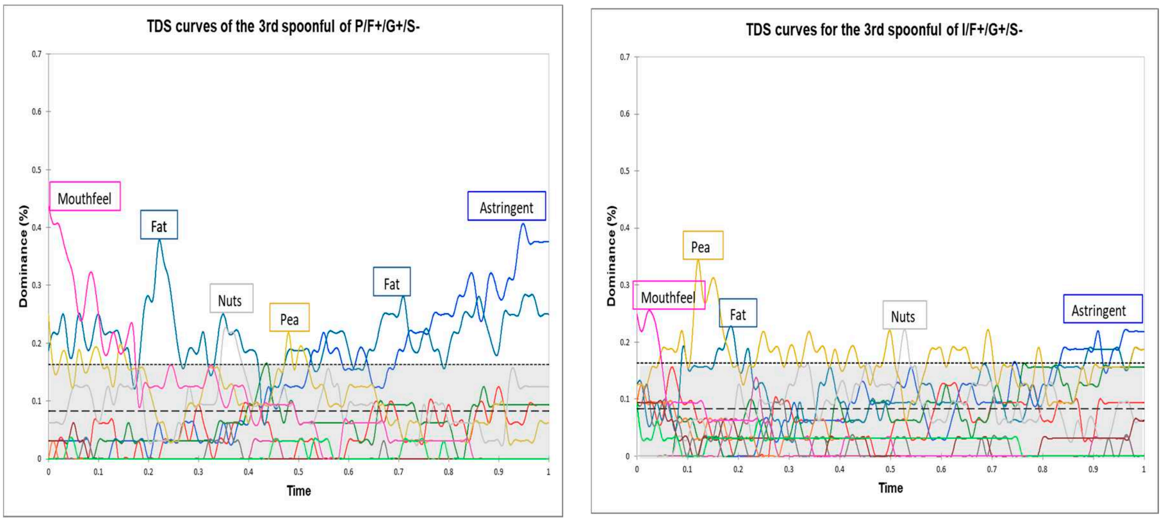

Figure 5. Standardized TDS curves for the two pea protein-based beverages (I/F+/G+/S− and P/F+/G+/S) evaluated using multi-intake TDS profiling. The curves depict attribute dominance over time (i.e., following the first spoonful, the second spoonful [after consuming 60 mL], and the third spoonful [after consuming 120 mL]). The two horizontal lines indicate the chance level and the significance level (see Figure 4). Abbreviations: I = isolate, P = pellet, F+ = 1.5% oil, G+ = 0.5% gellan gum, and S− = 0.08% salt.

The results for the first spoonfuls consumed during the multi-intake TDS sessions did not fully match the results for the single spoonfuls consumed during the mono-intake TDS sessions. When I/F+/G+/S− was evaluated using the multi-intake TDS method, the attributes bitter and nuts were dominant for the longest amount of time after the first spoonful of beverage was consumed. In contrast, when the mono-intake TDS method was used, the attributes mouthfeel, fat, and pea were the most dominant. Similarly, when P/F+/G+/S− was evaluated using the multi-intake TDS method, the attributes bitter, astringent, pea, and almond were dominant for the longest amount of time after the first spoonful of beverage was consumed. In contrast, when the mono-intake TDS method was used, the attributes mouthfeel and fat were the most dominant. These contrasting results may stem from methodological differences. During the mono-intake TDS sessions, panelists evaluated a total of 12 spoonfuls of beverage at random points during a given session. Thus, these single spoonfuls do not truly correspond to the “real” first spoonfuls taken during the multi-intake TDS sessions.

Attributes decreased in dominance throughout the evaluation period for I/F+/G+/S−. Panelists perceived the beverage’s attributes quite differently by the time they reached the end of consumption. For example, the dominance of the attributes pea and astringent declined between the first and the third spoonful (from 45% to 35% and from 32% to 25%, respectively). For P/F+/G+/S−, the same decline in dominance was observed for the attributes pea, nuts, and almond. However, astringency was still highly dominant at the end of the evaluation period, and the attribute fat increased in dominance over time.

4. Discussion

This study aimed to understand better how product composition affected the sensory perception of pea protein-based beverages using three different sensory profiling methods. The first part of the discussion focuses on how beverage composition affected the perception of texture and sapidity. The second part examines the perception of aroma and the sensory interactions of flavor with taste and texture. The third part addresses the importance of employing a combination of sensory profiling methods (static/temporal, mono-intake/multi-intake) when evaluating potential food products.

4.1. Perception of Texture and Sapidity

In this study, the composition of the pea protein-based beverages greatly impacted perceptions of texture and sapidity. When the static block profiling method was used (i.e., when sensory attributes were evaluated immediately after consumption), gellan gum content, salt content, and oil content were found to increase the perceived intensity of fattiness and mouthfeel significantly. This result suggests a relationship exists between the two attributes. Similarly, when the mono-intake TDS method was used (i.e., where sensory attributes were evaluated over a 2-min period following consumption), the attribute mouthfeel was perceived as more dominant for beverages with low gellan gum and salt contents. The attribute of fat was perceived as more dominant for beverages with high gellan gum contents that also contained oil.

When beverages had a lower salt content, the perceived intensity of saltiness was lower (as measured via static block profiling), and the attribute salt was less dominant (as measured via mono-intake TDS profiling). When beverages had higher gellan gum content, the perceived intensity of astringency was lower (as measured via static block profiling), but the attribute bitter was highly dominant (as measured via mono-intake TDS profiling). Here, however, in contrast to other studies, there was no significant effect of fat content on bitterness [42], perhaps because the differences in oil content were small (1.5% vs. 0%).

The type of protein used to make the beverage (isolate vs. pellet) also affected perceptions of texture and sapidity. Based on static block profiling, pellet-based products were perceived as being fattier, bitterer, and less salty and as having a more pronounced mouthfeel. Based on mono-intake TDS profiling, astringency was highly dominant in pellet-based products. Protein type has a compositional effect on food products. Although pea pellets and isolates both contain similar levels of total proteins, pellets are richer in insoluble proteins, while isolates are richer in minerals, sugars, polyphenols, volatile molecules, and peptides. Analyses of protein extracts have identified the proteins and peptides responsible for bitterness: they have hydrophobic side chains rich in proline and leucine [43,44]. Astringency results from the saliva proteins (e.g., salivary amylase, mucin, esterase) binding with the polyphenols present in pea protein isolates, and then precipitating [9,45,46]. Thus, it can be assumed here that differences in protein type were at the origin of differences in attribute perception.

As observed in previous studies, texture attributes initially dominate food perception [24,27,47]. In addition, swallowing occurs more quickly, after a few seconds (during the first part of the evaluation period), for liquid products, a result that could be explained by the oral processing dynamics of liquid foods [48]. While solids need to be fragmented and mixed with saliva to form a cohesive bolus, liquids can be swallowed immediately after being diluted by saliva and warmed to body temperature [49]. Thus, liquids usually remain in the mouth for a much shorter period than do solids.

The results obtained with multiple-intake TDS profiling (i.e., where the sensory attributes of a full beverage portion were evaluated) revealed a gradual decrease in the dominance of texture attributes and bitterness over time. This decrease was more pronounced for the pellet-based beverage than the isolate-based beverage. Such attributes might become less noticeable after repeated tasting due to sensory adaptation [33]. There was also a gradual increase in perceived fattiness across time, which could be due to the lingering and build-up of sensations [32,33]. These results fit with those from several other studies showing that perceptions of fattiness build up in the mouth due to fat lingering on oral surfaces (i.e., the tongue and the palate) [50,51]. The persistence of the sensation of fattiness may stem from the presence of residual fat or oil in the oral cavity after swallowing, which can increase the attribute's intensity throughout repeated ingestion [50,52].

4.2. Perception of Aroma and the Interactions of Flavor with Taste and Texture

Beverage composition greatly influenced the perception of aroma. Static block profiling showed that products with greater gellan gum content were perceived as having lower overall aromatic intensity and less pronounced almond and broth notes. In contrast, mono-intake TDS profiling revealed that the attribute pea was relatively dominant in this beverage type. The impacts of hydrocolloid solutions on the sensory perception of food depend on a large number of variables (e.g., hydrocolloid type, range of viscosity, food matrix type, choice of sensory evaluation technique). Only a few studies have explored the effects of hydrocolloids on the perception of thickened beverages [53–55], and, to our knowledge, none have looked at gellan gum. However, these studies generally found that an increase in beverage viscosity led to a decrease in aroma perception [56–58], which is consistent with the results of this study.

Beverages containing oil were perceived as having higher overall aromatic intensity and more intense almond and nut notes based on static block profiling. When mono-intake TDS profiling was used, these beverages displayed the highest dominance of almond and the lowest dominance of broth. Past research has repeatedly shown that lipids can modify the sensory perception of food. They function as reservoirs for numerous aroma compounds, resulting in delayed release and perception [59–62]. In addition, in static block profiling, beverages with a higher salt content were perceived as displaying more intense brothiness, and in mono-intake TDS profiling, they were perceived as having the least dominant almond note. This result can be explained by sodium chloride, causing the salting out of hydrophobic aroma compounds [62].

Protein type influenced the perception of overall aromatic intensity. Pellet-based products were perceived as less aromatic than isolate-based products, based on static block profiling. The results for mono-intake TDS profiling provided additional support for this finding, where the attributes pea and nuts were perceived as less dominant in pellet-based products than in isolate-based products. Previous research has extensively examined interactions in protein-based foods between aroma compounds and proteins [63,64]. These interactions can be modified by different factors: protein conformation and composition; the properties of aroma compounds, such as hydrophobicity; and environmental conditions, such as pH [64–67]. Thus, it can be assumed that the above sensory differences arose from differences in protein type and, more specifically, differences in interactions between aroma compounds and proteins.

Here, it was found that aroma attributes were dominant during the latter part of the evaluation period, based on mono-intake TDS profiling. This finding concurs with what has been seen in previous studies. During the swallowing process, the liquid bolus is held first on the upper surface of the tongue [68]. During this step, the soft palate is most often closed, and aroma compounds have limited access to the nasal cavity, which may explain why only texture and sapidity attributes were dominant during the initial part of the evaluation period. Then, the tongue generates a wave of pressure that squeezes the liquid backward through the mouth and pharynx toward the esophagus [69]. Immediately after the liquid passes the epiglottis, the soft palate is re-opened [70]. For liquid foods, this is the first moment in which aroma compounds have access to the nasal cavity [71], and the highest aroma release signal is generally observed during the first expiration after swallowing (called the swallow breath) [72]. This series of events may explain why aroma attributes were more dominant during the latter part of the evaluation period. After a few seconds, the concentration of volatile compounds in the mouth and nasal cavity decrease significantly [73]. In contrast, non-volatile compounds remain on oral surfaces (i.e., the tongue and palate) and continue to influence perceptions [50,51], which may explain why astringency was dominant later in the evaluation period. Multiple-intake TDS profiling showed that beaniness gradually decreased over time. This decrease was more-pronounced for pellet-based beverages. However, these attributes might become less noticeable after repeated tasting due to sensory adaptation [33].

Beverage composition had a limited effect on the sensory interactions of flavor with taste and texture. However, there were some prominent taste–flavor interactions. When the panelists used nose-clips to evaluate attributes related to texture and sapidity, bitter and salty notes were perceived as less intense than when the nose-clip was not used. Beverages were also perceived simultaneously as more beany, bitter, and salty, suggesting congruent effects. These results are consistent with those found in other studies on bitter beverages. For example, cocoa flavoring enhanced bitterness in a cocoa beverage [74], and the addition of aroma compounds increased bitterness in beers [75]. These results suggest that the effects of congruency induce interactions between taste and aroma.

4.3. The Importance of Employing a Combination of Sensory Profiling Methods

Static block profiling, in which beverage attributes were evaluated immediately after consumption, revealed that the perception of beaniness was strongly affected by beverage composition. At the same time, the differences between the different attributes contributing to beaniness (pea, nuts, almond, and broth) were not very pronounced. Mono-intake TDS profiling, in which beverage attributes were evaluated over a 2-min period following consumption, provided more detailed information about differences among beverages, especially in terms of the different attributes contributing to beaniness. In particular, results suggest that pellet-based beverages were perceived as more brothy and less pea-like than isolate-based beverages. Static block profiling found that perceived astringency was moderate, and the intensities for the stand-alone attributes (blocks 1 and 2, Figure 1) were correlated strongly with the intensities for attribute persistence. In contrast, mono-intake TDS profiling highlighted that perceived astringency was strongly persistent over the evaluation period and that the perception of other attributes shifted. The static block profiling method made it possible to rapidly and independently evaluate attribute intensity. However, it is difficult for panelists to assess attribute dominance and intensity at the same time during TDS [19], and thus, there is a risk of interdependence among attributes [27,76]. That said, static block profiling requires panelists to integrate their changing sensory perceptions throughout oral processing to come up with a summary evaluation [77], and it is hard to control the point in the oral process at which products are evaluated. Thus, it makes sense to jointly use static block profiling and TDS profiling to obtain a better understanding of attribute intensity and dominance in food products.

Conventionally, in TDS profiling, different attribute families (taste, texture, and aroma) can be evaluated during different parts of a study ([37]). Here, however, the choice was made to evaluate the different attribute families at once. Although the influence of listing attributes from different families in the same list remains unknown [19], this methodological approach makes it possible to assess all the attributes simultaneously and to identify specific sensory phases. Texture attributes dominated the first part of the evaluation period. Then, depending on the product and the panelist, different attributes became dominant. Finally, in the latter part of the evaluation period, astringency became dominant.

The results obtained with the multi-intake TDS profiling method underscore that quantifying sensory experiences over time could provide additional information about how consumers perceive foods. For example, perceived fattiness became more dominant over the course of consumption, while other attributes (except astringency) became less dominant, perhaps because repeated tasting led to sensory adaptation. Previous research using multi-intake TDS profiling found that attributes related to texture and sapidity gradually increased over time but that there was no intake effect on how long aroma attributes remained dominant [34,36–38,78,79]. However, in these studies, panelists evaluated multiple spoonfuls of product in a row. In contrast, the present study had panelists evaluate spoonfuls of beverage at three distinct periods, corresponding to the beginning, the middle, and the end of the consumption of a full product portion. Another study that examined temporal changes in attribute perceptions during the consumption of an entire portion of an oral nutritional supplement found that there were differences in the aroma attribute “praline” over time [36].

These findings raise questions regarding the ideal number of spoonfuls and the amount of product that should be consumed by panelists. Here, it seemed to be more useful to have panelists evaluate spoonfuls taken at specific moments during the consumption of a full beverage portion than to have panelists consume several spoonfuls of beverage in a row. In other contexts, it could make more sense to evaluate multiple spoonfuls consumed ad libitum, such as when the goal is to investigate the effect of sensory-specific satiety, which is a decrease in attribute perception for a specific food following repeated exposure [80]. Nevertheless, both these methodologies (i.e., consumption of a full portion or ad libitum consumption) share the disadvantage that only one replicate of one product can be evaluated per session. Thus, in addition to being time-consuming, there is a risk of failing to pick up on differences among products. For this reason, it is important to explore how spoonful numbers and the amount of product consumed influence the results obtained.

Finally, for food production companies, improving methods for characterizing the sensory profiles of products is key to better understanding consumers' experiences. This study did not take into account temporal hedonic profiles. However, it could be interesting to combine descriptive and hedonic analyses with multi-intake TDS profiling. This approach could provide further insight into pea protein-based products, leading to their improvement ([36,38]).

5. Conclusions and Perspectives

In conclusion, this study's use of three methods—static block profiling, mono-intake TDS profiling, and multi-intake TDS profiling—helped clarify how the composition of pea protein-based beverages affected sensory perceptions. The static block profiling method, in which beverage attributes were evaluated immediately after consumption, revealed that the perception of beaniness depended on protein type, where it was higher when the pea protein source was an isolate than when it was a pellet. Perceived beaniness also increased when gellan gum content was lower, and the oil content was higher. The mono-intake TDS profiling method, in which beverage attributes were evaluated over a 2-min period following consumption, showed that beverages differed markedly in the dynamics of their aroma attributes. In particular, almond notes were more dominant, and pea notes were less dominant in pellet-based beverages than in isolate-based beverages. These characteristics were accentuated from one spoonful to the next. Perceptions of astringency and bitterness were impacted mainly by protein type and gellan gum content. While static block profiling found a moderate level of perceived astringency, mono-intake TDS profiling highlighted that astringency was strongly persistent and that this persistence seemed to be limited by gellan gum and salt contents. The use of the nose-clip during static block profiling indicated that there were few interactions of flavor with texture and taste. It also yielded evidence of a weak effect of congruency between the bitter/salty notes and the beany note. Specific sensory phases were also identifie: texture attributes were more prominent during initial consumption, and astringency was more prominent during later consumption. Finally, the multi-intake TDS profiling results suggest that, over time, the perception of fattiness built up, and the perception of beaniness shifted because of sensory adaptation. Thus, taken together, this study's findings have enhanced understanding of sensory perceptions of pea protein-based beverages under conditions that more closely resemble those associated with real-life consumption. They also provide clues for reformulating pea protein-based products to reduce beaniness, bitterness, and astringency.

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Conflicts of Interest: The sponsors had a role in the operational issues of the study and on the choice of the used products. However, the sponsors had no role in the design, execution, interpretation, and writing of the study.

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foods

Article

Seasonal Sensory Evaluation of Low Commercial Value or Unexploited Fish Species from the Portuguese Coast

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Abstract: Overfishing is increasing over time, and according to FAO (Food and Agriculture Organization), about one third of the world's fish stocks are now overfished. Thus, diversifying the target species is essential for fisheries sustainability contributing to improve resource-efficient processes. Non-target species can be valuable resources for the development of new food products. However, those species are scarcely studied, and it is of high importance to trace their seasonal sensory profile as a first step towards their valorisation. Therefore, in this study, seasonal influence on sensory properties of five low commercial value or unexploited fish species, namely *Trachurus picturatus* (blue jack mackerel), *Spondyliosoma cantharus* (black seabream), *Trigla lyra* (piper gurnard), *Serranus cabrilla* (comber) and *Capros aper* (boarfish), was assessed in order to identify the most favourable season for catching each species. Fish samples were assessed by a panel of 16 semi-trained assessors for sensory attributes previously identified. The evaluation takes place every 2 months. Statistical differences were reported between attributes and seasons for all species, except for *T. lyra*, which did not present any difference in its sensory attributes throughout the year.

Keywords: sustainability; sensory characterisation; discarded fish; seafood; fishing; season

1. Introduction

By-catches (the catch of species for which there is no direct effort) and discards (the part of the by-catch that is not used and is, therefore, thrown overboard) are a global phenomenon resulting from fisheries and have been of great concern for all stakeholders in the sector, such as industries, fishermen or scientists [1]. Since the early 1980s, some studies have shown that discards have reached 38 million tonnes (representing 40% of the total catch) but, as a result of further research and restrictions, they fell to around 27 million tonnes by 2014 [2].

By-catches occur because some fishing gears are less selective than others (for example, longline is more selective than gillnets and trawl), catching many more species than those targeted by the fishery [3].

This may lead to discards of many fish species which may be due to: (a) technical reasons for marketable species (e.g., onboard storage capacity, bad weather), (b) economic reasons (e.g., species with no or low commercial value, inexistence of a ready market for certain species, damage or poor quality of fish), (c) legal and administrative reasons (e.g., minimum legal sizes of marketable species, commercial fishing quotas already exceeded, unauthorised fishing licenses) and (d) biological/ecological reasons (e.g., patterns of distribution of species which in turn conditions the directed fishery for one or multiple species) [1,4,5]. In this context, challenging aspects are therefore: (i) understanding which species of low or no commercial value have an added potential for their nutritional value, to be used as food, and (ii) the progressive reduction of fish discards, developing alternatives for valorisation of those species, aiming of maximising the return on fishing captures and contributing to long-term environmental, economic and social sustainability.

The Atlantic Ocean is a valuable source of fish, which is a high-protein, low-fat food that provides a range of health benefits. As highly reported, depending on species, seafood can be an important source of proteins of high biological value, rich in polyunsaturated fatty acids of the omega-3 series, a source of vitamins (such as vitamin D) and minerals (such as Se, P and Ca), and essential amino acids [6]. Besides this, it is well known that fish plays an important role in global food security and nutrition, contributing essential nutrients, which are important to combat malnutrition throughout the world, especially for coastal populations in many undeveloped and developing countries. However, we live in a world of limited biological resources and, consequently, improving the efficiency of fish value chains to reduce losses and waste, in an effort to improve access and affordability to all, is of utmost importance and is essential for fisheries' sustainability contributing to improve resource-efficient processes and circular economy [7].

What is meant by "commercial species" and "low commercial values species"? In the beginning of this century, the authors of Reference [8] collated information from European laboratories and government agencies on commercial species in Europe, considering commercial species as "one that is subject to a contemporary local or regional fishery in a certain period of their life (whether as a target species, or a by-catch which is landed)". In total, 162 fish species from the Atlantic area were catalogued, and generally speaking, there is a tendency for an increase in the number of commercial species from northern to southern areas, with a mean number of 18.7 species from Baltic, North Sea and Celtic Sea areas to 44.7 species in the Iberian Peninsula [1]. This increase in the number of commercial species is due not only to the higher biodiversity in southern areas but also to the more diverse fish-eating habits in both Portugal and Spain [9]. This larger number of commercial species with different commercial value, associated with the traditional feeding habits of Portuguese consumers, established different categories of market prices for fish species, with the less known and the smaller species traditionally having a lower commercial value. Despite its costal location, the two most consumed species in Portugal are imported (the cod and the salmon) and sold at ca 10 € per kilo, a price above other very popular and local species, like hake, octopus and scabbardfish, sold between 3.5 and 6.5 € per kilo in the first auction [10].

Among species with low commercial value, the selected species *Trachurus picturatus* (blue jack mackerel), *Spondyliosoma cantharus* (black seabream) and *Trigla lyra* (piper gurnard) are particularly important. Firstly, for their landings (e.g., *T. picturatus* can reach 2800 t yr^{-1} in the last decade), but also due to the price they can achieve in the first auction that, during this study, ranged between 1.37 and 2.06 € per kilo.

Among species without commercial value, *Serranus cabrilla* (comber) and *Capros aper* (boarfish) are particularly abundant, the latter being species object of concern by the International Council for the Exploration of the Sea (ICES) in terms of its sustainability, given the high catches taken, for example, in the Celtic Sea [11]. In fact, species that have lower or even no interest to be used in human consumption are used for non-food purposes like pet food, or as raw material for direct feeding in aquaculture, livestock and fur animals. In 2018, 22 million tonnes (12% of the global fish production) were in this category [8], and for these reasons, ICES has recommended monitoring programmes for stock management, as well as the acquisition of biological information on these species [11]. *S. cabrilla* and *C. aper* are included in the species that are caught as by-catch and have no commercial value in national waters, being discarded on board, unlike other European countries. In Portuguese waters, *S. cabrilla* is one of the most important species in terms of rejection of several fisheries, namely gillnets and trawls, while *C. aper* is among the ten most important species in terms of abundance, being caught as bycatch in both crustacean and fish trawl fishing [1,12–14].

The referred species are some examples of low or no commercial value, but due to their mentioned characteristics, they can provide an alternative to the species normally caught/consumed (species of high commercial value) and contribute to decreasing overfishing.

One of the ways to contribute to marine ecosystem maintenance is to shift the consumer demand towards more sustainable seafood products, to reduce the overexploitation of most consumed fish species [15]. However, to achieve that behaviour shift, it is crucial to understand if discarded or low commercial value fish species present properties that stimulate their purchase in detriment of others. Nevertheless, the valorisation of underutilised species can be achieved not only by direct human consumption or added value bioproducts for the food sector, but also by bio compounds' extraction (e.g., enzymes, collagen and gelatines; pigments) for different applications, including in medical and pharmacological sectors, meals and silage from marine species and leather [3,16]. Thus, to promote these species, it is necessary, among other factors, to understand their seasonal sensory properties, as well as the most favourable season for their catch. Therefore, the consumption of these discarded fish can be enhanced, which promotes their commercial valorisation. In this sense, and among the different sensory analysis methods, the use of a semi-trained panel of tasters can be used as an instrument to assess the magnitude of sensory attributes. Thus, this investigation aims to characterise five fish species, namely blue jack mackerel, black seabream, piper gurnard, comber and boarfish, based on their sensory properties, as well as to outline the relationship between fish attributes and season of the year, enabling the selection of the best season for their capture.

2. Materials and Methods

2.1. Fish Samples Preparation

The species under study (blue jack mackerel, black seabream, piper gurnard, comber and the boarfish) were captured in the Portuguese coast during 2019 and collected every 2 months (in January–February, March–April, May–June, July–August, September–October, November–December), from the Peniche fishing harbour, and kept at 4 °C on the capture day. The samples were packed and stored at −20 °C in polyethylene bags until further analysis (7–9 days). On the experiment day, the fish previously thawed overnight (4 °C) were cut into fillets with skin and steam-cooked (without addition of salt or oil) at 100 °C for 10 min using a kitchen robot (Bimby, Vorwerk, Thermomix 31-1, Wuppertal, Germany).

2.2. Sensory Analysis

Sixteen selected and semi-trained assessors undertook the sensory descriptive analysis on five fish samples. Performance is a measure of a panel or evaluator's ability to make valid attribute assessments of the evaluated products. It can be monitored at a certain point in time or tracked over time. Performance comprises the ability of a panel to detect, identify and measure an attribute, use attributes in a similar manner to other panels or assessors, discriminate stimuli, use a scale appropriately, repeat its own results and reproduce the results of other panels or assessors [17]. The generation of the descriptors was based on the identification of their main sensory descriptors that were selected in our previous study [18], using CATA (Check-all-that-apply) methodology and a semi-trained panel, formed as previously reported [18]. In the CATA method, the panel members select the descriptors that best describe the test product from a given list. Those main sensory descriptors generated a list of attributes that was used by the panellists in the present study, to evaluate each fish species every 2 months throughout the year. The checklist was divided into four categories: odour, appearance, taste/flavour and texture (Table 1). For each sample, the panel members were instructed to mark on the checklist the intensity degree (from 1 to 5, where 3 is the ideal, 1 is absent and 5 too many) perceived for each descriptor.

Table 1. Descriptors checklist used for sensory analysis throughout the year for each species [19].

Descriptors \ Species	Blue Jack Mackerel	Black Seabream	Piper Gurnard	Comber	Boarfish
Appearance	Dark veins	Ivory colour	Colour uniformity	Ivory colour	Brightness
	Ivory colour	Brightness	White colour	Colour uniformity	White colour
	Laminar structures	Laminar structures	Laminar structures	Laminar structures	Laminar structures
Odour	Butter Sea Seaweed	Seaweed Sea Potato	Sea Seaweed Butter	Sea Seaweed Potato	Metallic Sea Seaweed
Flavour	Fat Fish oil Sea Fat content	Butter Sweet Sea Fat content	Butter Sweet Sea Fat content	Sea Butter Sweet Fat content	Butter Sea Fish oil Fat content
Texture	Firmness Chewability Cohesion	Firmness Chewability Cohesion	Firmness Chewability Cohesion	Cohesion Firmness Chewability	Firmness Chewability Cohesion

All tests were conducted in accordance with ISO (International Organization for Standardization) standards ISO 8586 [19] and ISO 11132 [20] in accordance with the International Organisation for Standardisation. Each sample was coded by three random digits, and cutlery, napkins and glass cups of mineral water were provided, as well as rusks to clean the palate between the samples. The panellists evaluated the cooked fish fillets in individual sensory booths in a sensory analysis laboratory (with temperature and lighting control).

2.3. Statistical Analysis

A one-way analysis of variance (ANOVA) was performed to assess the statistically significant differences between months for each species descriptor. Data normality and homogeneity of variance were also validated, and multi-comparison tests were performed by the Tukey or LSD (Least Significant Difference) tests [21]. The use of the ANOVA proved to be adequate, as it is sufficiently robust, in order to withstand violations of the interval data assumption and moderate skewing [22,23]. When the ANOVA assumptions were not met, the non-parametric Kruskal–Wallis test was performed followed by the Games–Howell multi-comparison test. The use of the Kruskal–Wallis test showed to be appropriate since it allows comparing distributions of two or more at least ordinal variables observed in two or more independent samples [24]. In order to compare the sensory pattern that is common for each species throughout the year, a matrix (input data) was constructed with the mean classifications of each month (rows) by descriptors (columns), followed by a principal component analysis (PCA) [25] to reduce the dimensionality of the data, but maintaining the relevant information contained therein [26]. The PCA procedure was performed on the covariance matrix, since the sensory scales are the same for all attributes [27]. The principal components (PC) are calculated by linear combination of original variables and adequately represent the original data [28]. For ANOVA, IBM SPSS Statistics 26 (Copyright IBM Corp. © 1989–2019, Armonk, New York 10504-1722, USA) was used. For the PCA, Canoco for Windows 4.5 software (Copyright Petr Smilauer © 2012–2019, Ithaca, New York 14850, USA) was used [25]. All results were considered statistically significant at the 5% level (i.e., whenever p-value < 0.05).

3. Results and Discussion

The complex nature of sustainable seafood consumption is dependent on motivational variables, such as intentions that are preceded by an attitude which are mainly formed through beliefs about taste, distaste, nutritional value, ease of preparation, familiarity and freshness [29]. Therefore, it is important to describe the sensory pattern of unexploited fish, in order to identify their market potential as a substitute of commercial species.

In the present study, the sensory data over the year for each fish species allowed the identification of their main sensory characteristics for direct consumption and/or application in a fish products formulation. These data will be discussed according to season for each species.

3.1. Blue Jack Mackerel

Blue jack mackerel sea odour, butter odour and ivory colour were statistically different bimonthly (ANOVA, *p*-value = 0.010, 0.037 and 0.007, respectively), as well as seaweed odour and stiffness (Kruskal–Wallis, *p*-value = 0.000 and 0.003, respectively). It is notable that the main differences occurred between winter (January and March), spring (May) and autumn (November) in relation to other seasons, although both winter months (January and March) also presented some differences between them (Tables 2 and 3). The highest ratings were reported in late winter (March) for sea and seaweed odour as well as for colour ivory, while they were achieved in the autumn (November) for butter odour and in the spring (May) for firmness. It should be noted that such high ratings, in all species in the present study, did not exceed the limit considered "ideal" (classification 3) by the panellists. Regarding PCA results, the two main components (PC1 and PC2) together explained 71.4% of the variability in blue jack mackerel descriptors (Figure 1a). The first component PC1 explained 39.2% of the sensory variability and is characterised by sea odour and flavour, as well as by seaweed odour and chewability (Figure 1a). These descriptors correlate in a positive and intense way, describe the sensory pattern at the end of winter (March) and are opposed to fat (Figure 1a). Although these are the descriptors that most describe the blue jack mackerel captured at the end of winter (March), cohesion and stiffness also showed some expressiveness, but with less preponderance than in spring (May) (Figure 1a). Thus, it can be concluded that the descriptors associated with the end of winter (March) were evaluated more positively than in autumn (November) (Figure 1a). On the other hand, in the beginning of winter (January), blue jack mackerel is associated with visible dark veins and stiffness, the latter with less expression (Figure 1a). Such descriptors were evaluated more positively at the end of winter (March), compared to the ivory colour, fish oil flavour and laminar structures, where this opposition characterises the second component PC2 which explained 32.2% of the sensory variability (Figure 1a). The summer has a low differentiating character in the sensory pattern of blue jack mackerel, although at the end of the season (September), this species was especially associated with fish oil flavour, laminar structures and butter odour (Figure 1a). Finally, it appears that blue jack mackerel cohesion had higher scores in the spring compared with its laminar structures and butter odour, proving to be opposite to the end of summer (September) and autumn (November) (Figure 1a). Considering these results, it appears that when blue jack mackerel is caught in the late winter (March), in autumn (November) or in late summer (September), it reveals a greater number of sensory descriptors compared to the other seasons (Figure 1a). It is important to note that when the objective of applying this species is to obtain the maximum fat content perceived by the consumer, the blue jack mackerel capture should be carried out, especially in the beginning of the summer (July) (Figure 1a). Therefore, this species revealed high potential to be marketed as fresh, especially at the end of winter (March), where the sea and seaweed flavour are more prominent. These attributes are considered as indicative of the fish freshness and, therefore, more appealing to the consumer. On the other hand, according to these findings, blue jack mackerel can also be applied in processed fish products, such as fish burgers, where the firmness and cohesion of the meat are important factors in the product integrity maintenance, with the most favourable season for the catch being spring (May).

Table 2. Sensory descriptors' mean range values for each fish species throughout the year.

Fish Species	Descriptor	Mean Values					
		January (d)	March (d)	May (a)	July (b)	September (b)	November (c)
Blue jack mackerel	Sea odour	2.8	3.2	3.1	2.8	2.9	2.8
	Seaweed odour	2.1	3.0	2.9	2.4	2.3	1.8
	Butter odour	2.1	2.5	2.3	2.8	2.7	3.1
	Dark veins	3.3	2.7	3.1	3.1	2.9	3.1
	Ivory Colour	2.2	3.1	2.1	2.9	2.9	2.3
	Laminar Structures	2.6	2.7	2.6	2.6	2.7	2.7
	Fish oil flavour	2.1	2.9	2.8	2.6	2.7	3.1
	Fat Content	2.6	2.5	2.5	2.2	2.3	3.1
	Sea Flavour	2.6	3	2.9	2.7	2.6	2.4
	Firmness	3.2	2.8	3.7	3.5	3.4	3.1
	Chewability	3.2	3.5	3.7	3.4	3.3	3.2
	Cohesion	3.3	3.1	3.3	2.9	3	2.9
Black seabream	Ivory colour	3.1	3.5	2.9	3.1	2.9	2.7
	Brightness	3.4	3.2	3.3	3.2	3.1	3.2
	Laminar structures	3.1	3.3	3.4	2.8	2.9	3.1
	Seaweed odour	2.8	3	2.9	2.7	2.6	2.7
	Sea odour	2.0	3.0	2.4	2.3	2.3	1.9
	Potato odour	2.5	3.0	2.7	2.9	2.9	2.7
	Butter flavour	3	2.9	2.7	2.5	2.7	2.9
	Sweet	2.8	2.7	3.3	2.4	2.4	3.5
	Sea flavour	2.7	2.4	2.6	2.9	2.7	2.3
	Fat content	2.8	2.9	3.1	2.9	2.9	2.9
	Firmness	3.1	3	2.7	3	2.9	2.9
	Chewability	3.3	3.3	2.8	3	2.9	3.3
	Cohesion	3.1	3.4	2.7	2.9	2.8	2.9
Piper gurnard	Colour uniformity	3	3	3.3	3.2	3.1	3.1
	White colour	3.2	3.1	3.4	3.1	3.3	3.4
	Laminar structures	3.4	3.0	3.1	3	2.9	2.7
	Sea odour	2.4	2.7	2.3	2.7	2.5	2.1
	Seaweed odour	2.3	2.3	2.2	2.1	2.2	1.7
Piper gurnard	Butter odour	2.9	2.7	2.3	2.2	2.3	2.5
	Butter flavour	3.4	2.9	2.6	3.1	2.7	3.1
	Sweet flavour	1.9	2.1	2.4	2.4	2.3	1.9
	Sea flavour	3.0	2.7	2.4	3.1	2.7	3.2
	Fat content	2.9	2.9	2.9	2.9	2.7	3.1
	Firmness	3	3.3	3.0	3.1	3.1	2.9
	Chewability	2.9	3.1	3.0	3.3	3.1	2.9
	Cohesion	3.1	2.9	3.1	3	2.9	2.9

Table 2. *Cont.*

Fish Species	Descriptor	Mean Values					
		January (d)	March (d)	May (a)	July (b)	September (b)	November (c)
Boarfish	Brightness	2.4	2.3	3.0	2.9	2.6	2.7
	White colour	2.7	2.9	2.5	2.4	2.5	2.7
	Laminar structures	2.7	2.3	2.2	2.5	2.4	2.7
	Metallic odour	2.4	3.3	2.5	3.2	3.1	2.7
	Sea odour	1.9	2.9	2.9	2.8	2.6	1.9
	Seaweed odour	2.9	3.9	3.4	3.3	3.3	4.1
	Butter flavour	3.1	2.5	3.1	2.8	2.7	2.7
	Sea flavour	2.6	2.4	2.5	2.9	2.5	2
	Fish oil flavour	2.9	2.7	2.7	2.7	2.5	3.6
	Fat content	3.4	2.6	2.9	3.1	2.5	3.1
	Firmness	2.9	3.3	2.9	2.5	2.6	2.8
	Chewability	3.1	3.3	3.2	2.7	2.8	2.7
	Cohesion	3.0	3.2	3.0	2.7	2.7	2.7
Comber	Ivory colour	2.8	3.1	2.7	2.9	2.6	2.6
	Colour uniformity	2.7	3.1	3.0	2.9	2.9	2.9
	Laminar structures	2.9	3.0	3.1	2.5	2.7	2.7
	Sea odour	2.4	2.1	2.2	2.3	2.2	2.2
	Seaweed odour	2.0	1.9	1.9	1.5	2	2
	Potato odour	2.7	2.6	2.3	2.3	2.6	2.6
	Sea flavour	2.5	1.7	1.8	2.7	2.1	2.1
	Butter flavour	2.9	2.5	2.3	2.2	2.5	2.5
	Sweet flavour	2.5	2.7	2.7	2.	3.1	3.1
	Fat content	2.9	2.3	3.1	2.7	2.7	2.7
	Cohesion	2.9	2.9	2.7	2.7	2.9	2.9
	Firmness	2.9	2.6	2.4	2.6	2.7	2.7
	Chewability	3.0	2.9	2.5	3	2.9	2.9
Legend:		(a) Spring	(b) Summer	(c) Autumn		(d) Winter	

Table 3. Sensory descriptors and statistical test value, for those with statistical differences between months/seasons, according to multiple comparison with LSD (Least Significant Difference), Tukey (T) or Games–Howell (GH) statistical tests.

Fish Species	Descriptor	Statistical Test Value	Comparison between Months		*p*-Value
Blue jack mackerel	Sea odour [LSD]	3.257	March (d)	January (d)	0.007 **
				July (b)	0.007 **
				September (b)	0.023 *
				November (c)	0.007 **
			May (a)	January (d)	0.023 *
				July (b)	0.023 *
				November (c)	0.023 *
	Butter odour [LSD]	2.490	January (d)	July (b)	0.037 *
				November (c)	0.004 **
			May (a)	November (c)	0.013 *
	Ivory colour [LSD]	3.470	January (d)	March (d)	0.009 **
				July (b)	0.026 *
				September (b)	0.043 *
			May (a)	March (d)	0.003 **
				July (b)	0.009 **
				September (b)	0.016 *
			November (c)	March (d)	0.026 *
	Seaweed odour [GH]	23.622	January (d)	March (d)	0.002 **
				May (a)	0.012 *
			July (b)	March (d)	0.018 *
			September (b)	March (d)	0.012 *
			November (c)	March (d)	0.000 **
				May (a)	0.000 **
	Stiffness [GH]	18.202	March (d)	May (a)	0.000 **
				July (b)	0.002 *
				September (b)	0.009 *
			November (c)	May (a)	0.019 *
Black seabream	Seaweed odour [T]	2.904	March (d)	January (d)	0.025 *
				November (c)	0.014 *
	Sweet taste [T]	4.230	November (c)	July (b)	0.011 *
				September (b)	0.011 *
Boarfish	Seaweed odour [LSD]	2.446	January (d)	March (d)	0.029 *
				May (a)	0.019 *
				July (b)	0.042 *
			November (c)	March (d)	0.027 *
				May (a)	0.018 *
				July (b)	0.039 *
	Chewability [LSD]	2.343	March (d)	July (b)	0.009 **
				September (b)	0.035 *
				November (c)	0.018 *
			July (b)	May (a)	0.035 *
	Stiffness [GH]	14.138	July (b)	March (d)	0.001 **
				May (a)	0.037 *
			September (b)	March (d)	0.004 *
Comber	Sea flavour [LSD]	2.725	March (d)	January (d)	0.025 *
				July (b)	0.005 **
			May (a)	January (d)	0.040 *
				July (b)	0.008 **
Legend:	(a) Spring	(b) Summer	(c) Autumn	(d) Winter	

* Results are significant at the 0.05 level; ** Results are significant at the 0.01 level.

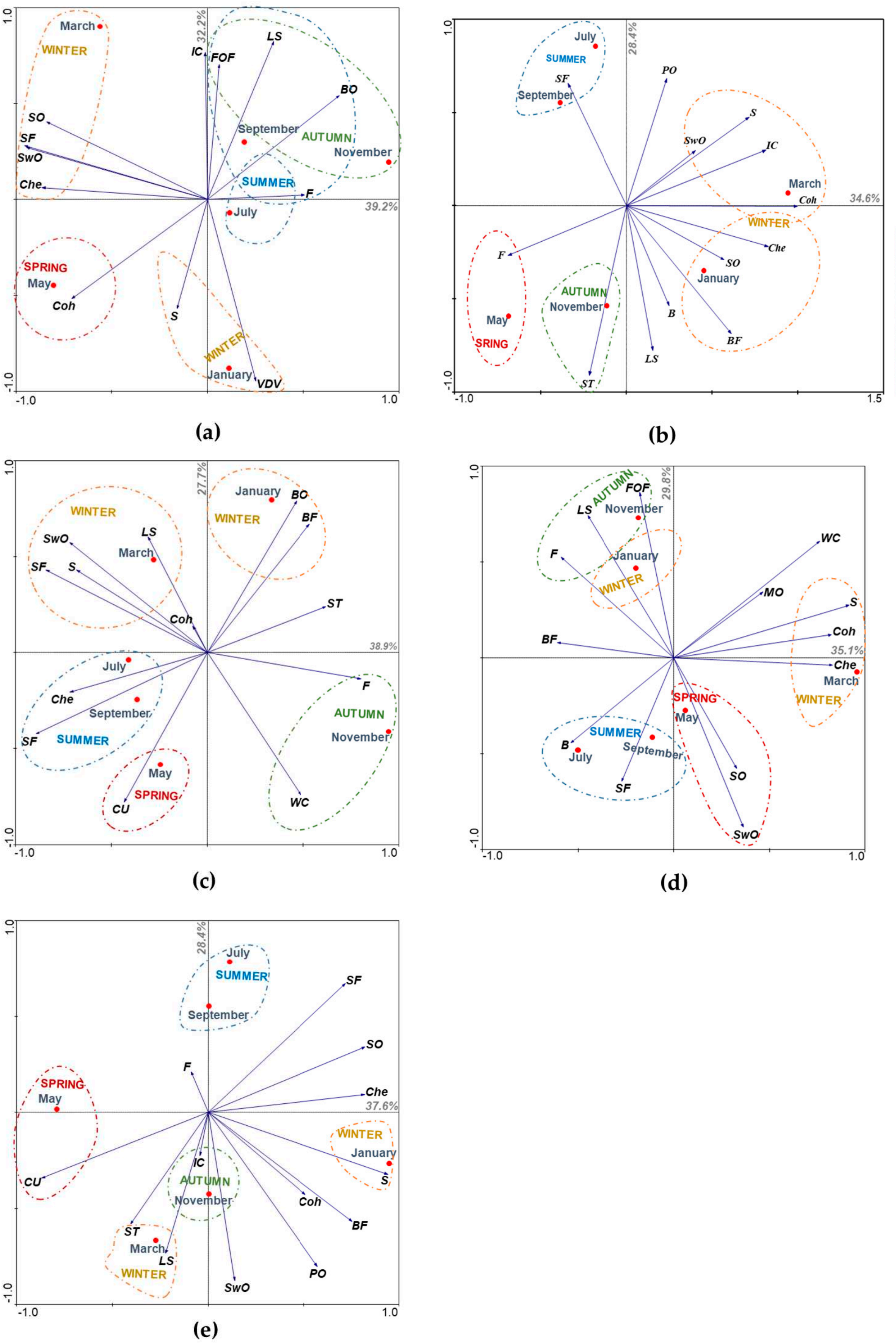

Figure 1. Principal Component Analysis (PCA) for sensory descriptors among species throughout the year for (**a**) blue jack mackerel, (**b**) black seabream, (**c**) piper gurnard, (**d**) boarfish and (**e**) comber. Legend: SO: sea odour; SwO: seaweed odour; BO: butter odour; VDV: visible dark veins; IC: ivory colour; LS: laminar structures; FOF: fish oil flavour; F: fat; SF: sea flavour; S: stiffness; Che: chewability; Coh: cohesion; PO: potato odour; B: brightness; BF: butter flavour; ST: sweet taste; CU: colour uniformity; WC: white colour; MO: metallic odour.

3.2. Black Seabream

Black seabream data reveal statistical differences in seaweed odour (ANOVA, p-value = 0.018) and sweet taste (ANOVA, p-value = 0.002), with the highest ratings being recorded in late winter and autumn, respectively (Tables 2 and 3). These differences were reported in seaweed odour between the winter months (January and March) as well as between the end of this season (March) compared to autumn (November) (Tables 2 and 3). Likewise, the black seabream sweet taste showed statistically significant differences between autumn (November) and summer (July and September) (Tables 2 and 3). According to PCA (Figure 1b), the first factorial plan explained 63.0% of the total data variability, where 34.6% is explained by PC1 and 28.4% by PC2. PC1 is mostly characterised by cohesion, followed by the intense and positive relationship between ivory colour, stiffness and seaweed odour (Figure 1b). Although cohesion is the most preponderant descriptor in late winter (March), this season is also associated with ivory colour, stiffness and seaweed odour, which are opposite to black seabream fat content that revealed higher rates in the spring (January and March) (Figure 1b). The beginning of winter (January) has a low differentiating character in black seabream sensory pattern, revealing some association with butter flavour, sea odour and chewability (Figure 1b). These descriptors reveal an opposite behaviour with sea flavour, which was evaluated more positively in the summer (July and September) (Figure 1b). Autumn (November) also has a low differentiating character in black seabream sensory pattern, revealing some association, especially with sweet taste, which opposes with potato odour, corresponding this opposition to the characterisation of the second component PC2 (Figure 1b). Therefore, when black seabream is captured in winter (January and March), it has descriptors classified more positively and in greater numbers compared with the other seasons, making this season the most favourable for catch (Figure 1b). On the other hand, when a higher level of fat perceived by the consumer is desired, the catch should be carried out in the spring (May) (Figure 1b). Due to the physical similarity of black seabream with the common species *Sparus aurata* (gilt-head seabream), its commercialisation will be facilitated, avoiding the need for transformation for its valorisation. Thus, considering the ivory colour as well as the attributes of freshness such as the seaweed odour, the end of winter (March) is considered the most favourable season for capture. On the other hand, due to the ivory colour of its meat, it can also be sold in substitution of *Merluccius merluccius* (hake) used in fish sticks, as well as in frozen fillets or loins form. Thus, considering stiffness and ivory colour as major factors for application on frozen fish sticks, fillets or loins, the most favourable season for the capture of this species will also be the end of winter (March).

3.3. Piper Gurnard

For piper gurnard, no meaningful descriptors were reported (p-value > 0.05). Thus, for this species, the descriptors evaluated did not suffer a significant effect of seasonality. PCA analysis throughout the year is presented in Figure 1c, where the first factorial plan explained 66.6% of the descriptors' total variability, divided in 38.9% for PC1 and 27.7% for PC2. PC1 is characterised by the opposition between laminar structures and white colour, where the first descriptor presents greater preponderance in piper gurnard sensorial pattern at the end of winter (March) (Figure 1c). At this time of the year, piper gurnard presents an intense and positive relationship between seaweed odour, stiffness and sea flavour, although they have little preponderance in the sensory pattern in the late winter (March) (Figure 1c). However, at the beginning of winter (January), piper gurnard is associated with butter odour and flavour, which are opposed to its colour uniformity that is associated when this species is captured in the spring (May) (Figure 1c). PC2 is characterised by the opposition between the summer (July and September) and autumn (November) (Figure 1c). In the summer, the piper gurnard is characterised by chewability and sea flavour, related in an intense and positive way (Figure 1c). In autumn (November), the sensory pattern of piper gurnard is characterised by fat and white colour, although the latter with less expression (Figure 1c). When this species is captured in late winter (March), in summer (July and September) and in spring (May), a greater number of descriptors are perceived compared to autumn (November) and the beginning of winter (January) (Figure 1c).

The commercialisation of this species as whole in fresh fish, may be hampered by the presence of spines in the operculum area and ventral fin, making the preparation process (such as evisceration) more laborious, discouraging the consumer to buy such a product. Therefore, because piper gurnard was not considered a species with firm meat and the fillets are thinner and less appealing, it is considered that the sale as a fillet may discourage its commercialisation. Considering the butter odour and flavour generally appreciated in snacks, the piper gurnard fillets can be dehydrated after frying with a consequent increase of the fillet's firmness, allowing the crispy texture so valued in this type of product. Such attributes are especially found in the beginning of winter (January) and it is recommended to capture the piper gurnard in this season. Additionally, with the development of this type of snack, the consumption of fish will be promoted, resulting in a healthier snack that can also be added to salads, nutritionally enriching this type of product.

3.4. Boarfish

Boarfish presented statistical differences in seaweed odour and chewability (ANOVA, p-value = 0.041 and 0.048, respectively), as well as in stiffness (Kruskal–Wallis, p-value = 0.015). As far as the seaweed odour is concerned, there are differences between the beginning (January) and the end of the winter (March), spring (May) and the beginning of summer (July), where a similar behaviour was reported when these seasons are compared with autumn (November) (Tables 2 and 3). The highest ratings were obtained in late winter (March) and spring (May) (Tables 2 and 3). On the other hand, the attributes related to boarfish texture revealed differences mainly between the end of winter (March), where the highest classifications of both attributes were reported, and summer (July and September) and spring (May) (Tables 2 and 3). According to boarfish PCA results (Figure 1d), the first factorial plan explained 64.9% of the total variability, where the PC1 explained 35.1% and PC2 29.8%. PC1 is characterised by the positive association between cohesion, stiffness and chewability that are opposed to brightness and sea flavour, and especially butter flavour, being the first descriptors associated with the end of winter (March) (Figure 1d). Boarfish caught in the summer (July and September) is characterised by butter and sea flavour, while sea and seaweed odours are associated with spring (May) (Figure 1d). Spring (May) revealed an opposite behaviour with autumn (November), which is characterised mainly by fish oil flavour and, to a lesser extent, by laminar structures and fat, corresponding this opposition to the characterisation of the second component PC2 (Figure 1d). The beginning of winter (January) has a low differentiating character in the sensory pattern (Figure 1d). Thus, it appears that a greater number of descriptors are obtained when the boarfish is captured at the end of winter (March) or autumn (November), compared to summer (July and September) and spring (May) (Figure 1d). Due to the small size of this species, the valorisation through processed products would not be profitable, which is a reason why this should be achieved through its commercialisation as whole and fresh fish. However, due to the unusual boarfish appearance, which may discourage its purchase, its valorisation may go through the heading and sale as fresh breaded and ready to cook. Thus, considering that the consumers are looking for more convenient and practical food products, the boarfish valorisation can be achieved. Considering that the attributes that vary statistically are not the most relevant in this type of product and that in fresh products the most important attributes fall on texture (cohesion, stiffness and chewability) and freshness (seaweed odour and sea odour), the best seasons for capture will be the end of winter (March) and spring (May).

3.5. Comber

Comber sea flavour was the only descriptor with statistical differences through the year (ANOVA, p-value = 0.025). Those differences were reported between the winter months (January and March), between the beginning of this season (January) and the beginning of summer (July), with a similar pattern in the spring (May) (Tables 2 and 3). According to comber PCA results (Figure 1e), the two main components together explained 66% of the descriptors' total variability. The PC1 explained 37.6%, while PC2 explained 28.4% of total variability (Figure 1e). PC1 is characterised mostly by the opposition between colour uniformity and sea flavour, sea odour and chewability, where the first descriptor has some association with spring (May) (Figure 1e). PC2 is characterised by the opposition between laminar structures, sweet taste and ivory colour with sea flavour, sea odour and chewability, as well as by the opposition between fat and seaweed odour, potato odour, cohesion, butter flavour and stiffness (Figure 1e). Both winter months (January and March) revealed different sensory patterns, where its beginning (January) is characterised by sweet taste and laminar structures, while, at the end, stiffness characterizes comber (Figure 1e). Summer (July and September) and autumn (November) have a low differentiating character in comber sensory pattern, although ivory colour has some association with the latest season (Figure 1e). Therefore, considering that most seasons are not strongly associated with the sensory descriptors, comber capture may be carried out at any time of the year, being aware that the firmness will be "ideal" in the beginning of the winter (January), with subsequent improvement of the sweet taste and laminar structures at the end of this season (March) (Figure 1e). This species has potential for commercialisation as fresh whole fish or for addition to processed products, however it will not be suitable for fillets given the small size of this species. As mentioned, its capture can be carried out at any time of the year, with the exception of products where firmness is the main attribute, and this must take place at the beginning of winter (January). Examples of such products are sausages and hamburgers, where firmness (in association with cohesion) allows the maintenance of product's integrity before, during and after cooking.

3.6. General Discussion

With the analysis of the data as a whole, the species under study revealed high acceptability throughout the year, consequently showing a huge unexploited potential for value adding. In fact, considering as an example a review by Egerton and colleagues about boarfish, there is a large number of potential products and by-products that could be produced with this species, reflecting its great valorisation potential [30]. Those products include fillets, fish mince blocks (for breaded consumables, fish cakes, surimi, etc.), surimi and protein hydrolysates peptides through muscle utilisation [30]. The boarfish skin, not being used, can be utilised for leather, collagen and gelatine and pigments, while viscera can be a source for fish silage, enzymes and oil [30]. Finally, the gonads can be a source of lectins and the headed and gutted fish can be commercialised as pan-fried or breaded [30]. Although nutritional analysis should be carried out to confirm the other species' potential, they can also be valorised, like boarfish. With the high growth of the world population, it is necessary to develop new policies to ensure the food supply, as well as to support sustainability in socioeconomics and environmental growth in the marine and maritime sector [31]. Thus, the use of discarded fish species must be carried out, for example, through the conversion of these new biomasses in medium–high added value products, such as minced muscle suitable for the preparation of different seafood products with different textures and flavours (e.g., burgers, nuggets or structured fingers) for those specimens above minimum conservation reference sizes (MCRS) [31]. For those specimens captured below the MCRS, their valorisation can be achieved by biotechnological transformation and by-products generated in the recovery of fish mince (heads, skins and bones) for industrial applications as nutraceuticals, pharma, food ingredients and others [31]. However, focusing on direct human consumption, it is important to make known the benefits of consuming discarded species to the consumer that are unknown to him [29].

Globally, results allowed perceiving the influence of the season in the sensory characteristics. In addition, the sensory analysis over the year allowed to identify which seasons are more favourable for the capture, considering certain target sensorial characteristics that enable the formulation of a fish product pleasant for the consumer. Despite the fact that most of the fish under study had some heterogeneity in the intensity scored in the sensory descriptors, homogeneity was also found in some cases, revealing that the capture can be carried out at any time of the year without changing the sensory characteristics for each species.

Despite the importance of the present study, it has some limitations that should be taken into account. Regardless of the seasonal influence on fish sensory descriptors, it should also be considered that there may be some variation in the panel's judgment due to the different times of the year that this evaluation took place. Therefore, further studies are needed, including consumers' acceptance studies, to confirm the conclusions of the present work. In addition, the importance of nutritional analysis of the studied species should be emphasised using instrumental methods to corroborate these results and conclusions, in particular those related to fat content.

4. Conclusions

The present study allowed to determine the principal sensorial features of five low commercial value or unexploited fish species captured in the Portuguese coast. With these data, it is possible to verify the time of year with the highest number of sensory descriptors perceived by the panellists, which can support the most favourable season for the species capture. In fact, all the species under study revealed statistical differences between attributes and seasons, except for piper gurnard. The lack of heterogeneity of the sensory descriptors throughout the year revealed that piper gurnard can be commercialised at any time of the year, without significant changes in its sensory characteristics. On the other hand, for the remaining species that revealed statistical differences, with the goal of selling them as fresh or processed and the need to be in their best sensory form in order to be appealing to the consumer, the present study described the best time to capture for this purpose. Except for comber, for all the other species, the most favourable season to catch is the end of winter (March) due to the some highlighted sensory attributes. For blue jack mackerel, there is a greater flavour of seaweed and sea at this time of year. For black seabream and boarfish, attributes of better texture and freshness are associated. For comber, there is an ideal firmness at the beginning of winter (January), with an intensification of sweet flavour and laminar structures at the end of this season (March). However, although this is the first study involving seasonal characterisation of these species, more research will be needed to validate these results. It should also be remembered that the species' valorisation with or without low commercial value does not only involve promoting their fresh sale but can also be achieved in the development of new food products, for cosmetic, pharmacological or medical purposes, and animal feed.

In the future, the nutritional composition of these species will be assessed, followed by new food products development, that will also be evaluated for their compositional nature. It is also important to analyse the fish consumption habits in Portugal, to verify whether discarded species are already consumed and the consumer's idea of sustainable habits. In addition, it would be important to perform consumers' acceptance studies regarding these fish species in order to verify if their preferences meet the panellists' results.

Author Contributions: F.S., A.M.D., S.M. and M.M.G. contributed to the conceptualisation and experimental design of the study; F.S., A.M.D. and E.M. undertook the study (investigation); V.S., A.R.V., A.N., L.G. and E.M. contributed to sample collection; F.S., A.M.D. and S.M. conducted the formal data analysis and presentation of the data; F.S. and A.M.D. wrote the original manuscript draft; reviews and editing of the completed manuscript were conducted by F.R.P., S.B., A.N., V.S., A.R.V., L.G., S.M. and M.M.G.; project administration was the responsibility of M.M.G. All authors have read and agreed to the published version of the manuscript.

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foods

Article

Sensory Acceptability and Proximate Composition of 3-Blend Plant-Based Dairy Alternatives

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Abstract: Limitations of plant-based dairy alternatives as sustainable foods are their relatively low protein content and low sensory appeal. In this study, we used a consumer-led product development approach to improve the sensory appeal of existing prototypes of 3-blend dairy alternatives produced from melon seeds, peanuts and coconut. We used Relative Preference Mapping (RPM) and consumer acceptance testing using the 9-point hedonic scale to respectively identify innovative flavours and deduce the effect of ingredient components on consumer sensory appeal. Mixture design was used as the formulation tool to obtain optimized prototypes of the 3-blend dairy alternatives. Proximate analysis of the new prototypes, instrumental color assessment and consumer testing provided a basis to select a sustainable 3-blend dairy alternative. This prototype had a relatively high protein content (2.16%), was considered innovative by target consumers and also had a moderate liking score (6.55 ± 1.88) on the 9-point hedonic scale. Prototypes with higher protein content had low sensory appeal and were not considered innovative. Other prototypes with innovative sensory appeal had low protein content. By combining different plant raw materials and utilizing different sensory testing methods, we were able to design sustainable plant-based dairy alternatives which can be further optimized.

Keywords: plant-based dairy alternatives; consumer acceptance; innovation; sustainable foods

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1. Introduction

The Food and Agriculture Organization (FAO) defines a sustainable diet as a diet that is nutritionally adequate, affordable, safe, and culturally acceptable while sparing natural and human resources [1]. The growing world population calls for the need to find sustainable ways to meet the increasing demand for food, especially protein-based foods. A sustainable diet should take into consideration not only the environmental impact but the nutrient density and adequacy of the diet [2–5]. Using livestock and their products to feed the world has a high environmental impact which includes the emission of greenhouse gases (GHGs) with the resultant negative impact on climate. Additionally, there is stress on the global nitrogen cycle and a negative effect on biodiversity. Water pollution, acidification, eutrophication and other adverse environmental impacts also result from rearing livestock [6–11]. Furthermore, the conversion of plant protein sources to animal protein for human consumption is only about 15% efficient [6,12,13] and this is not an environmentally sustainable process. There is thus a pressing need to find sustainable ways to feed the world with nutrient-rich diets that do not rely heavily on animal-sourced foods.

A plant-based diet is recommended as a means of mitigating the effects of relying on animal and animal products to meet the protein and nutritional needs of a growing world population [7,14]. Consuming a plant-based diet has a less negative environmental impact, uses less land and water, is relatively less expensive and more abundant than animal-based diets. Though some researchers have advocated that a balanced plant-based diet can provide all the nutrients needed for everyday life [8,12], others believe that plant-based diets are nutritionally inferior to diets including animal products [15,16].

Dairy alternatives are also called by various names including plant milk, plant milk alternatives, plant-based milk alternatives or other similar variations, but in the European Union (EU) and Canada, the term 'milk' is only used for the "normal mammary secretion obtained from one or more milkings without either addition thereto or extraction therefrom" [17,18]. In this article, we will refer to the dairy alternatives as plant-based dairy alternatives. Plant-based dairy alternatives are water extracts of dissolved and/or disintegrated plant material which look like dairy milk [15,16]. They have become popular and are typically consumed by people who have dairy milk allergy, are lactose intolerant, who have a preference for the vegan diet or who want to consume lower calories as part of special diets [10,16]. They are good dairy alternatives in places where dairy milk is too expensive or scarce [19]. Most plant-based dairy alternatives have health-promoting ingredients such as dietary fiber, antioxidants, minerals, vitamins, flavonoids, etc. [16]. Analysis of various plant-based dairy alternatives has shown that, apart from soymilk, most have low or no protein (<0.5) [10,20]. Additionally, most plant-based dairy alternatives do not have appealing sensory profiles [10,15]. Blending of different plant materials to produce plant-based dairy alternatives may be one way to improve both the nutritional and sensory profile of these products [16,21].

In our previous study, one, two and three blend plant-based dairy alternatives using melon seeds, peanut and coconut were formulated based on the functionality and perceived health benefits of these plant materials, their low cost and wide availability in Ghana [22]. An opportunity to improve the acceptability of these prototypes using a consumer-led approach was identified and formed the basis of this study. Various methods have been applied to products and process optimization using consumer appeal. Traditionally, consumer acceptance testing is used at the end of the development phase to evaluate the acceptability of products. Although this method allows direct measurement of consumer appeal and allows selection of the most appealing product, the unidimensional approach of acceptance testing does not adequately identify what drives appeal and how to improve or position the winning product. Recently, the Relative Preference Mapping (RPM) method, developed for wine public tastings to highlight innovative products, has been identified as a useful tool to guide product development optimization processes [23]. The method allows for quick identification of innovative flavours within a product prototype when compared to a known reference product. This comparison allows rapid selection of improved flavour prototypes which may be launched or taken into further development. Although RPM is useful to identify innovative flavours, it is limited in detailing the drivers of liking, since no sensory verbalization step is included in the technique. Formulation designs (or mixture designs), in combination with consumer acceptance tests, can be used to specify the ingredients or processes, with their interactions, that drive consumer acceptability.

This work follows up a previous study in order to develop, optimize and characterize 3-blend plant-based dairy alternatives formulated from locally available, inexpensive ingredients that are abundant, using a consumer-led product development approach [22]. We applied RPM to identify the innovations in flavour developed from a combination of melon seeds, peanuts, tiger nuts and coconut milk, then used mixture regression analysis of the consumer acceptability scores generated from samples obtained from the mixture design, to understand how the ingredients or their interactions drive consumer appeal for the product prototypes.

2. Materials and Methods

2.1. Materials

Melon seeds (*Citrullus lanatus* L.), peanuts (*Arachis hypogea* L.), coconuts (*Cocos nucifera* L.) and tiger nuts (*Cyperus esculentus* L.) were purchased from local markets in Ghana. Xanthan gum (Micrite Group Gh Ltd, Accra, Ghana) buffers: KH_2PO_4 and K_2HPO_4 (SureChem Prototypes Ltd., Suffolk, UK) were obtained in Accra while Bromelain tablets

(Source Naturals, Scotts Valley, CA, USA) were obtained from the United States of America. Even ultra-high temperature pasteurized (UHT) full cream milk, a commercial pasteurized dairy milk was purchased and sweetened to a specified level and used as the reference sample for the RPM consumer test. Vitamilk, a commercial soymilk beverage (a popular plant-based dairy milk alternative) was also purchased and included in the product test set.

2.2. Methods

2.2.1. Product Formulation

Focus group discussions with target consumers (unpublished data) were used to glean information on product characteristics for an appealing plant-based dairy alternative. Three focus group discussions with seventeen (17) participants were organized. Participants were aged between 18 and 49 years and the three groups were made up of eight (8) females aged between 18 and 30 years, four (4) males aged from 18 to 30 years and a mixed group of five (5) males and females aged between 31 and 49 years. These took place in the meeting room of the sensory evaluation laboratory of the University of Ghana. Each discussion lasted for 90 min. The discussions centered around which plant materials to include and the expected sensory characteristics desirable in a plant-based dairy alternative for consumers. We incorporated product tasting during the discussions to guide consumer responses. Based on consumer feedback from the focus group discussions, the prototypes developed earlier by Odoom (2018) [22] were optimized in three key ways; ingredient change, process change and re-formulation using a four-component lattice mixture design from Minitab v. 17.1.0 (Minitab Inc., State College, PA, USA). The three elements are outlined as follows:

- Ingredient change: tiger nut was added as a new ingredient to the original ingredients (melon seeds, peanuts and coconut) to use as raw material.
- Process change: a new process was developed to process peanut milk; peanuts were roasted instead of soaking in 2% $NaHCO_3$ for 24 h.
- Reformulation: a four-component mixture design using Minitab v. 17.1.0 (Minitab Inc., State College, PA, USA), instead of a three-component mixture design used in the previous study by Odoom (2018) [22].

The software (Minitab v. 17.1.0) generated 19 product formulations for the four-component mixture design. The upper and lower bound constraints for the four-component mixture design are shown in Table 1. The resulting 19 trial runs included 1-, 2-, 3- and 4-blend formulations as shown in Table 2. Only 3-blend prototypes were used for the consumer test using RPM, as we wanted to leverage on the nutritional and sensory characteristics of three plant-based dairy alternatives instead of 1 or 2 to produce a nutritionally adequate and consumer acceptable plant-based dairy alternative. A four blend plant-based dairy alternative was not investigated in this study.

Table 1. Lower and upper limits of the four component raw materials.

Component	Lower Limit (%)	Upper Limit (%)
Coconut	25	100
Peanut	0	100
Tiger nut	0	100
Melon Seeds	0	100

Table 2. Design matrix for a four-component mixture design for the plant-based dairy alternatives.

Run Order	Prototype	X_1 (%)	X_2 (%)	X_3 (%)	X_4 (%)	Total (%)
1	**A**	**50.000**	**0.000**	**25.000**	**25.000**	**100**
2	B	34.375	9.375	46.875	9.375	100
3	C	71.875	9.375	9.375	9.375	100
4	D	34.375	9.375	9.375	46.875	100
5	**E**	**25.000**	**37.500**	**37.500**	**0.000**	**100**
6	F	25.000	0.000	75.000	0.000	100
7	G	25.000	75.000	0.000	0.000	100
8	**H**	**25.000**	**37.500**	**0.000**	**37.500**	**100**
9	I	62.500	0.000	37.500	0.000	100
10	J	25.000	0.000	0.000	75.000	100
11	K	34.375	46.875	9.375	9.375	100
12	L	100.000	0.000	0.000	0.000	100
13	M	62.500	37.500	0.000	0.000	100
14	**N**	**50.000**	**25.000**	**0.000**	**25.000**	**100**
15	O	62.500	0.000	0.000	37.500	100
16	**P**	**50.000**	**25.000**	**25.000**	**0.000**	**100**
17	Q	43.750	18.750	18.750	18.750	100
18	**R**	**25.000**	**0.000**	**37.500**	**37.500**	**100**
19	S	25.000	25.000	25.000	25.000	100

X_1—Coconut Milk, X_2—Peanut milk, X_3—Tiger nut milk, X_4—Melon Seed Milk. Formulations in **bold font** are the 3-blend formulations used for consumer preference test using Relative Preference Mapping (RPM).

2.2.2. Processing of Plant-Based Dairy Alternatives

Each plant-based dairy alternative was extracted separately to obtain a single dairy alternative before blending them according to the predetermined ratios obtained from the mixture design (Table 2). The plant-based dairy alternatives were processed based on the method described by Odoom (2018) [22] with the following modifications: Bromelain enzyme was added to hydrolyze the proteins in the melon seed milk to control viscosity before blending in the formulations. This was done because Odoom (2018) [22] realized that melon seed milk coagulated when heated; this is caused by the unfolding of proteins and the exposure of non-polar amino acids to water, increasing the surface hydrophobicity. The increased protein to protein interaction leads to aggregation or gelling [10]. Another modification was that the peanuts were roasted at 120 °C for 40 min instead of soaking in 2% $NaHCO_3$ for 24 h during peanut milk processing. This was done in response to consumer feedback from the focus group discussions. To produce tiger nut milk, tiger nuts were manually sorted to remove contaminated and defective nuts. The nuts were washed with water and roasted for 15 min at 120 °C in an electric convection fan oven (HC 62062, Kaiser, Berlin, Germany). The tiger nuts were blended with water in the ratio of 1:4 in an automatic home soymilk mixer (PB103, AliExpress Ana zhang Store, China) for 2 min. The slurry was filtered using a plastic kitchen mesh strainer to obtain tiger nut milk. To each single plant-based dairy alternative, weighed quantities of buffer, cane sugar and stabilizer were added, heated to 70 °C and homogenized by passing through a colloid mill (Premier 84, Premier Colloid Mills Limited, Walton on Thames, Surrey, UK).

To produce the various formulations, the four pretreated milk samples were mixed according to the ratios obtained using the four-component lattice mixture design (Table 2). The samples were pasteurized at 80 °C for 20 min. The pasteurized milk was hot-filled into 500 mL chlorine sterilized PET plastic bottles with caps and closed. They were rapidly chilled to 5 °C and stored at 4 °C.

2.2.3. Identifying Products with Innovative Flavour Using RPM

Relative Preference Mapping was designed to be used in a social setting [23]; as such, this test was carried out at selected product and food fairs to depict a social setting as described by the developers of the method. The T-Map scale shown in Figure 1 was used for the evaluation of the prototypes. It has two axes, the *y*-axis which is the liking axis, and the *x*-axis which is the difference axis. The same test protocol as described for RPM using the T-Map scale was used [23]. The T-Map scale was printed on an A0 sheet, which was set up using a flip chart stand. Assessors were given a strip of colored dots with the different product codes: they were instructed to place the product codes on the T-Map scale based on their assessment. A total of 90 consumers of plant-based dairy alternatives participated in this study. Participants were selected by a one-on-one interview using a recruitment questionnaire. They were verbally screened for any known allergy to any of the ingredients used for the formulations. Participants chosen were those who indicated that they were consumers of plant-based dairy alternatives. They proceeded with the tasting after they had signed an informed consent form. Of the 19 runs obtained from Minitab, six (6) were 3-blend formulations and were the main test products in this study (Table 3). The RPM protocol requires a reference product which is repeated in the product set as a blind control product. In this study, Even ultra-high temperature pasteurized (UHT) full cream milk, a commercially available dairy milk product, was used as the reference, R, and blind control, BC. This product was sweetened to the same level of added sugar as the prototypes to reduce bias caused by sweetness as a source of consumer appeal. This was done by adding 4% *w/v* of granulated sugar to the dairy milk sample and stirring to ensure that all the sugar was dissolved. This was the same quantity of sugar added to the prototypes during processing. A limitation of this consumer test was that the extra sugar added to the dairy milk sample could have influenced consumer perception of the reference sample. Vitamilk, a popular and widely consumed plant-based dairy alternative, made from soybeans, was also added to the product set as sample V. This product is already sweetened and was used "as is". Altogether, assessors evaluated eight (8) products in this test. Each assessor was served with 20 mL of the reference sample to familiarize themselves, after which 10 mL of each test prototype was served to them in a predetermined randomized order based on the William's Latin Squares design in Compusense. Each assessor tasted the product set only once. They were allowed to re-taste the reference as often they wished during the evaluations and could be served more if required. All samples were served chilled at 10 ± 2 °C. They were maintained at this constant temperature by placing them in a chill box when they were not being tasted. To make a judgement, assessors were instructed to simultaneously evaluate how different was, and how much they liked, the test product compared to the reference product, after which they placed the corresponding product code on the T-map scale.

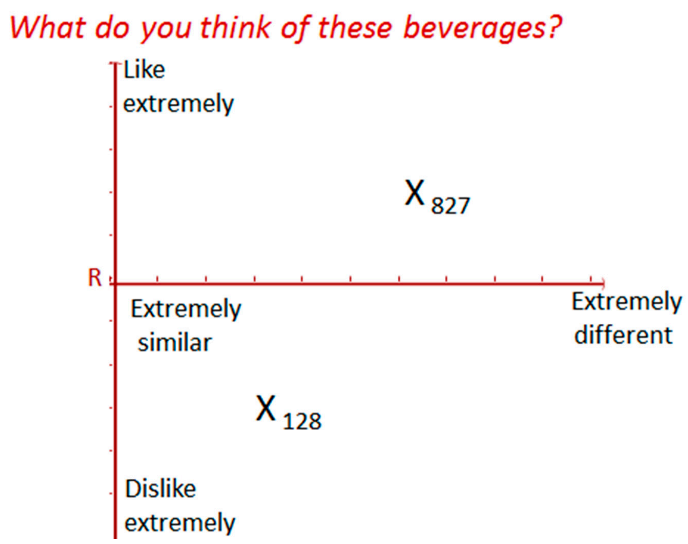

Figure 1. T-Map Scale used for RPM. X_{128} represents a mark (X) placed on the map by an assessor to show the position of product 128 on the T-Map Scale. This means that product 128 is perceived as liked less compared to the reference (R) and quite similar to the reference. Product 827 is perceived as liked more compared to the reference (R) and more different from the reference (R).

Table 3. Products used for Relative Preference Mapping.

Product Number	Product Code	Product Details	Other Details
1	A	C $_{(50\%)}$ T $_{(25\%)}$ M $_{(25\%)}$	Prototype
2	E	C $_{(25\%)}$ P $_{(37.5\%)}$ T $_{(37.5\%)}$	Prototype
3	H	C $_{(25\%)}$ P $_{(37.5\%)}$ M $_{(37.5\%)}$	Prototype
4	N	C $_{(50\%)}$ P $_{(25\%)}$ M $_{(25\%)}$	Prototype
5	P	C $_{(50\%)}$ P$_{(25\%)}$ T$_{(25\%)}$	Prototype
6	R	C $_{(25\%)}$ T $_{(37.5\%)}$ M $_{(37.5\%)}$	Prototype
7	V	Vitamilk	Commercial product
8	BC	Even ultra-high temperature pasteurized (UHT) full cream milk	Commercial product sweetened to the same concentration as the prototypes

C—Coconut milk, T—Tiger nut milk, P—Peanut milk, M—Melon seed milk. Subscripts indicate the percentage component of the ingredient in the final formulation based on the mixture design method.

2.2.4. Consumer Acceptance Test and Mixture Design Analysis to Understand Ingredient Contribution to Product Acceptance and to Identify Optimal Formulation

To explore which ingredients influence consumer appeal, mixture design regression analysis was used. Consumer acceptance scores served as the dependent value in the model and required that the full set of 19 prototype runs were evaluated by consumers. Considering the large number of products to be tasted by consumers, a Balanced Incomplete Block Design (BIBD) [24] method was used for this test. The BIBD design was set up using SAS® v. 9.4 (100 SAS Campus Drive, Cary, NC, USA) and required 19 regular consumers of plant-based dairy alternatives to complete the taste test. Each assessor evaluated 9 out of the 19 prototypes. Assessors used the traditional 9-point hedonic scale with descriptors and numbers to score how much they liked each of the products. On this scale, a score of 1 means: dislike extremely and a score of 9 means like extremely. This was a paper-based test.

Each assessor received 15 mL of each prototype which was served in 20 mL disposable transparent plastic cups at a temperature between 8–10 °C. In this study, only the 19 prototypes were assessed; the commercial products (dairy milk sample (BC) and the plant-based dairy alternative, Vitamilk (V)) used in the RPM test were not included as the objective of this consumer test was not to compare the acceptability of the prototypes with these samples.

Assessors were asked to evaluate the prototypes based first on their overall liking of the prototype, after which they proceeded to evaluate how much they liked the appearance, flavour, mouthfeel, consistency and after taste sensations. After evaluating each product, assessors were asked to write down what they liked or disliked about each prototype. They rinsed their mouths with water before proceeding to the next prototype. The consumers used in this study were not the same as those who participated in the RPM study.

2.2.5. Proximate Composition and Instrumental Colour Evaluation

Proximate Composition

The proximate composition of the prototypes, the commercial dairy milk alternative (V) and the dairy milk product (BC) were assessed. Total moisture was determined as described by Pinelli et al. (2015) [25]. For each beverage 20 mL was dried in a hot air oven at 105 °C till constant mass. The nitrogen content (N) of the samples was determined using the Kjeldahl method as described by the Association of Official Analytical Chemists (AOAC) (2005) [26] (method 991.20). The total protein was calculated by multiplying N (the total nitrogen) with 6.25 as the conversion factor. The total solids content was calculated by subtracting the total moisture content from 100%. The total fat content was determined using the Rose-Gottlieb Method AOAC (2005) [26] (method 905.02). The total ash was determined by heating 2 g of the sample in a furnace at 600 °C for 6 h as described by AOAC (2005) [26] (method 935.45). Total carbohydrate content was determined by difference as described by Pinelli et al. (2015) [25]: Crude Carbohydrates = 100% − (%protein + %moisture + %crude fat + % crude ash).

Color

The color of the products used for RPM was measured as described by Aidoo et al. (2010) [27]; measurements were based on the L*a*b* color system and were determined using a Minolta Chroma Meter (Data Processor DP-301, for Chroma Meter CR-300 series). The color difference (ΔE) was determined using the following formula: (ΔE = (L* − L) 2 + (a* − a) 2 + (b − *b) 2)1/2. The standard white tile to which the samples were compared had the following color indices: (L* = 97.95, a* = −0.12, b* = +1.64).

The determinations were carried out in triplicate; means and standard deviations are reported.

2.2.6. Data Analyses

Identifying Products with Innovative Flavours using RPM

The scores from RPM were analysed as described by Blay et al. (2012) [28]. The difference and liking axes of the T-Map scale were each 50 cm long with intervals of 1 cm. The scores were derived by reading the mark made by each assessor from the end of each axis. For the difference axis (x-axis), the end R was taken as the starting point and, as the mark moved away from R, this was considered more different from the reference. For the liking axis, the starting point was at the bottom of the y-axis and increased as the data points moved up. Lower values meant that the product was disliked or was similar compared to the reference and high values meant that the product was liked and was different compared to the reference. Data from the liking axis and difference axes were analyzed separately using a one-way analysis of variance (ANOVA). Individual product maps created by consumers were condensed into a consensus product map using the Generalized Procrustes Analysis (GPA) method. The region of innovation was highlighted as the space between the liking and difference axes on the consensus map. All analyses of RPM data were carried out using XLSTAT (Addinsoft 40, rue Damrémont 75018, Paris, France).

Understanding the Role of Ingredients in Product Acceptability

Regression analysis for mixture design using Minitab v. 17.1.0 was performed. The dependent variable for the regression models were the consumer acceptance scores obtained from the BIBD study using the 9-point hedonic scale. The independent variables were coconut milk (X_1), peanut milk (X_2), tiger nuts milk(X_3) and melon seed milk (X_4). Cox response plots were generated for overall liking, appearance, flavour, mouthfeel, consistency and aftertaste.

Product liking scores were analyzed using a one-way analysis of variance (ANOVA). Post-hoc analysis was based on Fisher's Least Significant Difference (LSD).

3. Results and Discussion

3.1. Proximate Composition of the 3-Blend Prototypes

The proximate composition of the prototypes, the commercial plant-based dairy alternative and the dairy milk product are shown in Table 4. The products are arranged in descending order of protein content as this component is of interest to our study. Overall, the plant-based dairy alternatives had protein content of 1.65% to 3.51%, fat content of 4.71% to 6.54%, an ash content of 0.25% to 0.49 and carbohydrate content of 4.28% to 7.26%. The moisture content was between 85.26% to 88.22% and total solids raged between 11.78% and 14.74%. Both commercial products had moisture and total solids content within this range.

Table 4. Proximate Composition of the products arranged in order of decreasing protein content.

Product	Composition (%)					
	Protein	Fat	Ash	Carbohydrates	Moisture	Total Solids
* BC	3.76 ± 0.00 [a]	2.49 ± 0.22 [f]	0.71 ± 0.02 [a]	5.23 ± 0.06 [e]	87.84 ± 0.01 [b]	12.17 ± 0.02 [e]
H	3.51 ± 0.02 [ab]	6.30 ± 0.42 [a]	0.25 ± 0.01 [f]	4.68 ± 0.01 [g]	85.26 ± 0.01 [f]	14.74 ± 0.01 [a]
* V	3.30 ± 0.04 [b]	3.36 ± 0.00 [e]	0.41 ± 0.01 [cd]	6.04 ± 0.01 [b]	86.89 ± 0.11 [d]	13.18 ± 0.11 [c]
R	2.31 ± 0.21 [c]	4.09 ± 0.05 [d]	0.51 ± 0.07 [b]	5.90 ± 0.03 [c]	87.19 ± 0.02 [c]	12.81 ± 0.02 [d]
N	2.16 ± 0.39 [cd]	6.54 ± 0.04 [a]	0.31 ± 0.02 [ef]	5.09 ± 0.01 [f]	85.89 ± 0.22 [e]	14.23 ± 0.22 [b]
A	1.89 ± 0.24 [de]	5.11 ± 0.20 [b]	0.49 ± 0.01 [bc]	4.28 ± 0.01 [h]	88.22 ± 0.13 [a]	11.78 ± 0.13 [f]
E	1.90 ± 0.09 [de]	4.71 ± 0.08 [c]	0.36 ± 0.02 [de]	7.26 ± 0.01 [a]	85.77 ± 0.01 [e]	14.24 ± 0.01 [b]
P	1.65 ± 0.06 [e]	5.00 ± 0.35 [bc]	0.34 ± 0.00 [de]	5.65 ± 0.01 [d]	87.36 ± 0.23 [c]	12.64 ± 0.23 [d]

Legend: H—37.5% melon seed milk, 25% coconut milk, 37.5% peanut milk; A—25% melon seed milk, 50% coconut milk, 25% tiger nuts milk; P—50% coconut milk, 25% tiger nuts milk, 25% peanut milk; N—25% melon seed milk, 50% coconut milk, 25% peanut milk; R—37.5% melon seed milk, 25% coconut milk, 37.5% tiger nuts milk; E—25% coconut milk, 37.5% tiger nuts milk, 37.5% peanut milk; V—Commercial plant-based dairy alternative and BC—Even ultra-high temperature pasteurized (UHT) full cream milk; * Commercial products. Values with the same letter (superscript) in a column are not statistically significantly different to each other.

Not surprisingly, the animal-sourced milk product, Product BC, had the highest protein content of 3.76%. Within the 3-blend prototypes, only product H ($M_{37.5\%}$, $C_{25\%}$, $P_{37.5\%}$) had protein content comparable to the dairy milk product, (3.51%) which was higher than the protein content for the commercial soymilk product V (3.30%). This is an important observation as it supports the notion that blending different plant materials could increase their overall protein content. Melon seeds and peanuts have considerably high protein content given that they are legumes. Peanuts have a protein content of 23.68% [16] while melon seeds have a protein content of 25.4% [29]. As such those prototypes with high contents of melon seeds and peanut milk also had considerably high protein contents. Prototype H ($M_{37.5\%}$, $C_{25\%}$, $P_{37.5\%}$) had the highest combination of melon seed milk and peanut milk in its formulation at 37.5% each with only 25% of coconut milk. Coconut and tiger nuts have a relatively lower protein content, 2.60% [30] and 5.04% [31], respectively, but higher fat and carbohydrate content. As such prototypes with high components of these ingredients had lower protein content but higher carbohydrate or fat content. Other prototypes with relatively high protein contents included prototype R ($M_{37.5\%}$, $C_{25\%}$, $T_{37.5\%}$) at 2.31% and N ($M_{25\%}$, $C_{50\%}$, $P_{25\%}$) at 2.16%. Prototype R ($M_{37.5\%}$, $C_{25\%}$, $T_{37.5\%}$) has a high melon seed content of 37.5%. Although N ($M_{25\%}$, $C_{50\%}$, $P_{25\,\%}$) has a high coconut milk content, its protein content was improved as a result of the blend of melon seeds and peanut milk. The prototypes with the lowest protein contents had high amounts of coconut milk and no or low melon seed milk or peanut milk. Specifically prototypes P ($C_{50\%}$, $T_{25\%}$, $P_{25\%}$), A ($C_{50\%}$, $T_{25\%}$, $M_{25\%}$) and E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) had the lowest protein contents of 1.65%, 1.89% and 1.90, respectively.

Dairy milk contains all the essential amino acids in their right proportions [32]. Peanut contains all the essential amino acids except for methionine. Cysteine is also a limiting amino acid in peanuts. The quantities of the other essential amino acids are comparable to that of dairy milk [33,34]. Coconut has all the essential amino acids but their quantities are lower than those found in dairy milk [34], although their quantities meet the FAO/WHO requirements for adults [35]. Glutamic acid and arginine are the most abundant amino acids in coconut [35,36]. Melon seeds also contains all the essential amino acids but lysine is the limiting essential amino acid and cysteine is found in low quantities [37]. Tiger nuts contains all the essential amino acids. A study of the amino acid profile of tiger nut by Rasaq et al. (2013) [38] indicated that tiger nut milk meets the amino acid requirement for both adults and children. Even when plant raw materials contain all the essential amino acids, plant proteins are not as easily digestible as animal-based proteins [10]. Prototypes containing peanuts, tiger nuts and coconuts can have all the essential amino acids though not of the same quality and proportions found in dairy milk, while prototypes with melon seeds, peanuts and coconuts will still lack cysteine. A combination of tiger nuts, melon seed and coconut milk will also have all the essential amino acids.

Coconut and tiger nut milk contribute to a high fat content in the final formulation since they have high fat contents of (21.33%) [39] and 24.49% [31], respectively. The products with high quantities of peanut milk had the lowest ash contents, and this was also the trend when Aidoo et al. (2010) [21] combined peanuts and cowpea to replace skimmed milk powder in chocolate. Those with high amounts of melon seed milk without peanut milk had higher ash content. Dairy milk has a calcium content of between 122 mg–134 mg/100 g [34], tiger nuts have a calcium content of 40 mg/100 g [40], peanuts, coconuts, melon seeds have a calcium content of 54 to 92 mg/100 g [34] and 18.1 mg/100 g [41] and 28.2 mg/100 g [42], respectively. Because of these low calcium levels in most plant raw materials, most plant-based dairy alternatives have to be fortified with calcium [10]. Prototypes with high levels of tiger nuts milk had high carbohydrate contents as tiger nuts have high carbohydrate content (43.3%) which is mainly made up of starch [31]. The relevance of blending different plant materials to develop a sustainable dairy milk substitute is the improved protein content of the final formulation. Notwithstanding, a sustainable diet should, in addition to being environmentally friendly, be nutritionally adequate and have an acceptable sensory appeal for consumers.

3.2. Colour of the 3-Blend Prototypes

With regards to product appeal, appearance is the first attribute of choice, although repeat purchase is most influenced by the flavour and taste of the product. A visual inspection of the extracts from the four materials used to formulate the 3-blend prototypes show that they appear whitish, cream and reddish-brown (Figure 2). Instrumental color assessment, however, provides an objective measurement. With regards to the appearance of milk, the lighter the color, the more acceptable it tends to be for consumers; however, too much lightness might reduce consumer appeal. The Hunter Lab Chromameter measured the degree of lightness L* and the hue; red-green (a-value) and yellow-blue (b-value). The L* value measures the lightness of a product. The higher the L* value, the whiter the product. The b* value when positive signifies a high yellowness of the product and when negative connotes a blue color. High positive a* values indicate redness, whilst a low or negative a* value indicates greenness. Generally, all the prototypes were light and had L* values ranging between 75.91 and 85.54 (Table 5). The dairy milk sample (BC) seen in Figure 3 had the highest L* value of 95.23 compared to the prototypes. The a* values were low and negative (in the green spectrum). The b* values were low and positive (in the yellow spectrum).

Figure 2. The different plant-based dairy alternatives: peanut milk, coconut milk, tiger nut milk and melon seed milk.

Table 5. Color indices of samples used in the RPM arranged in order of decreasing L * values.

Product	L *	A *	B *	ΔE
* BC	95.23 ± 0.10 [a]	−0.93 ± 0.01 [h]	13.66 ± 0.05 [e]	12.01 ± 0.01 [h]
N	85.54 ± 0.50 [b]	0.52 ± 0.04 [g]	12.74 ± 0.05 [g]	16.64 ± 0.01 [g]
* V	85.31 ± 0.02 [b]	1.41 ± 0.01 [b]	16.25 ± 0.04 [a]	19.36 ± 0.01 [e]
H	83.13 ± 0.32 [c]	0.86 ± 0.02 [e]	13.74 ± 0.06 [d]	19.07 ± 0.06 [f]
A	80.06 ± 0.77 [d]	0.58 ± 0.02 [f]	13.21 ± 0.05 [f]	21.32 ± 0.01 [d]
P	79.32 ± 0.05 [e]	0.98 ± 0.05 [c]	13.62 ± 002 [e]	22.17 ± 0.01 [c]
E	78.22 ± 0.13 [f]	1.87 ± 0.03 [a]	14.61 ± 0.01 [c]	23.69 ± 0.01 [b]
R	75.91 ± 0.13 [g]	0.91 ± 0.01 [d]	15.36 ± 0.04 [b]	25.93. ± 0.01 [a]

Legend: H—37.5% melon seed milk, 25% coconut milk, 37.5% peanut milk; A—25% melon seed milk, 50% coconut milk, 25% tiger nuts milk); P—50% coconut milk, 25% tiger nuts milk, 25% peanut milk; N—25% melon seed milk, 50% coconut milk, 25% peanut milk); R—37.5% melon seed milk, 25% coconut milk, 37.5% tiger nuts milk; E—25% coconut milk, 37.5% tiger nuts milk, 37.5% peanut milk; V *—Commercial plant-based dairy alternative) and BC *—Even ultra-high temperature pasteurized (UHT) full cream milk * Commercial products. Values with the same letter (superscript) within a column have no statistically significant difference from each other.

Figure 3. Even ultra-high temperature pasteurized (UHT) full cream milk used as reference sample, R and also as blind control (BC) for RPM test.

There were statistically significant differences between all the measured color indices of the different prototypes. Prototypes that contained high quantities of coconut milk had higher L* values while those that contained high quantities of tiger nut milk had lower L* values. Product BC had the highest L* value of 95.23 and amongst the dairy milk alternatives, Prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$), which had a high percentage of coconut milk and no tiger nut milk, had the highest L* value of 85.54. Prototype R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) had the lowest L* value (75.91), while prototype E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) had the second lowest L* value (78.22). Both prototypes contain high percentages of tiger nut milk and low amounts of coconut milk in their formulations which could account for the darkness of the prototypes. That none of the formulations had lightness value exceeding that of commercial dairy milk is a positive outcome, as they will not appear unnaturally white to detract from its consumer appeal.

3.3. Identifying Products with Innovative Flavours Using RPM

Data from RPM was analysed as described by Adjei et al. (2020) [23] by generating a consensus product map using GPA. The area of innovation is the area where products are loaded in the area of the angle formed between the difference and liking axes on the 2D map. In this study, when compared to the commercial animal sourced milk (BC), the products that were considered innovative flavours were products E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$), P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$), and V (Figure 4). These products had no melon seeds but had coconut and peanuts. The commercial product made from soybeans was also considered innovative in flavour. Prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$) fell on the border of the area of innovation.

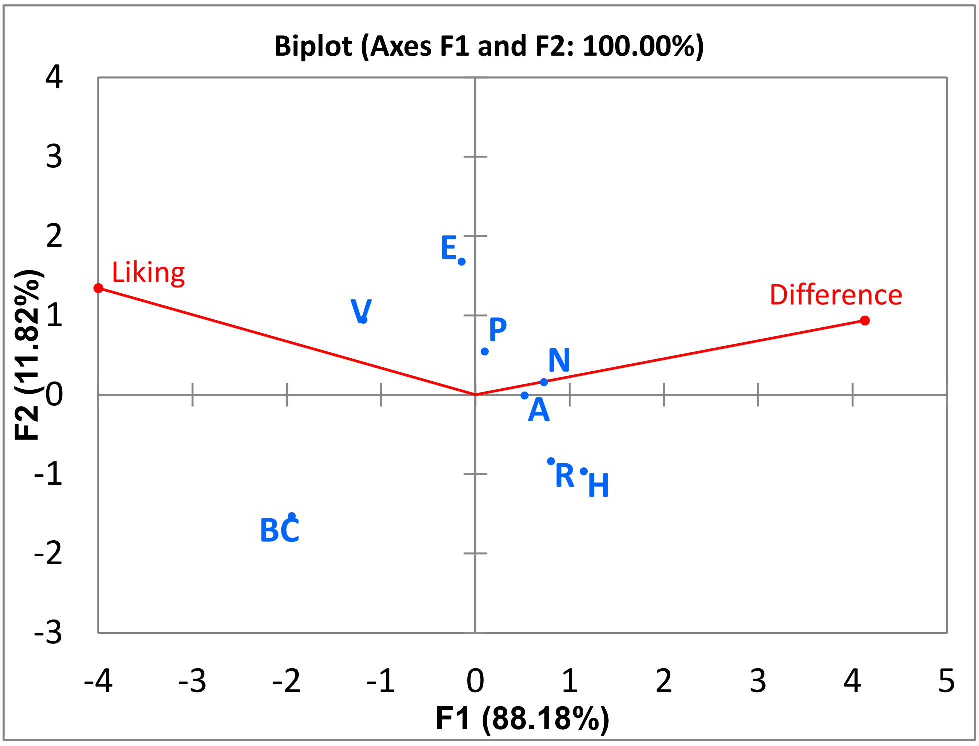

Figure 4. Product Map showing the area of innovation between the difference and liking axes. Legend: H—37.5% melon seed milk, 25% coconut milk, 37.5% peanut milk; A—25% melon seed milk, 50% coconut milk, 25% tiger nuts milk; P—50% coconut milk, 25% tiger nuts milk, 25% peanut milk; N—25% melon seed milk, 50% coconut milk, 25% peanut milk; R—37.5% melon seed milk, 25% coconut milk, 37.5% tiger nuts milk; E—25% coconut milk, 37.5% tiger nuts milk, 37.5% peanut milk; V*—Commercial plant-based dairy alternative and BC*— Even ultra-high temperature pasteurized (UHT) full cream milk; *—Commercial products.

According to Gruneert et al. (1997) [43], an innovative product is that which is perceived by people as new. Johannessen et al. (2001) [44] asserted that innovation depends on the people assessing the product; as such, what could be considered an innovation by someone might not be considered so by another individual or organization. In our research, an innovative product was one which was different from the reference (commercial milk product, BC) and liked enough by consumers to load into the "area of innovation". Although products V (Soymilk), prototypes E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) and P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$) were the least different from the reference product, they were different enough to be considered innovations by consumers and their difference from reference scores were statistically different from the dairy milk product, BC (Figure 5). Diarra et al. (2005) [45] suggested that plant-based dairy alternatives that have similar sensory characteristics to dairy milk were more accepted, and Sakthi et al. (2020) [46] found that the more similar the sensory profile of a dairy milk alternative is to dairy milk, the more it is accepted. Prototypes E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) and P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$) are comparable to the already commercial product V (Vitamilk), which also loaded in the innovation area, and with further optimization could be potential new products for the dairy alternative market. The least liked prototypes H ($C_{25\%}$, $P_{37.5\%}$, $M_{37.5\%}$) and R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) were also perceived as the most different.

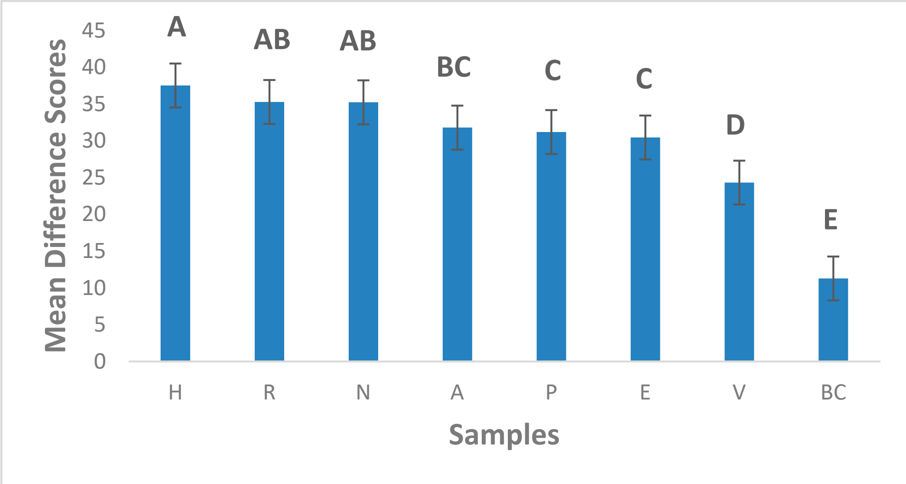

Figure 5. Mean difference from reference scores. Error bars are standard errors of the mean. Letters represent Fishers Fisher's Least Significant Difference (LSD) Post hoc analysis of the means. Samples with no letters in common are statistically different at the 95% confidence level. Legend: H—37.5% melon seed milk, 25% coconut milk, 37.5% peanut milk; A—25% melon seed milk, 50% coconut milk, 25% tiger nuts milk; P—50% coconut milk, 25% tiger nuts milk, 25% peanut milk; N—25% melon seed milk, 50% coconut milk, 25% peanut milk; R—37.5% melon seed milk, 25% coconut milk, 37.5% tiger nuts milk; E—25% coconut milk, 37.5% tiger nuts milk, 37.5% peanut milk; V*—Commercial plant-based dairy alternative and BC*— Even ultra-high temperature pasteurized (UHT) full cream milk; *—Commercial products.

Figure 6 shows the liking scores of the experimental prototypes compared to the dairy milk reference (Even ultra-high temperature pasteurized (UHT) full cream milk). Product BC (Even ultra-high temperature pasteurized (UHT) full cream milk) and V (commercial dairy milk alternative) were the most liked, and there was no statistical difference between their liking scores. All the 3-blend prototypes were liked less than the two commercial products tested, suggesting that there is still room for improvement in this current formulation of the 3-blend products to obtain an optimum product. Prototypes E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) and P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$) were the most liked amongst the 3-blend prototypes and their liking scores were not statistically significantly different from each other. Thus, either of these two products could be considered innovative flavours; however, these two products had the lowest protein content when the proximate analyses were done. Further improvement in this formulation will be required to improve its protein content while retaining its acceptance as an innovation in flavour. Product H ($C_{25\%}$, $P_{37.5\%}$, $M_{37.5\%}$) was the least liked prototype, although this was the product with the highest protein content when the proximate concentrations were evaluated. This product was not considered an innovation at all. However, prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$), which fell on the borderline of the innovation area, could be highlighted as a potential product for optimization as a sustainable plant-based dairy alternative since it had a relatively higher protein content 2.16% and shows some innovation. Product R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) had a higher protein content than N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$); however, it did not fall in the innovation area although there was no significant difference in its liking scores compared to Product N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$). It is possible that the color of product R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$), may have influenced its position on the consensus map as the instrumental color assessment shows a significant difference between product R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) and N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$), with product R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) having the lowest lightness intensity (Table 5). The advantage of the RPM method is that it allows evaluation of product innovation on a two-dimensional axis as opposed to the one-dimensional approach of using only the traditional liking scale. Thus, true innovations in product sets are evaluated on a holistic basis when a relevant reference product is selected.

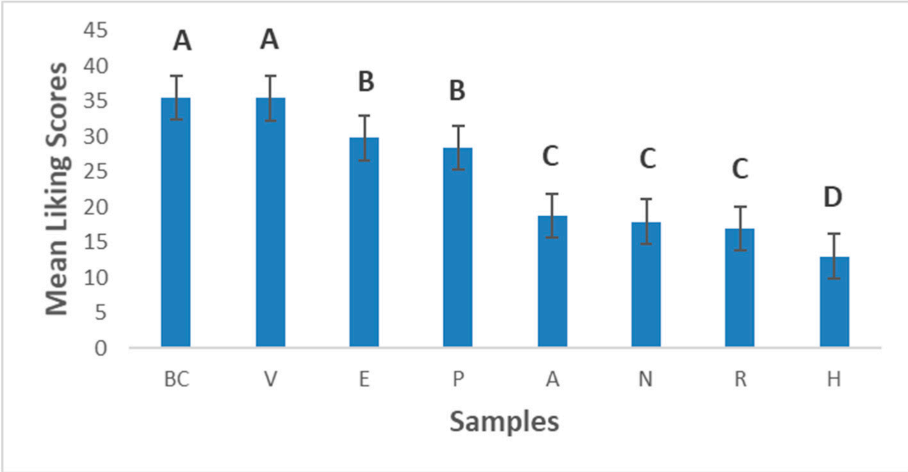

Figure 6. Mean liking compared to the reference. Error bars are standard errors of the mean. Letters represent Fishers Fisher's Least Significant Difference (LSD) Post hoc analysis of the means. Samples with no letters in common are statistically different at the 95% confidence level. Legend: H—37.5% melon seed milk, 25% coconut milk, 37.5% peanut milk; A—25% melon seed milk, 50% coconut milk, 25% tiger nuts milk; P—50% coconut milk, 25% tiger nuts milk, 25% peanut milk; N—25% melon seed milk, 50% coconut milk, 25% peanut milk; R—37.5% melon seed milk, 25% coconut milk, 37.5% tiger nuts milk; E—25% coconut milk, 37.5% tiger nuts milk, 37.5% peanut milk; V*—Commercial plant-based dairy alternative and BC*— Even ultra-high temperature pasteurized (UHT) full cream milk; *—Commercial products.

3.4. Understanding the Role of the Ingredients That Drive Liking

3.4.1. Effect of the Ingredients on Overall Liking Scores

Figure 7 shows the Cox response trace plot for overall liking. As the quantity of coconut and peanut milk is increased in the formulation, the overall liking scores rise; on the other hand, tiger nut milk increases the overall liking scores as its proportion increases up to a point (+0.30 deviation from the reference blend) and then decreases liking scores as its proportion continues to increase. Melon seed milk, however, leads to a reduction in the overall liking scores of the product as its proportion increases in the formulation.

Table 6 shows the regression coefficients for the different sensory properties. Although strong positive regression coefficients for overall liking and the other modalities were observed, they did not have statistical significance at the 95% confidence level (apart from consistency and after taste liking). This is probably due to the reduced number of replicates using the BIB design instead of a complete block design. The observations may be considered to be trends, as similar observations have been described elsewhere. For instance, in this study, coconut milk and peanut milk have the most positive effect on overall liking. This observation is similar to other findings using these ingredients, such as Obinna-Echem and Torporo (2018) [47] observed about coconut milk increasing acceptability scores for tiger nut/coconut milk blends. Likewise, Sakthi et al. (2020) [46] found that roasted peanut milk had the best sensory acceptability amongst different pre-treatments for peanut milk preparation when comparing soaking, germination, blanching and roasting. Melon seed milk has a less positive effect, though its effect was greater than tiger nut milk. The interactions between coconut and peanut milk, coconut and melon seed milk, and peanut and melon seed milk had a negative effect on the overall liking scores, while that between coconut and tiger nut milk, peanut and tiger nut milk and tiger nut and peanut milk had a positive effect on the overall liking scores.

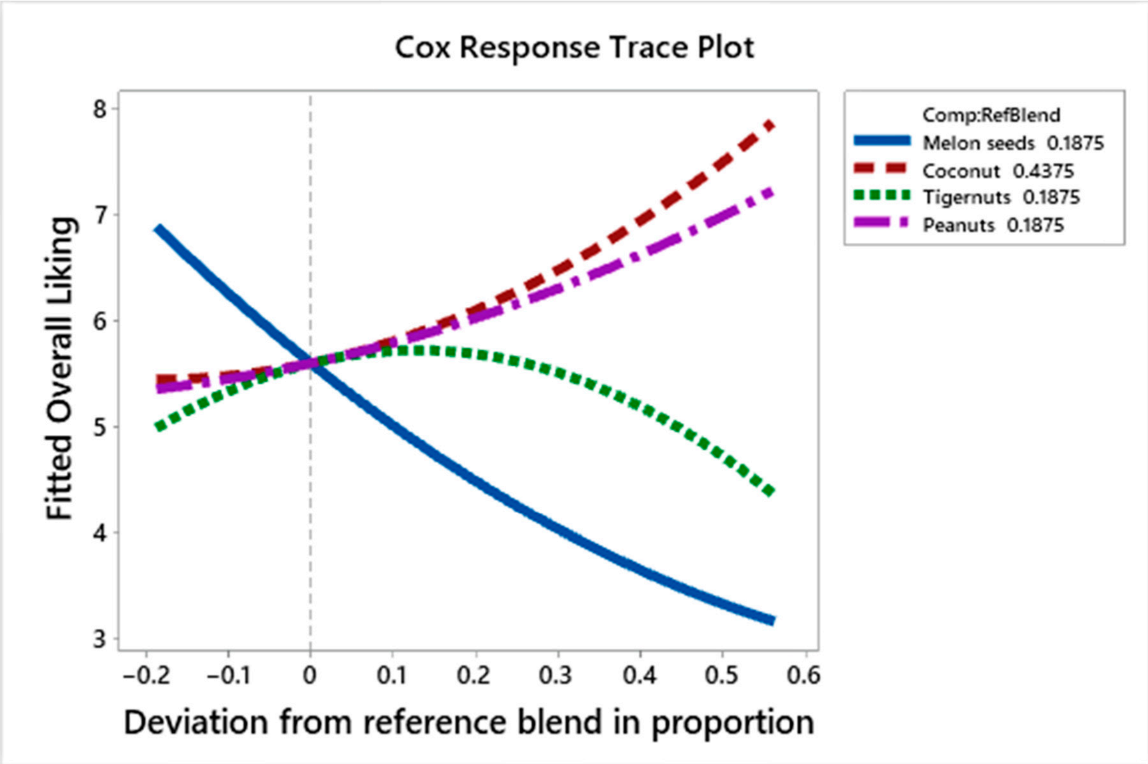

Figure 7. Cox response trace plot to show effect of ingredient on overall liking scores.

Table 6. Regression coefficients for sensory scores.

Predictor Variable	Coefficients					
	Overall Liking	**Appearance**	**Flavour**	**Mouthfeel**	**Consistency**	**Aftertaste**
X1	7.874	7.332	7.824	7.967	7.382	7.713
X2	8.396	6.751	8.794	9.16	8.813	8.751
X3	2.354	1.137	3.1	2.98	3.353	2.865
X4	2.769	5.151	4.815	5.083	6.816	3.215
X1X2	−5.01	3.002	−6.302	−7.756	−4.589	−7.483
X1X3	4.669	6.251	0.754	2.135	3.131	3.241
X1X4	−8.923	4.815	−8.635	−8.272	−6.567 *	−7.945 *
X2X3	3.94	6.069	2.092	5.496	−0.187	6.739
X2X4	−1.749	−4.847	−4.927	−6.491	−6.724*	−6.028
X3X4	8.719	−5.55	1.339	2.61	−2.164	5.487
R^2 (%)	79.91	89.33	82.81	88.44	90.55	93.88
R^2 Adjusted (%)	59.82	78.67	65.63	76.88	81.11	87.76

(X1)—Coconut milk; (X2)—Peanut milk; (X3)—Tiger nuts milk and (X4)—Melon seed milk; * Significant ($p \leq 0.05$).

Table 7 shows the liking scores for the 19 formulations. 100% coconut milk, prototype L($C_{100\%}$) had the highest overall liking score of 7.89; prototypes containing high quantities of coconut milk and peanut milk had high overall liking scores, for example, prototypes E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$), G ($C_{25\%}$, $P_{75\%}$) and I ($C_{62.5\%}$, $T_{37.5\%}$) had overall liking scores of 7.44, 7.44 and 7.22, respectively. Even though tiger nut milk interacts positively with the other components, prototypes with tiger nut milk above 50% had low overall liking scores; an example of this is prototype F ($C_{25\%}$, $T_{75\%}$) which had an overall liking score of 4.44. Prototypes with coconut milk, peanuts and tiger nut milk had high overall liking scores. However, those with high quantities of melon seed milk had low liking scores. The prototypes with the lowest scores for overall liking had high melon seed milk. This is because melon seed milk interacts negatively with the other components. This is exemplified by prototypes O ($C_{62.5\%}$, $M_{37.5\%}$), D ($C_{34.4\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{46.9\%}$) and H ($C_{25\%}$, $P_{37.5\%}$, $M_{37.5\%}$), whose liking scores were 2.77, 4.0 and 4.11, respectively. Prototype J ($C_{43.8\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$) had the lowest overall liking scores of 2.56, even though it had high quantities of peanut and coconut milk; the high quantities of both coconut and peanut milk might have led to a negative interaction as their regression coefficient is negative (−5.01), as seen in Table 6. The results of this consumer test agree with the results of the RPM as the 3−blend prototypes with coconut milk, peanut and tiger nut milk had high liking scores while those with melon seed milk had low overall liking scores. Only prototype P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$) had lower than expected overall liking scores.

Table 7. Mean liking scores for the 19 formulations arranged in order of decreasing overall liking scores.

Product Code	Sensory Scores					
	Overall Liking	Appearance	Flavour	Mouthfeel	Consistency	Aftertaste
L ($C_{100\%}$)	7.89 ± 0.78 ^{a}	7.11 ± 1.62 ^{abcd}	7.78 ± 0.83 ^{a}	7.78 ± 0.83 ^{a}	7.33 ± 1.23 ^{ab}	7.78 ± 0.97 ^{a}
E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$)	7.44 ± 1.74 ^{ab}	7.11 ± 1.45 ^{abcd}	7.00 ± 1.80 ^{ab}	7.44 ± 1.24 ^{ab}	6.56 ± 2.46 ^{abc}	7.00 ± 2.45 ^{ab}
G ($C_{25\%}$, $P_{75\%}$)	7.44 ± 1.13 ^{ab}	7.44 ± 1.33 ^{abc}	7.22 ± 1.20 ^{ab}	7.44 ± 1.88 ^{ab}	7.44 ± 1.51 ^{a}	7.11 ± 2.01 ^{ab}
I ($C_{62.5\%}$, $T_{37.5\%}$)	7.22 ± 1.30 ^{abc}	7.00 ± 1.23 ^{abcd}	6.56 ± 1.81 ^{abc}	6.89 ± 1.76 ^{abc}	6.67 ± 1.66 ^{abc}	6.67 ± 2.24 ^{abc}
M ($C_{62.5\%}$, $P_{37.5\%}$)	7.00 ± 1.00 ^{abcd}	8.11 ± 0.93 ^{a}	7.00 ± 1.32 ^{ab}	6.78 ± 1.79 ^{abcd}	7.00 ± 2.00 ^{abc}	6.44 ± 1.33 ^{abc}
N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$)	6.55 ± 1.88 ^{abcd}	7.56 ± 1.13 ^{abc}	6.00 ± 2.00 ^{abcde}	5.78 ± 2.91 ^{abcde}	5.78 ± 2.77 ^{abc}	5.11 ± 3.22 ^{bcdef}
C ($C_{71.9\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{9.4\%}$)	6.55 ± 2.40 ^{abcd}	7.78 ± 0.97 ^{ab}	6.11 ± 2.42 ^{abcd}	6.78 ± 2.49 ^{abcd}	6.67 ± 2.65 ^{abc}	6.11 ± 2.57 ^{bcd}
A ($C_{50\%}$, $T_{25\%}$, $M_{25\%}$)	6.00 ± 0.50 ^{bcde}	5.77 ± 1.30 ^{def}	5.89 ± 0.83 ^{abcde}	5.44 ± 2.13 ^{bcde}	6.00 ± 2.35 ^{abc}	5.78 ± 0.97 ^{abcde}
B ($C_{34.4\%}$, $P_{9.4\%}$, $T_{46.9.\%}$, $M_{9.4\%}$)	5.78 ± 2.49 ^{bcdef}	5.44 ± 1.24 ^{ef}	4.78 ± 2.28 ^{cdef}	5.56 ± 2.07 ^{bcde}	5.67 ± 2.12 ^{abc}	5.78 ± 2.86 ^{abcde}
K ($C_{34.4\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$)	5.68 ± 2.29 ^{bcdef}	6.77 ± 1.72 ^{abcde}	6.00 ± 2.55 ^{abcde}	5.67 ± 2.40 ^{bcde}	6.78 ± 1.79 ^{abc}	6.00 ± 1.87 ^{abcd}
Q ($C_{43.8\%}$, $P_{18.8\%}$, $T_{18.8\%}$, $M_{18.8\%}$)	5.44 ± 2.60 ^{cdef}	6.22 ± 1.56 ^{cde}	5.00 ± 2.74 ^{cdef}	5.44 ± 2.88 ^{bcde}	5.67 ± 2.65 ^{abc}	5.22 ± 2.44 ^{bcdef}
P ($C_{50\%}$, $P_{25\%}$, $T_{25\%}$)	5.33 ± 2.29 ^{def}	6.44 ± 1.33 ^{bcde}	5.33 ± 2.29 ^{bcdef}	6.00 ± 1.73 ^{abcde}	5.89 ± 1.76 ^{abc}	6.00 ± 2.35 ^{abcd}
S ($C_{25\%}$, $P_{25\%}$, $T_{25\%}$, $M_{25\%}$)	5.33 ± 2.12 ^{def}	5.44 ± 2.00 ^{ef}	5.00 ± 2.06 ^{cdef}	5.33 ± 2.35 ^{cde}	5.22 ± 2.05 ^{bc}	5.56 ± 2.56 ^{bcdef}
R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$)	4.44 ± 1.67 ^{efg}	4.78 ± 1.64 ^{fg}	4.44 ± 2.30 ^{def}	5.11 ± 1.97 ^{cde}	5.00 ± 2.60 ^{c}	4.11 ± 1.69 ^{defg}
F($C_{25\%}$, $T_{75\%}$)	4.44 ± 2.83 ^{efg}	3.67 ± 2.40 ^{g}	4.33 ± 2.83 ^{def}	4.44 ± 2.45 ^{e}	4.88 ± 2.62 ^{c}	4.67 ± 2.74 ^{cdefg}
H ($C_{25\%}$, $P_{37.5\%}$, $M_{37.5\%}$)	4.11 ± 1.83 ^{fgh}	6.44 ± 1.24 ^{bcde}	5.00 ± 1.73 ^{cdef}	5.11 ± 2.67 ^{cde}	5.78 ± 2.82 ^{abc}	3.78 ± 2.49 ^{efg}
D ($C_{34.4\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{46.9\%}$)	4.00 ± 1.94 ^{fgh}	6.67 ± 1.33 ^{bcde}	3.78 ± 2.17 ^{f}	4.11 ± 2.03 ^{e}	5.33 ± 2.50 ^{abc}	3.89 ± 1.83 ^{efg}
O ($C_{62.5\%}$, $M_{37.5\%}$)	2.78 ± 2.10 ^{gh}	7.67 ± 1.50 ^{ab}	4.22 ± 2.49 ^{def}	4.78 ± 3.03 ^{de}	5.44 ± 2.46 ^{abc}	3.67 ± 2.69 ^{fg}
J ($C_{43.8\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$)	2.56 ± 1.94 ^{h}	6.44 ± 1.81 ^{bcde}	4.11 ± 2.52 ^{ef}	4.33 ± 2.64 ^{e}	5.78 ± 2.77 ^{abc}	3.00 ± 2.06 ^{g}

Values with the same letters in a column (superscripts) do not show statistically significant difference.

3.4.2. Effect of the Ingredients on Appearance Liking

Figure 8 shows the Cox response trace plot for appearance liking. Melon seed and tiger nut milk cause a decline in liking scores as their proportion increases. Tiger nut milk lowers the liking scores more; this could be due to its darker color compared to the other plant−based dairy alternatives (Figure 2). Coconut milk increases liking scores up to a point (+0.40 deviation from the reference blend), then reduces them as its amount increases; coconut milk had an extremely white color (Figure 2) that did not look like the natural color of milk, which had the potential to make the prototypes too light in color if the proportion deviates by about +0.40 from the reference blend.

The regression coefficients (Table 6) show coconut milk, peanut milk and melon seed milk have higher positive effects on the appearance liking scores compared to the lower positive effect that tiger nut milk has. The interactions between tiger nut and peanut milk, and tiger nut and coconut milk were positive as they made the resulting prototype lighter, but the interaction between peanut and melon seed milk, and tiger nut and melon seed milk were negative. The appearance liking scores (Table 7) show that M ($C_{62.5\%}$, $P_{37.5\%}$), C ($C_{71.9\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{9.4\%}$) and O ($C_{62.5\%}$, $M_{37.5\%}$) had the highest liking scores of 8.11, 7.78 and 7.67, respectively; these contain high quantities of coconut milk and low or no tiger nut milk. Prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$) had the highest L* score (85.54) amongst the 3−blend prototypes and loaded on the borderline of the innovation area on the product map (Figure 4); in contrast, prototype R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$), which was liked as much as N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$) in the consumer test using RPM (Figure 5), was not innovative and was amongst the products which scored lowest for appearance liking (Table 7). This confirms the earlier assertion that the color of the product is an important factor which affects the appeal of the product.

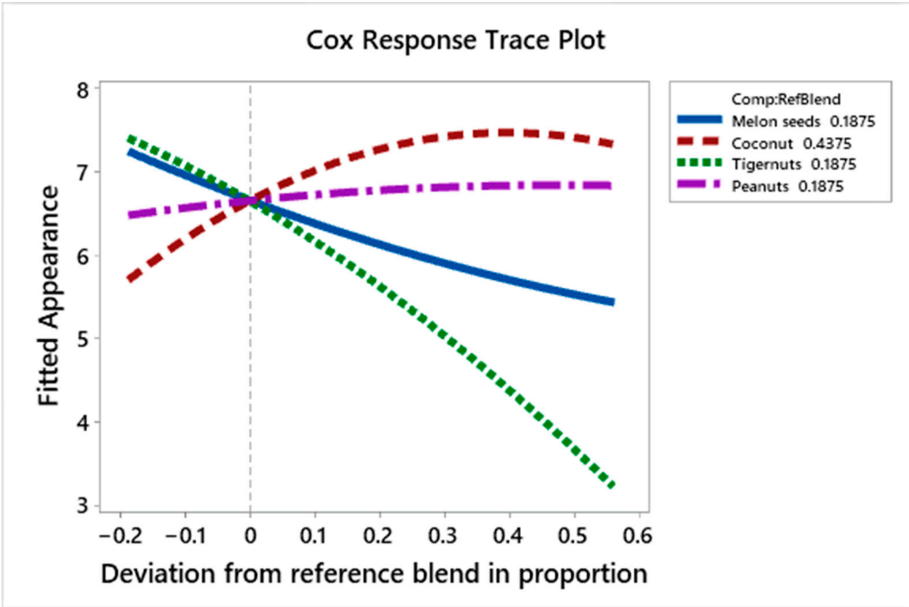

Figure 8. Cox response trace plot to show effect of ingredient on appearance liking scores.

3.4.3. Effect of the Ingredients on Flavour Liking

Figure 9 shows the effect of the ingredients on flavour liking scores. Melon seed milk decreases the liking scores as its proportion increases, but appears to increase these scores as its quantity deviates from the reference blend by +0.55, whilst the effect of tiger nut milk is neutral up to the 0.0 deviation from the reference formulation, then decreases the liking scores for flavour as its deviation from the reference formulation increases. On the other hand, as the amounts of coconut and peanut milk increase, the liking scores for flavour rise.

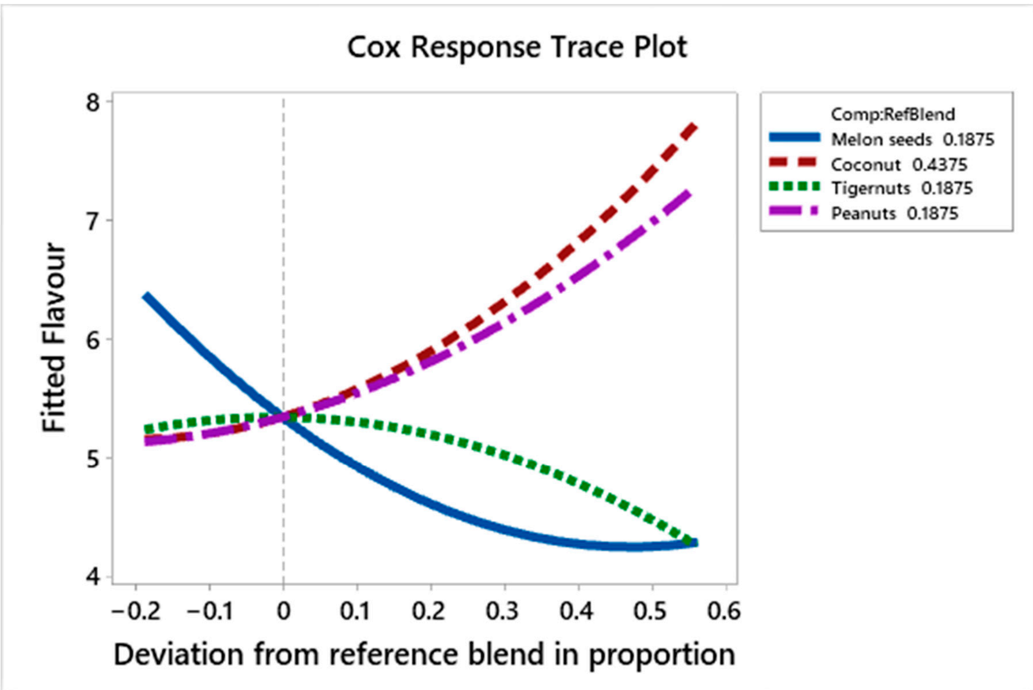

Figure 9. Cox response trace plot to show effect of ingredient on flavour liking scores.

The regression coefficients (Table 6) show that peanut and coconut milk have the most positive effect on the flavour liking scores, respectively. Melon seed milk has a slightly higher positive effect on the flavour scores compared to tiger nut milk. The interactions between coconut and tiger nut milk, peanut and tiger nut milk and tiger nut and melon seed milk have a mild positive effect on flavour liking scores while those between coconut and peanut milk, coconut and melon seed milk, and peanut and melon seed milk have a higher negative effect on flavour liking scores. The liking scores for flavour show that prototypes L ($C_{100\%}$), G ($C_{25\%}$, $P_{75\%}$), and E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) have the highest liking scores with scores of 7.78, 7.22 and 7.0, respectively; these contain mainly coconut and peanut milk with some tiger nut milk and without any melon seed milk; while the prototypes with the lowest scores for flavour D ($C_{34.4\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{46.9\%}$), J ($C_{43.8\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$), and O ($C_{62.5\%}$, $M_{37.5\%}$), with liking scores of 3.78, 4.11 and 4.22, have high quantities of melon seed and tiger nut milk and show negative interaction between peanut milk and coconut milk.

3.4.4. Effect of the Ingredients on Mouthfeel Liking

Figure 10 shows the effect of the ingredients on the mouthfeel liking scores of the prototypes. Melon seed milk decreases the liking scores as its volume increases but appears to improve these scores as its proportion increases up to a point (+0.55 deviation from the reference blend), whilst tiger nut milk shows the opposite effect; it increases the liking scores up to the 0.0 deviation from the reference blend, then decreases liking scores as its amount increases in the blend. Coconut milk and peanut milk both increase the liking scores as their quantity increases.

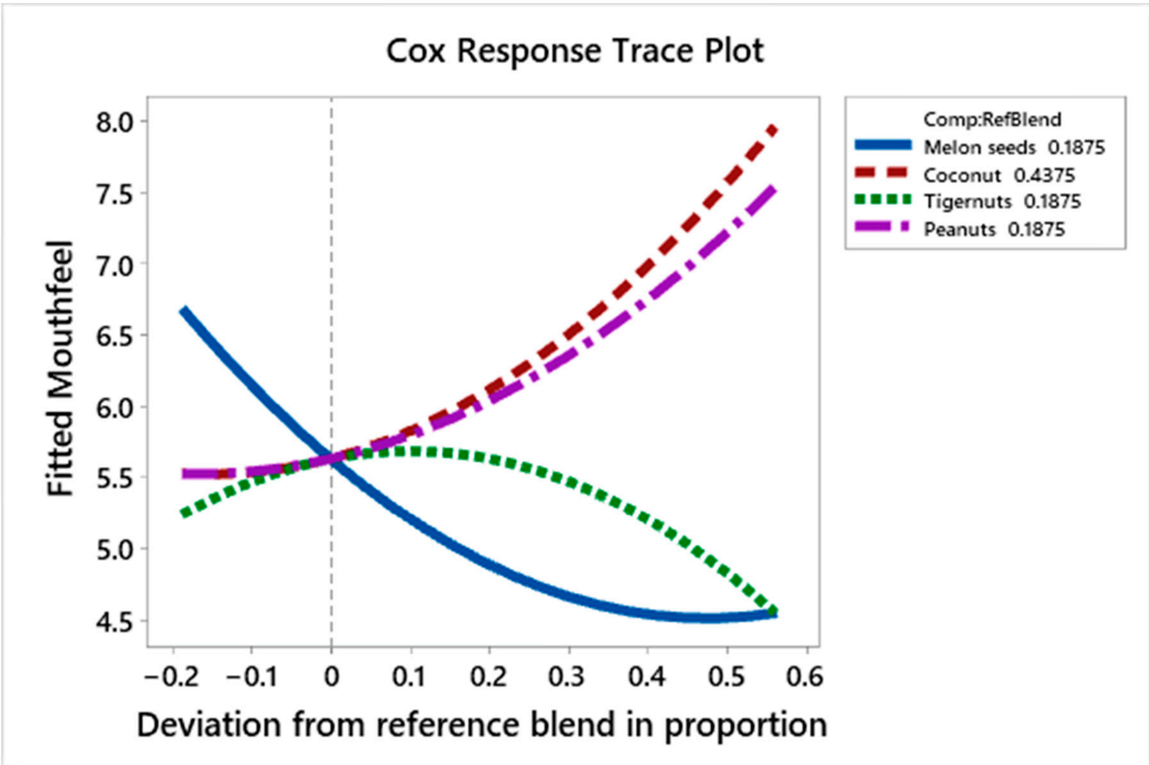

Figure 10. Cox response trace plot to show effect of ingredient on mouthfeel liking scores.

The regression coefficients (Table 6) show that coconut milk, peanut milk and melon seed milk have higher positive effects on the mouth feel liking scores compared to the lower positive effect that tiger nut milk has on the liking scores. The interactions between coconut and tiger nut milk, peanut and tiger nut milk and tiger nut and melon seed milk are positive, while those between coconut and peanut milk, coconut and melon seed milk and peanut and melon seed milk are negative. Table 7 shows that the prototypes with the highest scores for mouth feel were L ($C_{100\%}$), E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$), and G ($C_{25\%}$,

$P_{75\%}$) with scores of 7.78, 7.44 and 7.44, respectively, while those with the lowest scores were D ($C_{34.4\%}$, $P_{9.4\%}$, $T_{9.4\%}$, $M_{46.9\%}$), J ($C_{43.8\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$), and O ($C_{62.5\%}$, $M_{37.5\%}$), with scores of 4.11, 4.33 and 4.44, respectively. This shows that those prototypes that contain high quantities of either coconut or peanut milk had high scores for mouthfeel, while those with high volumes of melon seed milk had low mouthfeel liking scores.

3.4.5. Effect of the Ingredients on Consistency Liking

Figure 11 shows the effect of the ingredients on consistency liking scores of the prototypes. Melon seed milk decreases the liking scores as its proportion increases, but appears to cause these scores to rise as its amount increases at +0.3 deviation from the reference blend, while the effect of tiger nut milk is neutral to a point (0.0 deviation from reference blend), then causes the liking scores to plunge as its proportion increases. Coconut milk and peanut milk both increase the liking scores as their quantity increases.

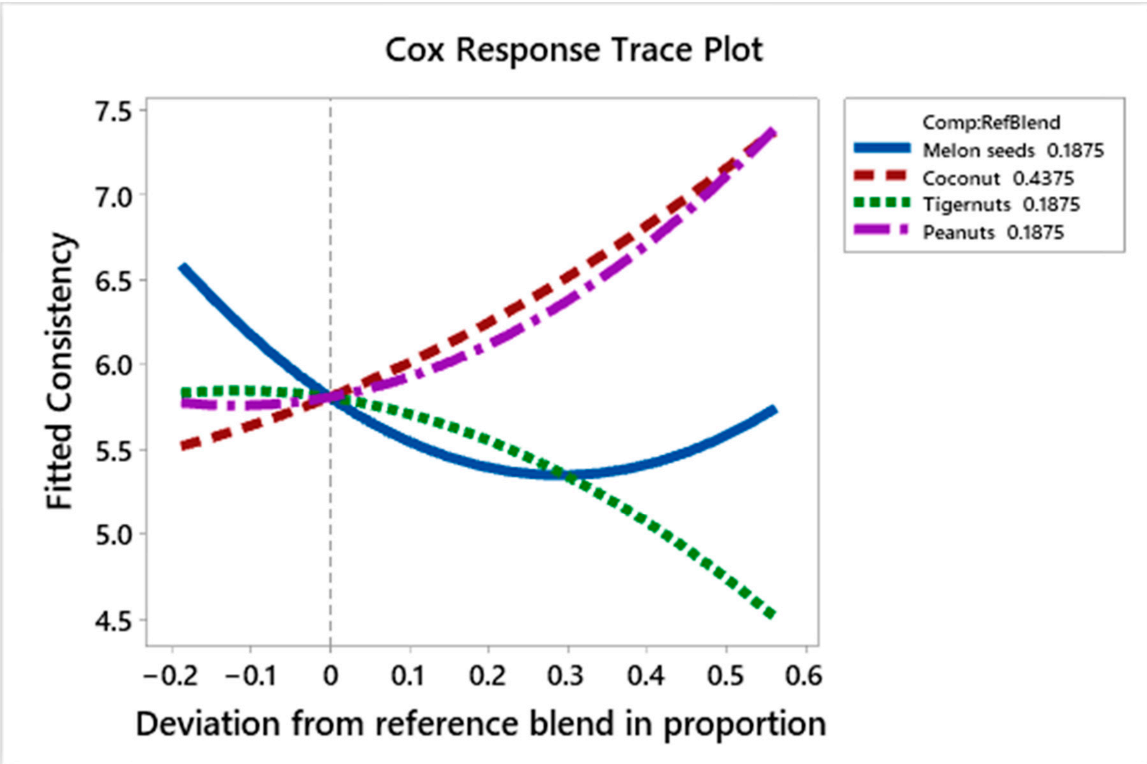

Figure 11. Cox response trace plot to show effect of ingredient on consistency liking scores.

The regression coefficients (Table 6) show that peanut milk and coconut milk have the most positive effect on the consistency liking scores, respectively. Melon seed milk has a higher positive effect on the consistency liking scores compared to tiger nut milk. The interaction between coconut and tiger nut milk was the only positive interaction between the components. The negative interactions between coconut and melon seed milk (−6.567) and peanut and melon seed milk (−6.724) were significant at the 95% confidence level. The prototypes with the highest scores for consistency G ($C_{25\%}$, $P_{75\%}$), L ($C_{100\%}$), and M ($C_{62.5\%}$, $P_{37.5\%}$), 7.44, 7.33 and 7.0, respectively, contained no melon seed milk. Those with the lowest scores F ($C_{25\%}$, $T_{75\%}$), R ($C_{25\%}$, $T_{37.5\%}$, $M_{37.5\%}$) and S ($C_{25\%}$, $P_{25\%}$, $T_{25\%}$, $M_{25\%}$), with scores of 4.89, 5.0. and 5.22, respectively, contained melon seed milk and a high amount of tiger nut milk.

3.4.6. Effect of the Ingredients on Aftertaste Liking

Figure 12 shows the effect of the ingredients on the aftertaste liking scores of the prototypes. Melon seed milk decreases liking scores for aftertaste as its proportion increases;

while tiger nut milk increases the liking scores to a point (0.35 deviation from reference blend) and starts decreasing these scores as its proportion increases. Peanut milk and coconut milk on the other hand increase the liking scores.

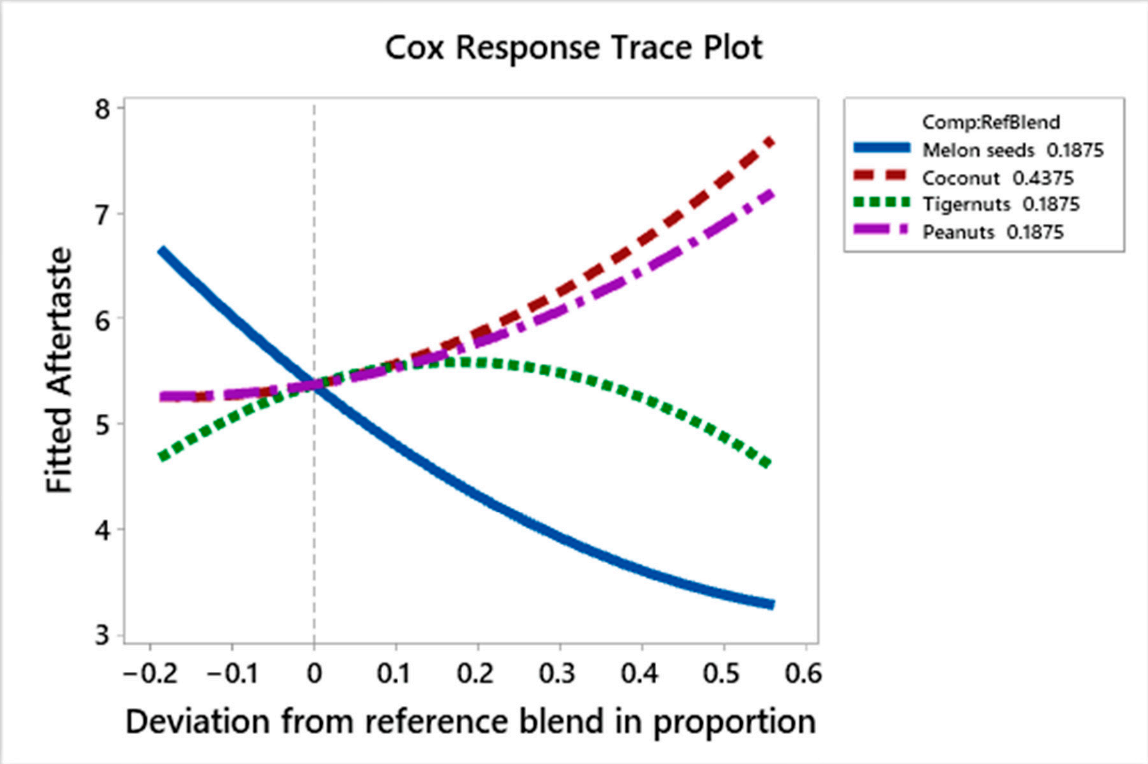

Figure 12. Cox response trace plot to show effect of ingredient on aftertaste liking scores.

Table 6 shows the regression coefficients for aftertaste. These show that peanut and coconut milk have the most positive effect on the consistency liking scores, respectively. Melon seed milk has a higher positive effect on the aftertaste scores compared to tiger nut milk. The interaction between coconut and melon seed milk has a significantly negative (−7.945) effect on the aftertaste of the prototypes. Prototypes L ($C_{100\%}$), G ($C_{25\%}$, $P_{75\%}$) and E ($C_{25\%}$, $P_{37.5\%}$, $T_{37.5\%}$) had the highest scores for aftertaste, at 7.78, 7.11 and 7.0, respectively, while J ($C_{43.8\%}$, $P_{46.9\%}$, $T_{9.4\%}$, $M_{9.4\%}$), O ($C_{62.5\%}$, $M_{37.5\%}$) and H ($C_{25\%}$, $P_{37.5\%}$, $M_{37.5\%}$) had high quantities of melon seed milk and had low aftertaste liking scores of 3.0, 3.67 and 3.78, respectively.

A limitation of this study was the low power of the consumer test using BIB, as each prototype was tasted only nine times.

4. Conclusions

Proximate analysis showed that products that were high in melon seed and peanut milk had higher protein contents, but those products had low consumer acceptance, while the products without melon seed were considered innovative but had a low protein content. Only prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$) fell marginally into the innovative area on the RPM map and could be considered an innovative sustainable plant−based dairy alternative given its considerably higher protein content, even though it needs some optimization to improve its protein content and amino acid profile. The color of the final formulation was important when defining sustainable innovative plant−based dairy alternatives as this impacted on the appearance liking of the product. Combining three plant raw materials was a useful approach to develop a sustainable plant−based dairy alternative that has high protein as well as positive sensory appeal. An optimum formulation may be developed based on any of these prototypes to enhance the nutritional content as well as the sensory appeal using the methods described in this study. From the current study, however, Prototype N ($C_{50\%}$, $P_{25\%}$, $M_{25\%}$) can be considered as the most innovative sustainable plant−based dairy alternative within this prototype set. A multi−blend approach to developing plant−based dairy alternatives may be more sustainable as this could reduce the over−reliance on a single plant raw material to provide sustainable foods with a good source of proteins. This also provide a natural means of improving the sensory appeal of such products without the need for adding flavours and with the added benefit of a better nutrient profile.

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Sensory Acceptability of Dual-Fortified Milled Red and Yellow Lentil (*Lens culinaris* Medik.) Dal in Bangladesh

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Abstract: This study evaluated the sensory properties of uncooked and cooked milled lentils that were fortified with varying concentrations of Fe and Zn in the form of NaFeEDTA and $ZnSO_4.H_2O$, respectively. Our study was carried out among 196 lentil consumers residing in rural Bangladesh who experience with growing, processing, and marketing lentils. A nine-point hedonic scale was used to rate the appearance, odor, taste, texture and overall acceptability of three uncooked and two cooked lentil (dal) samples made from each of the three milled lentil product types (LPTs), red football, red split and yellow split. Preferences for sensory properties were found to be significantly different among all uncooked lentil samples, but not significantly different for cooked samples, with a few exceptions. This means that the fortification process minimally affects dual-fortified lentil sample (fortified with 16 mg of Fe and 8 mg of Zn per 100 g of lentil), which was compared to another cooked sample (unfortified control), in terms of consumers liking for all four attributes (appearance, odor, taste, and texture).

Keywords: dual fortification; sensory evaluation; iron and zinc deficiency; lentil

1. Introduction

Iron (Fe) and zinc (Zn) micronutrient deficiencies are two of the most prevalent nutritional threats in the world. About one third and one fifth of the human population are Fe and Zn deficient, respectively [1]. These two micronutrients share common dietary sources and are abundant in the human body [2]. Plant-based diets are becoming popular throughout the world, and legumes such as lentils, chickpeas, dry peas, beans, and fava beans are major dietary sources of protein. Among the legumes, lentils are important for human nutrition because of their relatively high amounts of protein, carbohydrates, and micronutrients compared to some of the staple cereals and root crops [3,4]. More than 50 countries in aggregate produce a global total of about 7.6 Mt of lentils, of which Canada produces about 50% (3.7 Mt) [5]. Lentils contain a substantial amount (dry weight) of protein (25.8 to 27.1%), starch (27.4 to 47.1%), dietary fiber (5.1 to 26.6%) [6–8], Fe (73 to 90 mg kg^{-1}), Zn (44 to 54 mg kg^{-1}), and selenium (425 to 673 μg kg^{-1}) [9]. A combination of rice and lentils makes a popular and commonly eaten dish known as "hotchpotch" in many Asian countries, for example, in Bangladesh. This dish provides all essential amino acids, carbohydrates, dietary fiber, and a number of minerals and vitamins. Although lentil has a significant amount of intrinsic Fe and Zn, some antinutritional factors, such as phytate, polyphenols, calcium, and protein can inhibit the absorption of both nutrients from food [9]. The improvement of the concentration of these micronutrients and their bioavailability using a sustainable approach is a prime area for research in order to provide an adequate amount of micronutrients and cope with micronutrient deficiency.

Several organizations are conducting research to improve the micronutrient concentration in crop or food products to cope with global micronutrient deficiency problems. Many approaches are used, including biofortification, food fortification, public health intervention, supplementation, nutrition education, dietary diversification, and food safety measures. These strategies are being employed for various staple crops or foods around the world [10]. In comparison to other approaches, food fortification is now more widely used due to its sustainability for improving the dietary quality of targeted groups or populations rapidly [10–12]. Around 84 countries have mandatory fortification programs for various food products based on their existing nutritional status [13]. Several micronutrient-fortified foods/food products are available and are mandatory in the market in different countries, for example, wheat flour in Indonesia, Philippines, Nepal, fortified rice in Papua New Guinea and Costa Rica, maize flour in the USA, soya sauce, salt and edible oil in Bangladesh, milk in Canada and China, etc. [13]. The fortification of pulse crops like lentils or chickpeas is a new research area that began in 2014 at the Crop Development Centre of the University of Saskatchewan, Canada, through the development of Fe-fortified lentils to address Fe-deficiency in humans. A laboratory-scale protocol for fortifying dehulled red lentils with the Fe fortificant NaFeEDTA (ethylenediaminetetraacetic acid iron (iii) sodium salt) was developed [14]. Fortification with 1600 ppm, NaFeEDTA provides 13–14 mg of additional Fe 100^{-1} g in cooked dehulled lentils (dal). An in vitro bioavailability study with Fe-fortified lentils showed that dehulled lentil dal fortified with 28 mg of Fe 100^{-1} g of lentils increased Fe bioavailability to 79% and reduced phytic acid to 25% [15]. The results from these studies led us to develop dual-fortified lentils with Fe and Zn to address Fe and Zn deficiency.

Lentil fortification with both Fe and Zn could have the potential to simultaneously reduce both Fe and Zn deficiency. In this approach, lentils are enriched with extra Fe and Zn to prevent iron deficiency in humans. In this project, research has been initiated to increase both Fe and Zn concentration and bioavailability through a fortification strategy using a modified technique of a previously developed fortification technique by Podder et al. (2017). Initially, a laboratory-based fortification protocol to develop dual-fortified lentil was established. The protocol included the selection of three lentil product types (LPTs) (dehulled red football (RF), red split (RS), and yellow split (YS)), the identification of appropriate methods of fortification, the selection of suitable dosage of added Fe and Zn, and colorimetric changes over the storage period, as well as the in vitro bioavailability of Fe from the dual-fortified lentils [16]. This report describes the results of a sensory analysis of dual-fortified lentil food products.

Sensory analysis is a multidisciplinary science that covers a wide range of social science areas, ranging from food science to statistics to psychology [17]. By definition, "sensory analysis is the identification, scientific measurement and interpretation of the properties (attributes) of a product as they are perceived through the five senses of sight, smell, taste, touch, and hearing" [18]. It captures unbiased human response to food, which helps stakeholders to identify brand effects [19]. Taste, flavor, appearance, and texture are the major attributes of sensory evaluations of food products. The remarks from consumers provide valuable information that help in the development of recommendations for food scientists or commercial food product developers. The present study was designed to undertake an exploratory sensory evaluation to determine the acceptability of dual-fortified lentils (both uncooked and cooked) among 16 to 65-year-old consumers living in Ishurdi, a northern sub-district of Bangladesh.

Lentils are the most frequently consumed legume in Bangladesh where they are a staple food in the daily diet. Similar to other developing and some developed nations, both Fe and Zn deficiencies are common in the Bangladeshi population. Around one third (30%) of Bangladeshi adolescents are anemic, attributable mostly to Fe deficiency [20]. The 2011–12 National Micronutrient Survey of Bangladesh found that the national prevalence of Zn deficiency was approximately 45%, 52%, and 66% among preschool-age children, slum-dwelling preschool children, and non-pregnant, non-lactating women, respectively [21,22]. The expectation from the current study is that dual-fortified red and yellow cotyledon lentil dal will be equally acceptable to the lentil consumers with respect to taste, odor, appearance, texture, and overall acceptability.

The acceptability of fortified food depends on the fortificant type, dose, chemistry of the food vehicle, and interactions between different fortificants [23]. Fortification may create a metallic taste in foods, generate undesirable flavor due to fat rancidity, develop an unacceptable change in color, and degrade the quality of vitamins (e.g., vitamins A and C, which are important for absorption and utilization of Fe) [24]. The expectation of any fortification program is to contain any undesirable changes in food or food products. An earlier study of consumer-level sensory evaluations of cooked and uncooked Fe-fortified lentils (NaFeEDTA) showed that fortified lentils were well received by consumers compared to both unfortified lentils and those fortified with other Fe fortificants [25]. In this study, we hypothesized that dual fortification has a significant effect on liking for the sensory attributes of dual-fortified lentils. This hypothesis was based on the assumptions that there may be identifiable differences between dual-fortified and non-fortified lentils, and that identifying the differences in sensory properties may have major scientific implications for the food science industry.

2. Materials and Methods

2.1. Study Design and Selection of Panelists

We carried out a cross-sectional study between 1 February 2019 and 30 April 2019 at the Regional Agricultural Research Station, Ishurdi, Bangladesh. A group of 196 untrained lentil consumers, aged 16–65 years, participated in the sensory evaluation. A total of 50–100 responses are desirable for sensory evaluation according to the sensory evaluation guidelines of the Institute of Food Technologists' Sensory Evaluation Data [26].

Panelists were included on the basis of their willingness to participate in the study and their general health. The exclusion criteria were (i) having a fever, cold or, gum inflammation; (ii) taking medicines for cancer, thyroid, neurologic, or psychotropic treatment; (iii) being susceptible to an allergic reaction to lentils, iron or zinc; (iv) pregnancy, (v) having chewed betel leaf with betel nut and tobacco (locally known as paan/jarda) less than an hour before the sensory evaluation. A face-to-face interview technique was adopted since it was the appropriate method for filling in the sensory evaluation data by trained research assistants. With the proposed sensory trials, a preliminary assessment of consumer acceptability was conducted prior to carrying out a large-scale study with consumers.

2.2. Preparation of Cooked and Uncooked Lentil Samples for Evaluation

The most suitable Zn and Fe fortificants were selected after a series of experiments at the University of Saskatchewan Lab [16]. Based on those results, this sensory acceptability study for dual-fortified lentils was conducted. Two dual-fortified uncooked and one unfortified control sample from each of the three milled lentil product types (LPTs) (red football (RF), red split (RS), and yellow split (YS)) were evaluated by the consumers (Figure 1). One randomly selected dual-fortified sample (fortified with 16 mg Fe and 8 mg Zn per 100 g of lentil) and one unfortified control sample from each of the three LPTs were used to prepare a popular traditional recipe [25,27] commonly consumed in Bangladesh (Figure 2).

Figure 1. Images of uncooked lentil samples of three lentil product types (red split, left column; red football, middle column; and yellow split, right column), including the unfortified control (**upper row**) and two dual-fortified samples (i) fortified with 16 mg Fe from NaFeEDTA and 8 mg Zn from $ZnSO_4.H_2O$ 100^{-1} g of lentil (**middle row**), and (ii) fortified with 24 mg Fe from NaFeEDTA and 12 mg Zn from $ZnSO_4.H_2O$ 100^{-1} g of lentil (**lower row**).

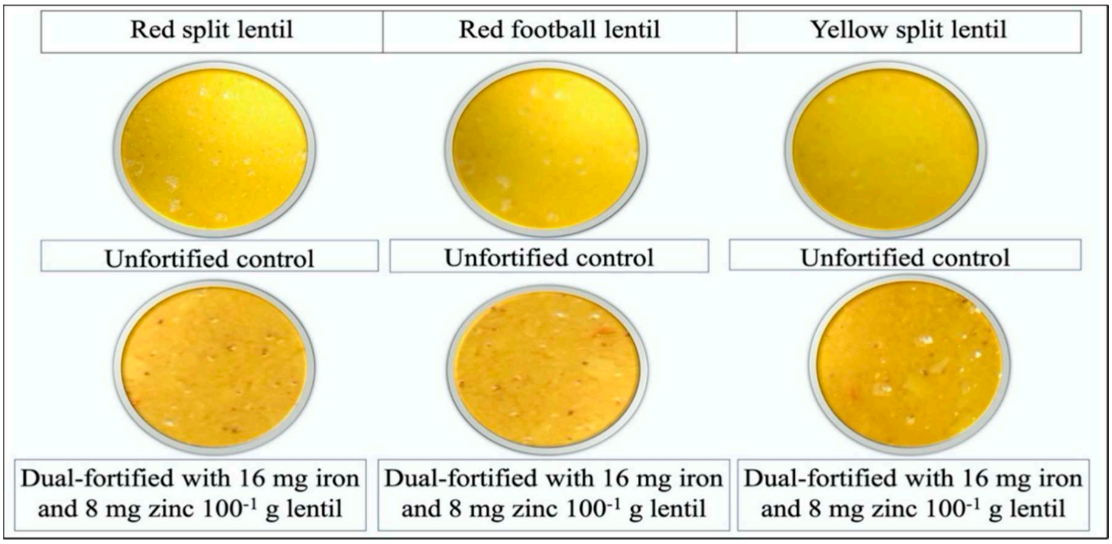

Figure 2. Samples of cooked dal prepared from each of the three product types (red split, left column; red football, middle column; and yellow split, right column) of lentil, including the unfortified controls (**upper three**) and dual-fortified samples (**lower three**) fortified with 16 mg of Fe and 8 mg of Zn 100^{-1} g of lentil.

Food samples were cooked in the food processing laboratory of the Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna, Bangladesh. Hygiene and quality were maintained by using stainless steel cookware to prepare all cooked samples. We prepared a semi-thick lentil soup with each of the 6 different lentil samples. A portion (500 g) of each lentil sample was cooked for about 25 min using a local recipe, i.e., de-ionized water (2.5 L), turmeric (10 g), table salt (20 g), canola oil (30 mL) and chopped onion (100 g). All of the nine uncooked samples were separated into 4-oz white-colored foam cups, labelled with 3-digit codes, for evaluation by individual participants. After completing the uncooked sample evaluation, each participant was given one tablespoon of a cooked lentil dish or lentil soup from each of the six samples separately in 3oz plastic cups labelled with 3-digit codes. Water for rinsing the mouth between tastings was provided to the participants before and after testing each of the dishes.

2.3. Data Collection Tools and Techniques

Data were collected at two stages. At the first (screening) stage, a sampling frame was created among the interested participants and we used a simple random sampling technique to finalize the participants. At first, a screening questionnaire was used to collect the information from 200 lentil consumers (aged 16–65 years, who expressed interest in participation) with selected sociodemographic variables. A total of 196 study participants were selected for the final sensory evaluation study. In the second stage, a separate structured questionnaire was used for sensory evaluation. Both questionnaires followed forward–backward translation (English and Bengali). The sensory evaluation form had three parts. Part I covered demographic information, Part II included an evaluation of liking for the appearance, odor, and overall acceptability of the uncooked lentil samples. Similarly, an evaluation of liking for four sensory attributes (appearance, odor, taste, and texture), and the overall acceptability of the cooked dual-fortified lentil samples was also included. Participants' responses were captured using a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely). In Part III, any opinions/comments from the participants regarding the tasted sample were documented (verbatim), whether they were positive or negative.

Sensory evaluation was carried out in a single day from mid-morning to mid-afternoon. A total of 20 research assistants (RA) were recruited a day before the interviews and were trained by a senior research investigator on the day of evaluation. The training mainly emphasized interview techniques and understanding the sensory evaluation form. After the training session, the data collection team practiced the administration of sensory evaluation forms to ensure the complete understanding and uniformity of the whole data collection process. We organized a total of 20 dual-fortified lentil booths that had uniform white light conditions and furniture for the testing of sensory attributes by the participants. Each participant scored the samples while seated face to face with the research assistant. Twenty participants took a test at one time and the sensory evaluation was conducted in single sessions to avoid reporting bias. Initially, uncooked samples were presented in a white tray for scoring. Then each participant was given one tablespoon of the cooked dishes or lentil soup from each of the samples separately. Deionized water was provided to the participants for oral rinsing before testing the first dish and after testing each of the dishes to cleanse the palate [25,28].

2.4. Ethical Considerations

The study was approved by the Research Ethics Office, the University of Saskatchewan, Canada (BH 14–729), the Bangladesh Medical Research Council, Bangladesh (BMRC/NREC/2016-2019/14) and the Asian Institute of Disability and Development (AIDD) Human Research Ethics Committee (HREC) (southasia-hrec-2019-3-01).

The anonymity and confidentiality of the study participants were strictly maintained. Written informed consent was received from each respondent. Unique identification numbers (UID) were assigned to each participant to maintain anonymity and confidentiality. Study participants had the right to withdraw from the study at any time during the interview or sensory evaluation process. No side effects were expected in consideration of the amounts of Fe and Zn fortificants that respondents would consume during the evaluation study. All fortificants were food-grade quality. The toxicity level for Fe in the human body compared to the dose provided was negligible. However, monitoring was undertaken, and an adequate supply of water and necessary precautions were taken before initiating the sensory evaluation. Consent forms were stored separately from the collected data, which was stored on a password-protected computer and all associated computers were also password protected. Hard copies were stored in a locked cabinet. Data will be stored for 5 years after submission of the final report, at which point the soft copies will be deleted from computers and hard copies will be shredded.

2.5. HunterLab Colorimetric Measurements of Unfortified and Dual-Fortified Uncooked Lentil Samples and Correlation with Sensory Attributes

The lightness (L*), redness (a*), and yellowness (b*) score of uncooked dual-fortified lentil samples from three LPTs were measured using a HunterLab instrument (Hunter Associates Laboratory Inc., Reston, VA, USA). L* indicates the darkness to lightness, ranging from 0 to 100; a* indicates greenness to redness, ranging from −80 to +80 and b* indicates blueness to yellowness, ranging from −80 to +80 (Wrolstad and Smith, 2010). The HunterLab L*, a* and b* scales were used for measurements three times per sample and the scores were analyzed using ANOVA in SAS 9.4 (SAS Inc. Cary, NC, USA). The sensory data of three attributes (appearance, and overall acceptability) of three LPTs of uncooked lentil samples were correlated with the L*, a*, and b* scores using Pearson's correlation test.

2.6. Statistical Analysis

After data collection was completed, a dataset was prepared in SAS (Statistical Analysis Software, SAS Institute Inc., Cary, NC, USA) version 9.4. Datasets were reviewed by first entering the pretesting questionnaire data as a means of testing the practicability, and to check whether it covered every variable mentioned in the questionnaire. Scores for appearance, odor, taste, texture, and the overall acceptability of the fortified lentils were presented as means with standard deviations (SD). A One-Way Analysis of Variance (ANOVA) was performed to determine mean score differences among food samples, including the control. Statistical significance was set at $p < 0.05$. We tabulated the frequency and percentage as appropriate and used box plots to present sensory data using a 1–9 scale.

2.7. Consistency Assessment for Sensory Data Based on Cronbach's Alpha

Cronbach's alpha (CA) coefficient was used to measure the consistency of the panelists' responses since it measures the internal consistency reliability (ICR) of a sensory panel in multi-item evaluation scores [29]. It assessed the measurement error (between zero and one) by squaring correlation (α values) and by subtracting the end results from one, which provides the variation in the error that occurred in the measurement [30–32]. The value after subtraction represents the error variance in the score. We assessed the ICR of the liking scores for sensory attributes of 196 panelists in Bangladesh, for the nine uncooked and six cooked samples. Although there is no strict cut-off for CA, several studies report acceptable ICR ranges from 0.70 to 0.95 [33,34].

3. Results

3.1. Demographic of the Study Participants

The sociodemographic profile of the consumers is presented in Table 1. Among the participants, 59.2% and 40.8% were male and female, respectively, with an age range from 16–65 years, with a major portion (40%) in the 26–35 age range group. In total, 77.7% of the participants were from households where between one and five people were employed. Almost half (48.0%) of the participants had a monthly income ranging between BDT 10,000 and 19,000 (USD ~121–240).

Table 1. Socio-demographic profile of consumers who participated in the dual-fortified lentil sensory evaluation study in Bangladesh.

Profile Characteristics		Number (%)
Sex	Male	115 (59.2)
	Female	80 (40.8)
Age (years)	16–25	40 (20.9)
	26–35	63 (33)
	36–45	42 (22)
	46–55	37 (19.4)
	56–65	9 (4.7)
Number of employed people in household	1–5	146 (77.7)
	6–10	41 (21.8)
	≥11	1 (0.5)
Total monthly income from all sources (Bangladeshi Taka)	5000–9999 (~90 to 120 USD)	19 (9.7)
	10,000–19,999 (~121 to 240 USD)	94 (48.0)
	20,000–29,999 (~241 to 360 USD)	38 (19.4)
	30,000–39,999 (~361 to 480 USD)	24 (12.2)
	≥40,000 (≥480 USD)	18 (9.2)
Education	Illiterate	3 (1.5)
	Elementary (primary; grade −5) incomplete	11 (5.6)
	Elementary passed	72 (36.9)
	Secondary (grade 10) School Certificate passed	45 (23.1)
	Higher Secondary (grade 12) Certificate passed	64 (32.8)

3.2. Consumer Attitudes toward Lentil Consumption

Among the participants, 52.0% and 13.8% of the respondents purchased 251–500 g and 751–1000 g of lentils per week, respectively (Table 2). Participants also bought other pulses at lower quantities compared to lentils—46.2% purchased 100–250 g of other pulses (chickpeas, mung beans, black gram, field peas, etc.) weekly, and 38.8% of the participants bought 251–500 g per week. Local markets were the primary source of purchased lentils (89.8%) followed by 8.1% from neighborhood grocery stores. The majority (76.5%) of panelists purchased lentils on a monthly basis and 89.9% preferred to buy red football LPT, followed by 9.7% who preferred red split LPT.

Table 2. Consumer habits and patterns of lentil consumption.

Observation	Consumer Pulse Purchases (g/Family/Week)	Number of Consumers (%)
Lentil purchases	100–250	35 (17.9)
	251–500	102 (52.3)
	501–750	20 (10.3)
	751–1000	27 (13.8)
	≥1001	11 (5.6)
Other pulse purchases (chickpeas, mung beans, black gram, field peas, etc.)	100–250	91 (46.2)
	251–500	76 (38.8)
	501–750	8 (4.1)
	751–1000	7 (3.6)
	≥1001	14 (7.1)
Lentil purchase source	Retail shops	176 (89.8)
	Wholesale	16 (8.1)
	Do not buy or produce	4 (2.0)
Frequency of lentil purchase	Several days in a week	16 (8.6)
	Weekly	18 (9.2)
	Fortnightly	11 (5.6)
	Monthly	150 (76.5)
Lentil product preference market?	Dehulled football	176 (89.8)
	Dehulled split	19 (9.7)

3.3. Liking for the Uncooked Fortified Lentil Dal

Figure 3 show the mean, range, dispersion and outliers of the sensory attributes for the nine uncooked samples. For all three LPTs (RF, RS, and YS), consumer responses varied significantly for appearance, odor, and overall acceptability. The liking scores for sensory attributes, and for overall acceptability were significantly different between control and fortified LPTs for the three samples of both RF and RS lentils; however, insignificant differences were observed within the fortified samples. In YS lentils, the odor and overall acceptability scores significantly varied between fortified and unfortified lentil samples as well as within fortified YS lentil samples. For all attributes and product types, the highest preference score was observed for unfortified control lentil samples, followed by samples fortified with 8 mg Zn from $ZnSO_4H_2O$ and 16 mg Fe from NaFeEDTA. The lowest score was recorded for the sample fortified with 12 mg Zn from $ZnSO_4H_2O$ and 24 mg Fe from NaFeEDTA.

Figure 3. Box plot analysis of hedonic scores (1 = dislike extremely, 9 = like extremely) obtained for

three uncooked lentil dal samples (unfortified control lentil polished with 0.5% canola oil; dual-fortified with 8 mg Zn from $ZnSO_4H_2O$ +16 mg Fe from NaFeEDTA (100^{-1} g of lentils)); dual fortified with 12 mg Zn from $ZnSO_4H_2O$ + 24 mg Fe from NaFeEDTA (100^{-1} g of lentils) from each of the three product types, red football (**A**), red split (**B**) and yellow split (**C**), evaluated for appearance (**A**–**C**(**a**)), odor (**A**–**C**(**b**)), and overall acceptability (**A**–**C**(**c**)), by 196 panelists in Bangladesh. Different letters after mean values in the right column indicated significant differences between three samples within each attribute. Each box plot displays the distribution of data for each sample type separately based on a five-number summary, "minimum", first quartile (Q1), median, third quartile (Q3), and "maximum".

In general, the box plots for the control samples had a smaller range and less dispersion than those of the two fortified samples for all three LPTs. The box plot skewed either to the right (positive skew) or was neutral for unfortified control, with the average score significantly ($p < 0.05$) higher than that of fortified samples for each of the product types and attributes. In all three LTPs, the mean liking scores for the dual-fortified sample, fortified with 8 mg Zn from $ZnSO_4H_2O$ and 16 mg Fe from NaFeEDTA, were significantly ($p < 0.05$) different but closer to the unfortified control compared to the other dual-fortified sample fortified with 12 mg Zn from $ZnSO_4H_2O$ and 24 mg Fe from NaFeEDTA.

3.4. Liking for the Cooked, Fortified Lentil Dal

For all three LPTs, unfortified cooked control samples received the highest mean score for all five attributes (appearance, odor, taste, texture, and overall acceptability) compared to the fortified samples (fortified with 16 mg Fe from NaFeEDTA and 8 mg Zn from $ZnSO_4H_2O$) (Figure 4). An insignificant variation was observed for the two cooked lentil dal samples from all three LPTs evaluated by panelists, except for texture and overall acceptability of RF, and for appearance and overall acceptability of YS lentils. The numerical differences between scores across all samples of each of the three LPTs were very low for all five attributes. Specifically, the box plots for cooked samples showed less dispersion and a narrower range of liking scores for all attributes compared to those for the uncooked samples. All samples scored well (~7.0 = like moderately) for all five attributes.

3.5. HunterLab Colorimetric Measurements of Unfortified and Dual-Fortified Uncooked Lentil Samples and Correlation with Sensory Attributes

The results of the lightness (L*), redness (a*) and yellowness (b*) scores of unfortified and dual-fortified lentil samples from three LPTs are shown in Table 3. For all three LPTs, a significant variation was observed between control and dual-fortified lentil samples for all L, a* and b* scores. Again, in all three LPTs, the highest and lowest L, a* and b* values were observed in unfortified-control and dual-fortified samples fortified with 24 mg Fe and 12 mg of Zn 100^{-1} g of lentils. Among the two red football and red split dual-fortified samples, insignificant differences were observed for the L value, but for a* and b* values there were significant differences. Non-significant differences were observed between two dual-fortified samples for all thee scales.

The correlation coefficients between L, a*, and b* scores obtained from HunterLab and sensory acceptability scores were significant at $p < 0.0001$ with a range from 0.92 to 0.99 (Table 4). In the previous study, when we added different doses of Fe solution, the colorimetric test showed that with the increase in Fe dose, the red color of the lentil also became darker [14]. This result also showed a significant correlation with the sensory evaluations of uncooked samples by panelists. The appearance, odor, and overall acceptability were influenced by the increase or decrease in the Fe doses.

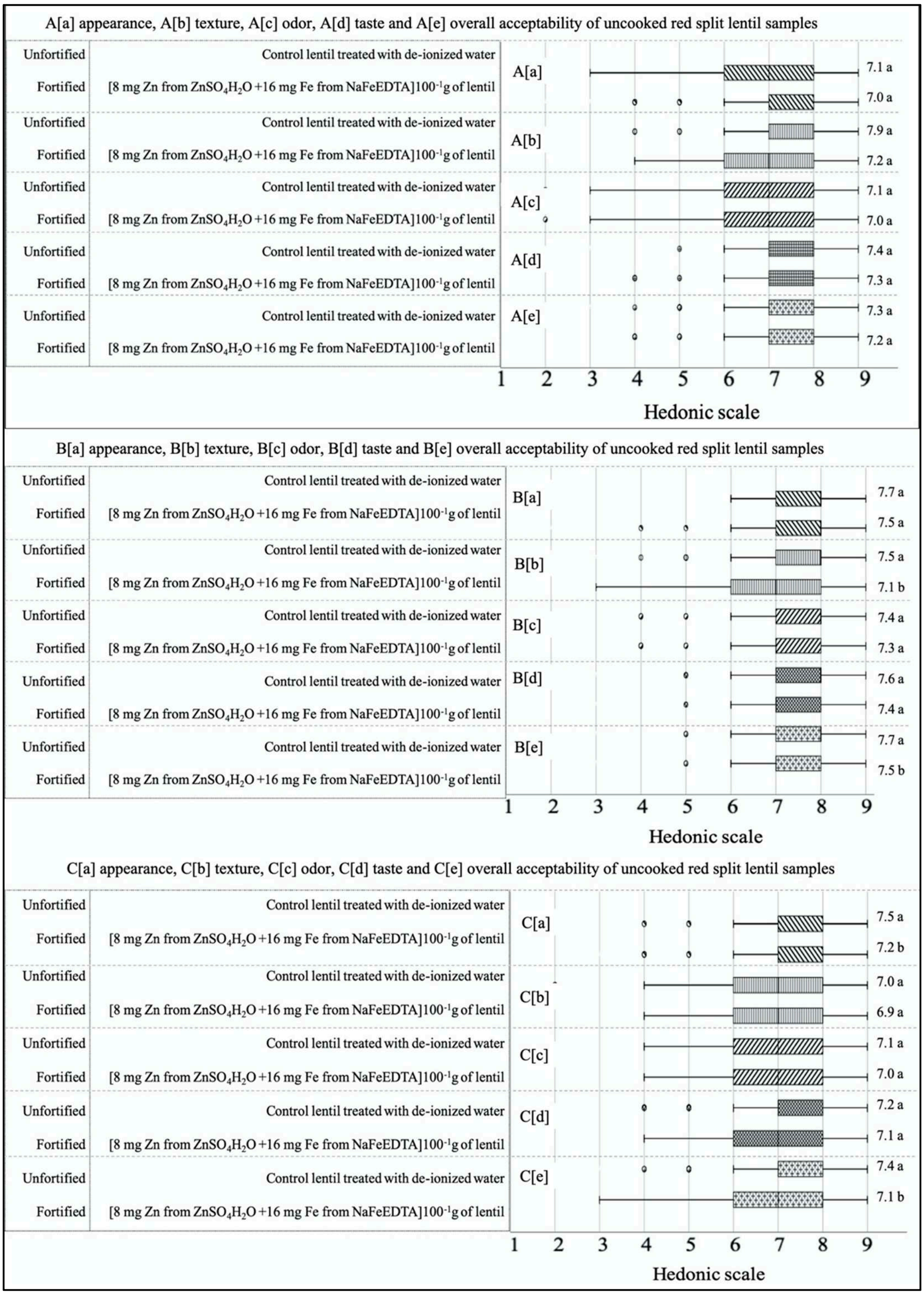

Figure 4. Box plot analysis of hedonic scores (1 = dislike extremely to 9 = like extremely) for two cooked lentil dal samples [unfortified control lentil polished with 0.5% canola oil; dual-fortified with 8 mg Zn from $ZnSO_4H_2O$ +16 mg Fe from NaFeEDTA (100^{-1} g of lentils) for each of the three lentil product types—red football (**A**) red split (**B**) and yellow split (**C**). Samples were evaluated for appearance (**A**–**C**(**a**)), texture (**A**–**C**(**b**)), odor (**A**–**C**(**c**)), taste ((**A**–**C**)(**d**)), and overall acceptability (**A**–**C**(**e**)), by 196 panelists in Bangladesh. Different letters after mean values in the right column indicate significant differences between two samples within each attribute. Each box plot displayed the distribution of data for each sample type separately based on a five-number summary, "minimum", first quartile (Q1), median, third quartile (Q3), and "maximum".

Table 3. Lightness (L*), redness (a*) and yellowness (b*) scores of one unfortified and two dual-fortified dehulled red football, red split and yellow split lentil samples prepared using Fe and Zn from NaFeEDTA and $ZnSO_4H_2O$, respectively.

Samples	Fortificant Dose/s Added/100 g of Lentil		CIELAB Color Score [a]		
	Fe (mg) from NaFeEDTA	Zn (mg) from $ZnSO_4H_2O$	Lightness (L)	Redness (a*)	Yellowness (b*)
Red football					
Sample 1 [b]	Unfortified and polished [d]		52.4 ± 0.1 a	31.7 ± 0.1 a	46.2 ± 0.1 a
Sample 2 [c]	16	8	50.8 ± 0.2 b	28.2 ± 0.2 b	40.6 ± 0.1 b
Sample 3 [c]	24	12	50.8 ± 0.3 b	27.8 ± 0.1 c	39.7 ± 0.2 c
Red split					
Sample 1 [b]	Unfortified and polished [d]		55.1 ± 0.3 a	31.4 ± 0.3 a	46.6 ± 0.4 a
Sample 2 [c]	16	8	53.3 ± 0.1 b	28.9 ± 0.2 b	43.4 ± 0.2 b
Sample 3 [c]	24	12	53.2 ± 0.2 b	27.0 ± 0.0 c	41.4 ± 0.1 c
Yellow split					
Sample 1 [b]	Unfortified and polished [d]		62.1 ± 0.2 a	12.5 ± 0.1 a	50.9 ± 0.1 a
Sample 2 [c]	16	8	59.5 ± 0.2 b	10.6 ± 0.3 b	45.6 ± 0.3 b
Sample 3 [c]	24	12	59.2 ± 0.3 b	10.6 ± 0.1 b	45.8 ± 0.3 bc

[a] Mean ± SD. Mean scores for lightness (L*), redness (a*) and yellowness (b*) score followed by different Roman letters within columns are significantly different ($p < 0.0001$). [b] Unfortified control lentil; [c] Dual-fortified lentil with NaFeEDTA and $ZnSO_4H_2O$; [d] polished with 0.5% canola oil.

Table 4. Correlation coefficients between colorimetric data lightness (L*), redness (a*) and yellowness (b*) score obtained from HunterLab and sensory acceptability scores from Bangladeshi consumers for three attributes (appearance, and overall acceptability) of each of three uncooked product types (red football, red split and yellow split) of lentil samples. all the correlation coefficients were found significant at $p < 0.0001$.

Sensory Attributes	Lentil Product Types								
	Red Football			Red Split			Yellow Split		
	L	a*	b*	L	a*	b*	L	a*	b*
Appearance (n = 3)	0.99	0.99	0.99	0.96	0.99	0.99	0.99	0.99	0.98
Overall acceptability (n = 3)	0.99	0.99	0.99	0.98	0.98	0.99	0.93	0.95	0.97

L*, Lightness; a*, redness; b*, yellowness.

3.6. Consistency Assessment for Sensory Data Based on Cronbach's Alpha

Cronbach's alpha (CA) was used to evaluate the reliability of the sensory data. It creates a "proximity measure between evaluation profiles" by considering both variance and covariance relationships [29]. Table 5 presents the CA scores of both fortified and unfortified cooked and uncooked samples. The CA was ≥ 0.75 for uncooked samples. All the CA scores for cooked samples, except for unfortified YS control lentils polished with 0.5% canola oil, were greater than or equal to 0.80. Mean CA scores for uncooked and cooked samples were 0.84 and 0.81, respectively, which represents a high consistency in the evaluations of all samples using the hedonic scales.

Table 5. Internal consistency reliability (CA) of the sensory panelists' ratings of uncooked red football, red split and yellow split lentil and cooked dal samples.

		Uncooked Samples	**CA Score**
Red football	Unfortified	Control lentil polished with 0.5% canola oil	0.88
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.87
	Fortified	[12 mg Zn + 24 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.86
Red split	Unfortified	Control lentil polished with 0.5% canola oil	0.81
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.75
	Fortified	[12 mg Zn + 24 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.81
Yellow split	Unfortified	Control lentil polished with 0.5% canola oil	0.89
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.81
	Fortified	[12 mg Zn + 24 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.87
		Average value for all the uncooked samples	0.84
		Cooked samples	
Red Football	Unfortified	Control lentil polished with 0.5% canola oil	0.80
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.81
Red split	Unfortified	Control lentil polished with 0.5% canola oil	0.83
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.87
Yellow split	Unfortified	Control lentil polished with 0.5% canola oil	0.64
	Fortified	[8 mg Zn +16 mg Fe]100^{-1} g of lentil and polished with 0.5% canola oil	0.89
		Average value for all the cooked samples	0.81

4. Discussion

Sensory evaluation encompasses effective measurements from consumers in terms of their liking, preference, and acceptability of food or food products [35]. The current study was undertaken to understand and evaluate the sensory attributes of dual-fortified lentils among lentil consumers in Bangladesh. The choice of Bangladesh as a study site was made for specific reasons. Lentils are considered a staple or partially staple food in many countries. About 56% of the lentils produced in the world are consumed in Asia [19], with a very high consumption in Bangladesh. Lentils are consumed frequently in daily meals due to their fast cooking properties, and they are also an inexpensive source of protein, carbohydrates, and micronutrients compared to animal sources. This study was conducted in one of the most important lentil-growing regions of Bangladesh. Most farmers of this region have experience with growing, processing, and marketing lentils. Moreover, the national Pulses Research Centre (PRC) of the Bangladesh Agricultural Research Institute (BARI) is located in this region. Several national and international organizations are actively involved with the Bangladesh national health sector in conducting research studies, sensory evaluations, and field trials with fortified foods, e.g., fortified rice. "Daal (pulses), vhat (rice)" or "hotchpotch", made with pulses (mostly lentils) and rice are common and popular dishes in most South Asian countries, including Bangladesh. Around 60% and 12% of Bangladeshi women consume lentils at a frequency of 3 and 4 days per week, respectively [36]. A similar study reported that 92% of the 384 respondents consumed hotchpotch at least once per week [36]. More than 80% of the lentil dal in the Bangladeshi market is imported from other lentil-growing countries, mostly from Australia and Canada. This provide an enormous opportunity to export dual-fortified lentil products to cope with both Fe and Zn deficiency problems in Bangladesh.

The concept of fortification is emerging in Bangladesh, although few fortified foods are available in the market, and some are under consideration. Two mandatory fortified foods, vegetable oil and salt with vitamin A and iodine, respectively, are now available in Bangladesh [22]. Research studies and evaluations of other fortified food products including rice, lentils, wheat flour, and sugar are underway in Bangladesh. A feasibility study of the field implementation of Fe-fortified lentil with adolescent girls in Bangladesh showed that respondents willingly consumed Fe-fortified lentil meals [22]. A large-scale double-blind community-based randomized controlled trial using Fe-fortified lentils with ~1200 adolescent girls in Bangladesh was recently completed, and results showed a significant effect of Fe-fortified lentils in improving the Fe-status of adolescent girls [37].

In any sensory evaluation study, consumers play a significant role in the preference assessments of product differences and characteristics [38]. The selection of the number of respondents in any consumer test depends on food/food products that need to be evaluated, the purpose of the test, the time frame, and the cost [39]. The recommended sample size for consumer acceptability tests suggest that 50–300 respondents are required for an acceptability test [40]. Suresh and Chandrashekara (2012) described a formula to calculate the sample size and showed that ~96 participants are acceptable to conduct research at the consumer level [41]. In this study, data from 196 participants were used to describe the objectives with statistical significance.

In a sensory analysis at the consumer level, sociodemographic data can be very useful to provide an insight as to whether or not the participants are representative of the total population when a specific food product is evaluated. An earlier study reported that socio-cultural diversity, socio-demographic factors and economic status affect consumer choice regarding functional foods [42]. In the current study, data recorded on participant diversity in terms of age, gender, monthly income, employment status, education, and lentil consumption attitudes confirmed the representativeness of the general consumers (Table 1).

Consumer attitudes toward lentil consumption showed that Bangladeshi consumers preferred red lentil dal compared to other pulses. Among the two product types of red lentil dal, the football type was more preferred (89.8%) than the split type (Table 2). Unlike red lentil dal, dehulled yellow cotyledon lentil dal is usually produced from lentils with green coats, and is not yet well known in the Bangladeshi market. Whole (not decorticated) green lentils have been using in the snack industry for several years, but not for soup preparation at the household level. As lentil demand is increasing around the world [43] and market research for green lentil products has been initiated in different South Asian countries, our goal was to introduce the dehulled yellow lentil dal to the lentil consumers and evaluate consumers' attitudes to this type of lentil along with the red type. Most of the consumers (around 90%) in Ishurdi bought lentils from the local market, where lentils are sold by scooping from open sacs or in 1–2 kg plastic bags. The previous study [43] in an urban market showed that 37% of consumers bought lentils from local markets or retail shops. This difference could be due to the sociodemographic differences between urban and suburban areas. Fortified lentil is considered a value-added food product that requires packaging in sealed bags to ensure quality and to reduce the risk of adulteration.

Sensory responses to uncooked lentil dal samples revealed significant differences between unfortified and dual-fortified samples for all three LPTs (Figure 3A-C). Although the differences were numerically very low, liking scores from all three attributes (appearance, odor, and overall acceptability) decreased significantly with the increase in Fe and Zn concentration. In all three LPTs, the unfortified controls received higher scores than the fortified samples for all three attributes. Among the three control samples from three LPTs, the RF control got the highest score compared to the other two control samples of RS and YS, indicating the preference for RF lentils compared to RS and YS lentils. Overall acceptability scores for RF, RS, and YS lentils ranged from 7.0 to 8.0, 6.8 to 7.5, and 7.3 to 8.0, respectively. For all the three LPTs, insignificant differences were observed between two dual-fortified lentil samples for all three attributes, except for the order and overall acceptability of YS lentils. A previous study [43] showed that with the increase in Fe fortificants, liking scores decreased in Fe-fortified lentils. The results from this study indicate that Zn fortificants might help to protect the lentil from darkening, even with higher doses of Fe (24 mg of Fe 100^{-1} g of lentil). The results also show that the dual fortification of YS lentils is more susceptible to the development of an off-color appearance than RF and RS lentils with higher doses of Fe and Zn fortificants. In three LPTs, three attributed mean scores of uncooked samples ranged from "like moderately, a score of 7" to "like very much, a score of 8". Moreover, from all three LPTs and three attributes, several participants scored "9, like extremely" for control samples and a dual-fortified sample fortified with 16 mg of Fe and 8 mg of Zn per 100 g. Overall, the results indicated that dual-fortification with Fe and Zn did not have a large adverse effect on the sensory characteristics of any LPTs.

Non-significant differences were observed between cooked control and dual-fortified lentil samples for all five attributes (appearance, odor, taste, texture and overall acceptability) of the three LPTs, except for texture and the overall acceptability of RF lentils and the appearance and overall acceptability of YS lentils. For all three LPTs, the control lentils received a numerically higher score for all five attributes compared to dual-fortified products. Overall, liking scores for all three LPTs indicated that both cooked samples from each of the three LPTs were accepted equally by the participants. Boxplot comparisons of both uncooked and cooked samples showed that some outlier scores might have greatly influenced the average score of the lentil samples. Some consumers scored the uncooked dual-fortified sample (fortified with 24 and 12 mg of Fe and Zn, respectively) with the two lowermost hedonic scores (dislike extremely, a score of one; dislike very much, a score of two). Some consumers also noted the floating of a black-colored substance, and black spots in the cooked and uncooked samples, respectively. The black spot is the micropylar region of dehulled lentils that is insoluble in water and, after cooking, this region detaches from the cotyledon and floats in the soup. During fortification, this whitish embryonic tissue absorbs fortificant from the solution, resulting in a slight discoloration caused by oxidation [25]. This dark micropylar region could, however, be used as an indicator to help consumers distinguish fortified lentils from unfortified lentils.

In this study, two samples from each of the three LPTs were selected for evaluation by consumers, including one control and one dual-fortified sample with 16 mg and 8 mg of Fe and Zn, respectively. A previous study [16] showed that dual-fortified RF, RS, and YS lentil products fortified with 16 mg Fe and 8 mg Zn per 100^{-1} g of lentils, can provide Fe and Zn at 27.1 to 13.9 mg, 28.0 to 13.4 mg, and 29.9 and 12.1 mg per 100^{-1} g of lentil, respectively. The control samples from each of the three LPTs contain Fe and Zn at 7.5 to 4.3, 7.1 to 4.4 and 5.9 to 3.9 mg per 100^{-1} g of lentil. Each of the 196 participants consumed 15 mg of lentils from each of the cooked samples. Each of the participants consumed a total of 90 g of lentils from both fortified and control lentil samples. From 90 g of lentils, each participant consumed 15.3 mg (4.06 + 4.20 + 4.5 + 1.1 + 1.1 + 0.89) of Fe and 7.76 mg (2.08 + 2.01 + 1.82 + 0.64 + 0.63 + 0.58) mg of Zn. The tolerable upper intake level of iron and zinc per day for males and females (19+ years) is 45 mg/day and 40 mg/day, respectively.

Liking scores for all sensory attributes and for overall acceptability from both uncooked and cooked samples showed that consumers scored differentially for similar samples when cooked lentils were compared to uncooked lentils. The wider range of scores observed for uncooked samples was narrowed down after cooking. The reduced score range could be due to cooking the lentils following a traditional lentil soup preparation recipe [27]. Dry turmeric (*Curcuma longa* L.) powder and onion (*Allium cepa* L.) are the two common ingredients used to cook lentils. The yellow color of turmeric would change the soup's appearance and suppress the darkness of fortified lentils. The pungent smell of onion also has a significant effect on changing odor and taste profiles and can suppress the metallic taste (if any is detectable) of fortified lentils after cooking [25]. Insignificant differences in sensory attributes were also reported for cooked conventional and fortified rice [44]. Iron and Zn from the fortificants may affect the taste. Since we did not measure biological assessments that affect taste, and as this study was conceptualized to capture a real working scenario in the study population, our study cannot address this issue. In addition, the fortified lentils used in this study were produced in the Saskatchewan Food Industry Development Centre, Canada. In Canada, canola oil is commonly used to polish the lentils after dehulling and cleaning to give them a shiny look that increases consumer attraction. In this study, we did not use palm oil or soybean oil to avoid any interaction between the two different oils, which may have altered the taste and odor. Moreover, participants had the recipe explained to them before the sensory evaluation started.

Sensory analysis helps to evaluate products in a relatively short time and at a low cost with representative consumers who consume the identified product and have sensory skills [45]. The effects of dual fortification on the sensory properties of food are highly variable and depend on the Fe and Zn fortificants and food items [23]. In this study, although consumers could easily distinguish the fortified samples from the control, the overall acceptability was more similar when the samples were cooked. The recommended intake of pulses is 50 g/day/person [46] and the estimated average requirement (EARs) of the Fe and Zn is 29.4 mg and 4.9 mg for males and 18.8 mg and 7.0 mg for females, respectively [23]. Consumption of dual-fortified lentils instead of unfortified lentils could be a prime option to provide a sufficient amount of Fe and Zn in a rapid manner in comparison to other micronutrient intervention approaches mentioned by Northop-Clewes (2013) [23].

The consistency of sensory data was assessed by calculating the Cronbach's alpha (CA) value, which showed that panelists were consistent in scoring both uncooked and cooked samples and that the CA values were within the acceptable range (0.75 to 0.95) [33,34]. Only one LPT sample (YS control, 0.64) was below the suggested range. This could be due to the inconsistent scoring of consumers for this sample. Although YS lentils were introduced to participants before scoring, some participants did not score the YS sample. One study reported that missing values have an effect on the psychometric properties of any test [47]. However, generalizability cannot be explained through this study since data were cross-sectional in nature. We therefore advise caution when interpreting these specific results.

5. Conclusions

Overall, dual fortification decreased consumers' liking for uncooked lentils, but not cooked ones. We also found high acceptability of the dual-fortified red lentils and no major issues related to acceptability were observed for sensory attributes. We estimated that the dual-fortified samples used in a cooked dal preparation for the three lentil product types can provide approximately 14 mg of Fe and 6.5 mg of Zn from 50 g of lentils. This represents a major part of the estimated average requirement (EARs) of Fe and Zn currently recommended by the World Health Organization (WHO).

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Legume Flour or Bran: Sustainable, Fiber-Rich Ingredients for Extruded Snacks?

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Abstract: The impact of using legume flour and bran on both sensory and texture properties in extruded, sustainable snack formulations was investigated. Sensory attributes determining consumer preference or rejection of legume-based snacks, as well as food neophobia and food technology neophobia were also explored. Seven samples of extruded snacks (R = 100% rice flour; C = 100% chickpea flour; P = 100% green pea flour; C30 = 30% chickpea bran and 70% rice flour; C15 = 15% chickpea bran and 85% rice flour; P30 = 30% green pea bran and 70% rice flour; P15 = 15% green pea bran and 85% rice flour) were subjected to the three-point bend method using a TA.XT plus texture analyzer. Seventy-two subjects (42 women; aged = 29.6 ± 9.3 years) evaluated the samples for liking and sensory properties by means of the check-all-that-apply (CATA) method. The sample made with 100% rice flour obtained the lowest liking scores, and it was not considered acceptable by the consumers. Samples P, C, C15, and P15 were the preferred ones. Crumbliness and mild flavor attributes positively influenced hedonic scores, whereas stickiness, dryness, hardness, and to a lesser extent, visual aspect affected them negatively. Neophilic and neutral subjects preferred the snacks compared with the neophobic ones, while no differences in liking scores were found regarding food technology neophobia. Extruded snacks with legume flour and bran were moderately accepted by consumers involved in the present study, albeit to a lesser extent for neophobic subjects, and could represent an interesting sustainable source of fiber and high-value proteins, as well as a valuable alternative to gluten-free foods present on the market.

Keywords: acceptance; sensory descriptive analysis; CATA; texture analyzer; pulses; green peas; chickpea; rice

1. Introduction

One of priorities of the food industry is to reduce the environmental impact of its production. This objective can be achieved using several strategies, including the improvement of food chains that have less of an impact than others and focusing on a “circular economy” to reintroduce bioactive components from waste or by-products into new food formulations.

Legume production can satisfy both the abovementioned strategies. Firstly, a plant-based food system requires less resources in terms of water, land, and energy compared with a meat-based food system [1]. Legumes supply nitrogen for fertilization, since they can fix atmospheric nitrogen, thus reducing the amount of fertilizer used on the crops and increase proteins in animal feeding [2,3]. Secondly, milling by-products could be recovered to obtain bioactive components to be used as value-added ingredients in innovative food products. Among these components, legume bran has a high amount of dietary fiber, ranging from about 75% to 90% for chickpea and pea, respectively. Specifically, legume hull fiber is mostly insoluble fiber, whose purity is above the 80% [4].

It is well known that potential health benefits have been associated with the consumption of an appropriate amount of fiber [5]. Specifically, several epidemiological studies have highlighted that dietary fiber decreases the incidence of various diseases such as some types of cancers (e.g., colon and ovarian) [6,7], cardiovascular disease [8], and, in general, decreases the risk of mortality [9]. Moreover, it has been reported that the significant reduction in fiber consumption observed in industrialized countries is related to a worrying increase in cases of overweight people. Fiber intake in place of other macronutrients would lead to a decrease in calorie intake that could be extremely important for the overall health of the Western world [10]. However, the total dietary fiber consumed by the average individual is rather low, about <50%, of the recommended daily amount [11]. Even if proper nutrition requires legumes as a staple food in consumer diets, this recommendation is not often followed because cooking legumes can require a rather long preparation and because legumes are often not generally appreciated from the sensory point of view [12]. In recent years, a great deal of interest has been placed on partially replacing cereal-based products, such as pasta and bread, with legume flours to increase their nutritional profile [13].

Even if fiber-enrichment adds value in the eyes of the consumer [14], the addition of fiber in a food matrix causes changes in the production process, sensory properties, as well as texture and rheological parameters [15,16]. Therefore, the impact of adding fiber to a specific product needs to be studied. From a technological standpoint, fiber breaks down the starch–protein matrix, leading to important structural changes. Adding a small concentration of fiber could improve the structure of some products thanks to its ability to bind with water, but a high amount of fiber is almost always associated with a worsening of structural characteristics [17]. The types of fibers, as well as the food matrices in which these components are added, influence hardness, adhesiveness, and sensory attributes that cannot be generalized [18]. Previous findings have highlighted that pulse flours can be added up to of 40% (based on flour) in baked products without reducing their sensory quality [19], while other results have revealed that acceptability starts to decrease when more than 20% of wheat flour is replaced with that of legumes [20]. In addition to baked goods (e.g., bread and crackers), legumes might partially or totally replace cereals in the production of extruded snacks, products for which consumer demand is increasing since they can satisfy the demand for healthy, minimally processed, ready-to-eat foods.

Therefore, the aim of the present study was to investigate the impact of using legumes and legume bran on the sensory and texture properties of extruded snack formulations. The sensory attributes determining consumer preferences with regards to the experimental samples were studied. Food neophobia, which is the fear to try new and unfamiliar foods [21], and food technology neophobia, which refers to new food technologies [22], were also explored as behavioral attitudes playing a key role in defining consumer behavior.

2. Materials and Methods

2.1. Materials

Flours from milled rice (82.00% carbohydrates; 9.13% proteins; 1.19% lipids; 0.95% fiber), decorticated green pea (59.00% carbohydrates; 25.00% protein; 1.97% lipids; 9.50% fiber), and decorticated chickpea (56.00% carbohydrates; 24.00% proteins; 6.60% lipids; 10.10% fiber) were kindly provided by Molino Peila S.p.A. (Valperga, Italy), as well as the bran obtained from green pea (92.00% fiber; 3.30% proteins; 0.22% lipids) and chickpea (78.00% fiber; 11.20% proteins; 5.30% lipids). All values are expressed on dry basis.

Co-extruded snacks were prepared from rice (R), green pea (P), and chickpea (C). Moreover, bran from both green pea and chickpea were included in rice-based snack formulation at 15% and 30% levels, obtaining four different bran-enriched samples: C15, C30, P15, and P30. Overall, seven formulations were tested. Co-extruded snacks were produced at an industrial level by Fudex Group S.p.A. (Settimo Torinese, Italy) in the shape of bars. Extrusion was performed using a co-rotating twin-screw extruder (model 2FB90; screw speed: 150 rpm; temperature: 110 °C; pressure: 70 bar; Settimo Torinese, Italy).

2.2. Instrumental Texture Analysis

The textural properties of the snacks were determined by a three-point bend method using a TA.XT plus texture analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with a 100 N load cell. Snack bars were compressed with the Heavy, Duty Platform/Three Point Bending (HDP/3PB) probe at a crosshead speed of 1 mm/s to 5 mm of the original diameter of the snack. The compression generated a curve with the force over distance. The highest value of force was taken as a measurement for hardness. The test was carried out on 35 pieces for each sample, and the average value was considered.

2.3. Sensory Evaluations

2.3.1. Subjects

Seventy-two subjects (42 women; mean age: 29.6 ± 9.3 years) were recruited among students and employees of the Faculty of Agriculture and Food Sciences of the University of Milan. The exclusion criteria were as follows: subjects who did not like rice and legumes, subjects suffering from food intolerances and allergies, as well as those who were on medical treatments that could modify taste perception. This study, approved by the Ethics Committee of the University of Milan, was conducted in compliance with the principles laid down in the Declaration of Helsinki. All subjects provided informed, written consent prior to participation.

2.3.2. Hedonic Evaluation

Subjects were asked to taste the products and to express their liking using a labeled affective magnitude (LAM) scale, anchored by the extremes "greatest imaginable dislike" (score 0) and "greatest imaginable like" (score 100) [23]. Prior to tasting, the experimenters provided to the participants instructions for the use of the scale.

2.3.3. Sensory Descriptive Evaluation

A separate group of 12 untrained subjects (mean age: 22.0 ± 4.1 years) were involved in a focus group, wherein they used a free listing questionnaire to define the appropriate sensory attributes to describe the extruded snacks [24]. Subjects had to evaluate the sensory characteristics of the snacks and identify all attributes for describing their color, appearance, odor, taste, flavor, and texture. After the development of the individual lexicon, an open discussion was made, and sensory attributes were selected by the experimenters considering the most commonly mentioned (frequency of terms selection at least of 40%) words in order to avoid synonyms [25]. Finally, the check-all-that-apply questionnaire consisted of a list of 23 sensory attributes: 3 for the appearance (dark yellow, light yellow, and green), 6 for the odor (strong, mild, toasted, rice, whole-meal, and legume), 3 for the taste (sweet, bitter, and salty), 6 for the flavor (strong, mild, rice, peas, chickpeas, and spicy), and 5 for the texture (crumbly, sticky, hard, porous, and dry). Subjects were asked to select the terms best describing each sample. Attributes' positions were randomized using the "to assessor" list order allocation scheme [26].

2.3.4. Questionnaires

Food Neophobia Scale

Neophobic traits were investigated through the Food Neophobia Scale (FNS) developed by Pliner and Hobden (1992) [21]. The FNS consists of 10 statements each offering 7 graded response alternatives, from "strongly disagree" (score 1) to "strongly agree" (score 7). After reversing the negatively worded statements, the FNS score was calculated as a sum of the responses, yielding a range of 10–70.

Food Technology Neophobia Scale

In order to investigate individual attitudes toward new food technologies, the Food Technology Neophobia Scale (FTNS) [22], consisting of 13 items, was used. Each statement offers 7 graded alternative responses, from "strongly disagree" (score 1) to "strongly agree" (score 7). Four of the 13 items reflect food neophilia, so responses had to be reversed in order to calculate the final neophobia score. The FTNS score was calculated as a sum of the participant's answers for each statement, yielding a range from 13 to 91. Higher scores indicate a higher food technology neophobia level.

2.3.5. Experimental Procedure

Subjects attended one online session and one laboratory session. During the online session, they were asked to complete a questionnaire including demographic variables and the food neophobia and the food technology neophobia scales. Subsequently, they were invited at the sensory and consumer science laboratory designed according to ISO guidelines (ISO 8589 2007) and were asked to refrain from consuming anything but water for 2 h before the test.

Samples were provided to the participants following a monadic presentation (one at a time) in a serving portion of approximately 30 g. The experimental samples were presented to the participants in plastic plates labeled with three-digit codes. Water was available for rinsing the palate between the samples. For each sample, subjects had to evaluate their overall liking and perform a sensory descriptive analysis by means of the check-all-that-apply (CATA) methodology. The entire session took approximately 30 min. Data were collected using the Fizz v2.47 software program (Biosystemes; Couternon, France).

2.4. Data Analysis

One-way analysis of variance (ANOVA) was applied to the data obtained from instrumental texture analysis, and the least significant differences were calculated by the Tukey's HSD test.

ANOVA model was performed on overall liking scores considering samples (R, P, C, C15, C30, P15, and P30), gender (women and men), age (≤26 years old; >26 years old) and their interactions as factors. When a significant difference ($p < 0.05$) was found, the LSD post hoc test was performed as a multiple comparison test.

The frequency of mention for each term of the CATA questionnaire was determined by counting the number of consumers who used that term to describe each sample. Cochran's Q test was applied to identify which sensory attributes were discriminating among samples. The relationship between samples and sensory attributes was evaluated by means of correspondence analysis (CA). The influence of sensory attributes' perception on hedonic scores was also investigated by means of penalty-lift analysis. This analysis suggests which sensory attributes are significantly ($p < 0.05$) positively or negatively associated with hedonic responses [27].

Correlations between instrumental and sensory texture data were examined using Pearson's correlation coefficient with a minimum significance level defined as $p < 0.05$.

The internal consistency reliability of the food technology and food technology neophobia scale was explored by Cronbach's alpha. ANOVAs were performed on FTNS and FNS scores considering age, gender, and their interactions as factors. To investigate the relationship between food neophobic traits and snack liking, subjects were categorized according to their neophobia scores into the following three groups: adults with scores in the lower 25th percentile of FNS scores, score <14 (Neophilic_FNS); adults with scores between the 25th and 75th percentiles, 14 ≤ FNS score ≤ 31 (Neutral_FNS); and adults with scores >31 (Neophobic_FNS). The same approach was used to identify subjects showing a lower (score < 31; Neophilic_FTNS), medium (31 ≤ FNTS score ≤ 46; Neutral_FTNS), or higher (score > 46; Neophobic_FTNS) level of food technology neophobia.

ANOVA models were performed on liking data considering FNS level, FTNS level, gender, age, and their interactions as factors. All analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY, USA) and XLSTAT (Version 2019.2.2, Addinsoft™, Boston, MA, USA).

3. Results

3.1. Hardness

Snack hardness is shown in Table 1. Snacks based on chickpea showed the highest value, almost two-fold higher than that of rice snack, which was used as control. On the other hand, snacks from green pea showed the least resistance to breakage. The addition of 15% bran from either green pea or chickpea did not significantly affect the snack texture in comparison with the 100% rice snack. Conversely, the type of bran was relevant when the milling by-product was included at 30% level. Specifically, adding 30% chickpea bran significantly decreased the force necessary to break the snack. On the contrary, in the case of 30% green pea bran, an increase (although not significant) in hardness values was recorded.

Table 1. Hardness values of co-extruded snacks. Mean (n = 35) ± SEM. Different letters in the column correspond to significant differences (Tukey's HSD test; $p < 0.05$).

Samples	Hardness (N)
R	48.3 ^{cd} ± 1.3
C	85.2 ^{e} ± 1.4
C15	47.4 ^{c} ± 0.8
C30	40.1 ^{b} ± 0.6
P	32.8 ^{a} ± 0.9
P15	46.4 ^{c} ± 0.9
P30	55.9 ^{d} ± 1.1

R = snacks from 100% rice; C = snacks from 100% chickpea; P = snacks from 100% green pea; C15 = snacks from 85% rice + 15% chickpea bran; C30 = snacks from 70% rice + 30% chickpea bran; P15 = snacks from 85% rice + 15% green pea bran; P30 = snacks from 70% rice + 30% green pea bran.

3.2. Hedonic Evaluation

Hedonic evaluation results are provided in Table 2. A significant sample effect was found for liking scores. The rice sample obtained the lowest liking score and was not considered acceptable by the consumers (mean hedonic score lower than middle of the scale = 50), while the samples with 100% pea and C15 were the preferred. Comparable liking scores were also provided for samples made with 100% C as well as formulations with 15% pea bran. These two last formulations were in turn comparable to the snacks made with legume bran at 30% (C30 and P30).

Table 2. Mean hedonic ratings ±SEM by samples, gender, and age groups. Hedonic scale range 0–100. Different letters show significant differences ($p < 0.05$) according to post hoc test.

Factors	Hedonic Ratings (Mean ± SEM)	F	*p*
Samples		5.58	**<0.0001**
R	42.4 ^{a} ± 1.9		
C30	49.2 ^{b} ± 1.6		
P30	49.8 ^{b} ± 1.5		
P15	51.5 ^{bc} ± 1.6		
C	53.0 ^{bc} ± 1.9		
C15	55.2 ^{c} ± 1.6		
P	56.0 ^{c} ± 2.3		
Gender		5.25	**0.02**
Females	49.3 ^{a} ± 0.9		
Males	52.7 ^{b} ± 1.1		
Age		5.95	**0.01**
≤26 years old	52.8 ^{a} ± 0.9		
>27 years old	49.2 ^{b} ± 1.0		

R = snacks from 100% rice; C = snacks from 100% chickpea; P = snacks from 100% green pea; C15 = snacks from 85% rice + 15% chickpea bran; C30 = snacks from 70% rice + 30% chickpea bran; P15 = snacks from 85% rice + 15% green pea bran; P30 = snacks from 70% rice + 30% green pea bran. Significant p-values are reported in bold

A significant gender effect on liking scores was also found, with men providing generally higher scores compared to women. Moreover, younger subjects gave generally higher scores compared to older subjects. The two- and three-way interactions were not significant.

3.3. Sensory Descriptive Evaluation

The frequency table of terms checked by consumers to describe snack samples is reported in Table 3.

Table 3. Frequency counts (%) of check-all-that-apply (CATA) terms used to describe the extruded snacks and results of Cochran's Q test for comparison among the samples.

Sensory Attributes	Samples						
	R	C30	P30	P15	C	C15	P
Appearance							
Dark yellow ***	1 [a]	34 [e]	25 [cde]	12 [abc]	18 [bcd]	9 [ab]	31 [de]
Light yellow ***	58 [c]	13 [a]	12 [a]	31 [b]	40 [b]	37 [b]	12 [a]
Green ***	0 [a]	0 [a]	0 [a]	0 [a]	0 [a]	1 [a]	24 [b]
Odor							
Strong **	0 [a]	2 [ab]	4 [ab]	2 [ab]	6 [ab]	1 [a]	9 [b]
Mild n.s.	32	31	30	27	28	37	27
Toasted ***	2 [a]	20 [b]	19 [b]	17 [b]	10 [ab]	17 [b]	9 [ab]
Rice ***	16 [c]	7 [abc]	4 [ab]	13 [bc]	1 [a]	14 [bc]	4 [ab]
Legume ***	3 [a]	6 [ab]	11 [abc]	3 [a]	18 [c]	6 [ab]	17 [bc]
Flavor							
Mild ***	39 [c]	28 [bc]	34 [bc]	38 [c]	12 [a]	38 [c]	19 [ab]
Strong ***	1 [a]	9 [a]	2 [a]	2 [a]	31 [b]	0 [a]	24 [b]
Chickpea ***	5 [a]	7 [a]	5 [a]	3 [a]	31 [b]	9 [a]	13 [a]
Rice ***	33 [c]	12 [ab]	24 [bc]	27 [bc]	5 [a]	34 [c]	5 [a]
Pea ***	0 [a]	5 [a]	2 [a]	3 [a]	10 [a]	0 [a]	44 [b]
Spicy ***	2 [a]	6 [a]	5 [a]	7 [a]	22 [b]	1 [a]	7 [a]
Whole-wheat ***	2 [a]	40 [bc]	46 [c]	27 [b]	3 [a]	39 [bc]	4 [a]
Taste							
Bitter n.s.	3	6	4	2	8	1	8
Salty n.s.	8	6	10	8	13	8	13
Sweet ***	10 [ab]	27 [c]	7 [a]	21 [bc]	8 [a]	6 [a]	12 [ab]
Texture							
Crumbly ***	26 [ab]	48 [c]	34 [bc]	46 [c]	16 [a]	43 [c]	48 [c]
Sticky ***	41 [b]	15 [a]	41 [b]	32 [b]	3 [a]	37 [b]	6 [a]
Hard ***	54 [b]	9 [a]	13 [a]	10 [a]	62 [b]	15 [a]	14 [a]
Porous ***	39 [b]	37 [b]	33 [b]	38 [b]	8 [a]	41 [b]	45 [b]
Dry n.s.	54	44	49	43	47	44	40

R = snacks from 100% rice; C = snacks from 100% chickpea; P = snacks from 100% green pea; C15 = snacks from 85% rice + 15% chickpea bran; C30 = snacks from 70% rice + 30% chickpea bran; P15 = snacks from 85% rice + 15% green pea bran; P30 = snacks from 70% rice + 30% green pea bran. Different letters show significant differences ($p < 0.05$) according to post hoc test. N.s.= not significant; ** $p < 0.01$; *** $p < 0.001$.

Cochran's Q test yielded both discriminating and non-discriminating sensory attributes. Significant differences were found in the frequency of mention for 19 out of 23 terms for the five categories considered, suggesting that consumers perceived differences between samples in terms of their sensory characteristics. The sensory attributes that were not useful in order to discriminate samples were: mild odor, salty taste, bitter taste, and dry. In fact, snacks samples were generally characterized by a mild odor and low salty and bitter tastes.

A bi-plot of the products based on sensory descriptive analysis was obtained by means of a correspondence analysis (CA). The CA performed on the total frequency of participants' counts for each attribute resulted in two dimensions accounting for 79.09% of variance of data. As shown in Figure 1, samples were discriminated according to bran percentages, with all samples containing bran (C15, C30, P15, and P30) positioned in the upper left side of the map well separated from the other samples not containing bran. In the other three quadrants, sample with 100% legumes (C and P) and 100% rice (R) were positioned.

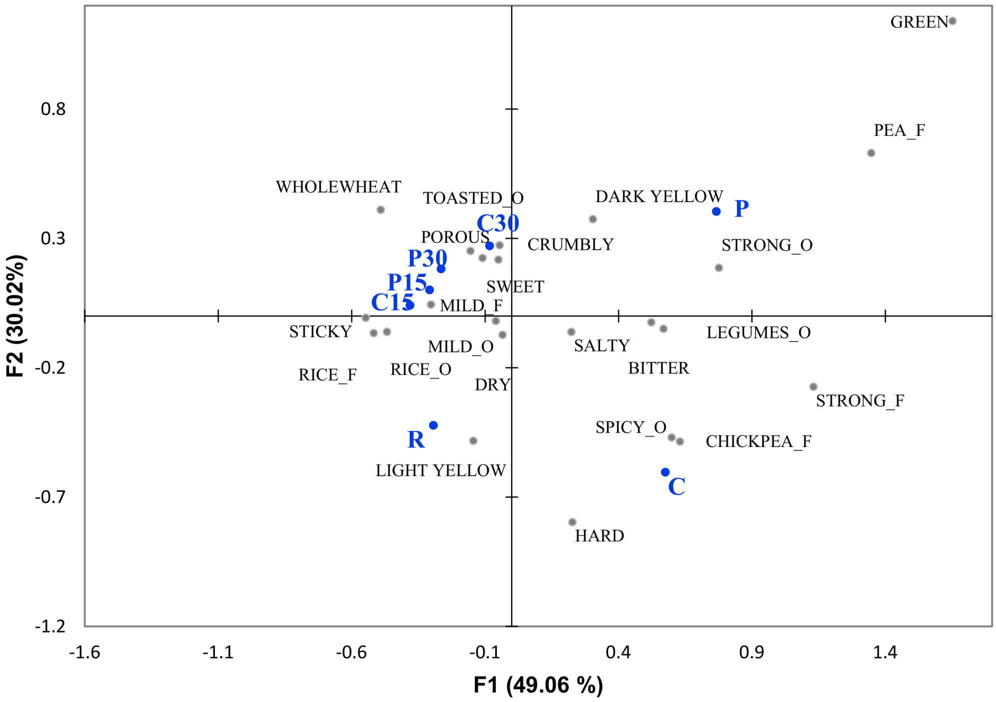

Figure 1. Correspondence analysis from check-all-that-apply data. Snack samples are reported in blue; the sensory attributes in black (O = odor, F = flavor).

The main sensory attributes that significantly ($p < 0.05$) influenced consumer hedonic perception are reported in Figure 2. Penalty analysis results revealed that two sensory attributes played a positive influence (drivers of liking: mild flavor and crumbly), and five attributes had a negative influence (drivers of disliking: light-yellow color, hard, dry, and sticky).

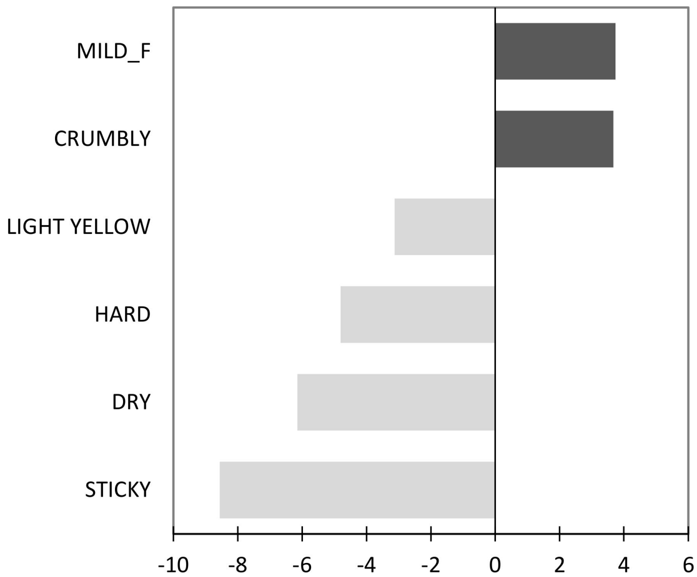

Figure 2. Penalty-lift analysis of sensory attributes across all snack samples. Only attributes that resulted in significant increase or decrease in overall liking are presented. (F = flavor).

Looking to Pearson's correlation coefficient in Table 4, significant correlation was found between texture results obtained by instrumental measurement and sensory data. In particular, positive correlations (p = 0.07) were highlighted between hardness (N) and "hard" attribute, while significant negative correlations were found between hardness (N) and crumbly, porous attributes.

Table 4. Pearson correlation coefficients among texture attribute perception and hardness measured by instrumental analysis (N).

	Hardness (N)	Crumbly	Hard	Porous	Sticky	Dry
Hardness (N)	1					
Crumbly	−0.87 *	1				
Hard	0.71 (*)	−0.92 **	1			
Porous	−0.96 **	0.79 *	−0.67	1		
Sticky	−0.20	0.04	−0.18	0.42	1	
Dry	0.39	−0.71 (*)	0.64	−0.26	0.53	1

(*) $p < 0.10$; * $p < 0.05$; ** $p < 0.01$.

3.4. Food Neophobia

Satisfactory internal consistency of food neophobia scale, as calculated by Cronbach's alpha test (Cronbach's alpha = 0.92), was observed among items. The mean food neophobia value of subjects involved was 23.4 ± 12.5. No significant differences in neophobic traits could be attributed to gender and age ($F_{(1,68)}$ = 0.44, p = 0.51; $F_{(1,68)}$ = 1.22, p = 0.27, respectively). A significant effect of food neophobia on liking scores was found ($F_{(2420)}$ = 3.46, p = 0.03). As reported in Figure 3, neophilic and neutral subjects gave generally significant higher liking scores (53.2 ± 1.6; 51.5 ± 0.9, respectively) compared with neophobic subjects (46.8 ± 1.9).

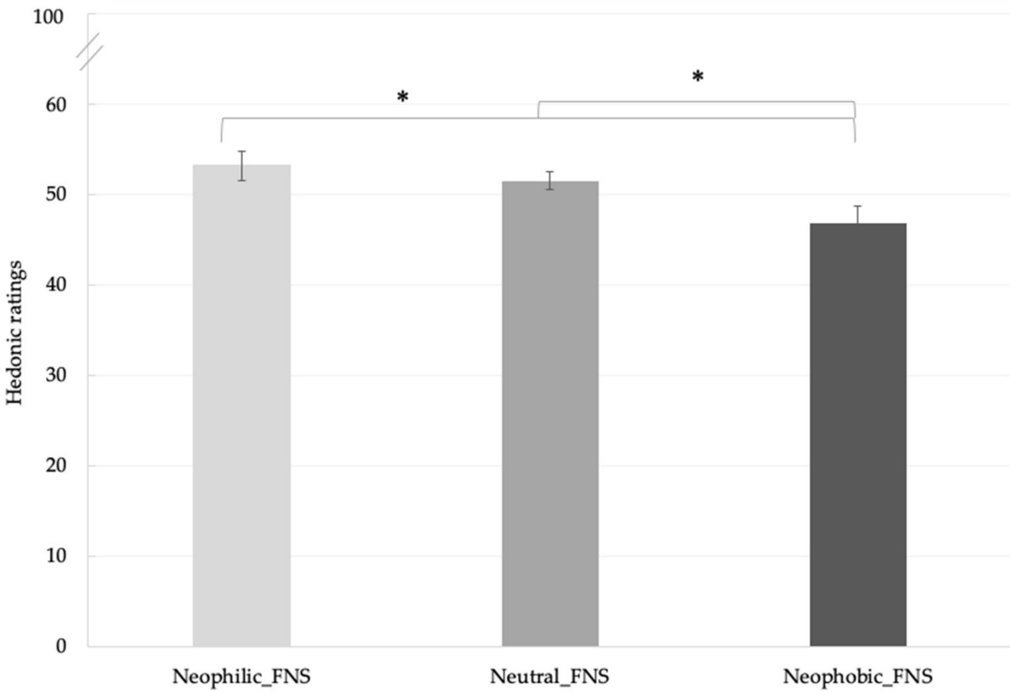

Figure 3. Mean liking scores ± SEM according to food neophobia levels. * $p < 0.05$. FNS = Food Neophobia Scale.

The food neophobia level × gender interaction was also significant ($F_{(2420)} = 4.58$, $p = 0.01$). As reported in Figure 4, no significant differences were found in hedonic scores according to gender in neophilic subjects (women: 55.1 ± 2.0; men 51.3 ± 2.5), while significant higher scores were provided by men with neutral food neophobia level (53.8 ± 1.4) and neophobic FNS (52.2 ± 3.0) compared with women (Neutral_FNS: 49.2 ± 1.3; Neophobic_FNS: 41.1 ± 2.4). No significant food neophobia level × sample effect was found.

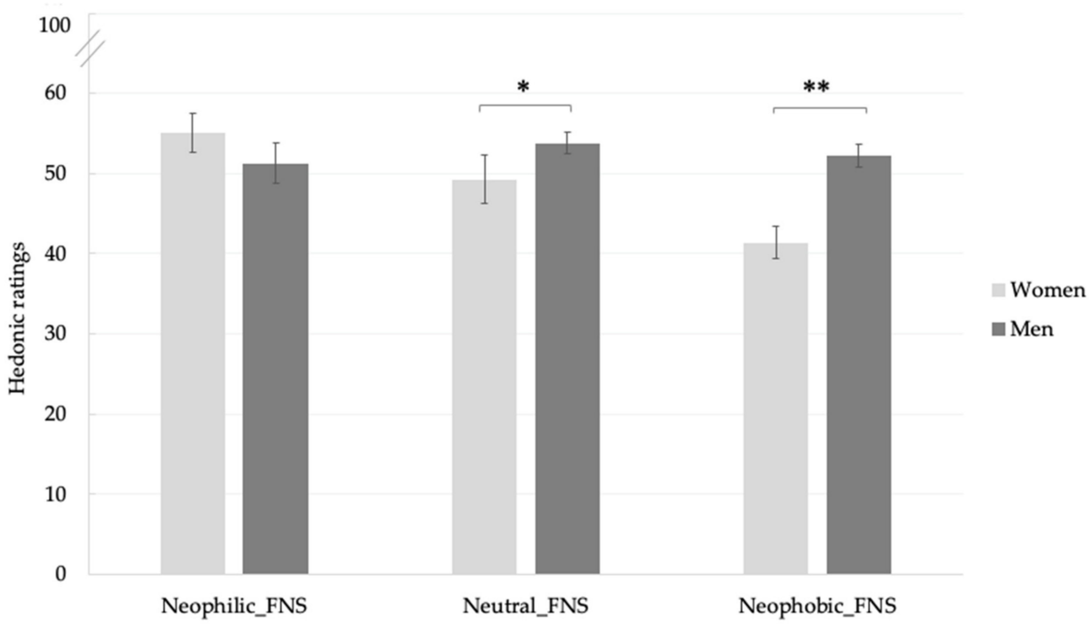

Figure 4. Mean liking scores ± SEM according to food neophobia levels and gender. * $p < 0.05$; ** $p < 0.01$. FNS = Food Neophobia Scale.

3.5. *Food Technology Neophobia*

Cronbach's alpha for the 13 items in the FTNS assessment showed a satisfactory internal consistency (Cronbach's alpha = 0.82). The mean food technology neophobia value was 40.3 ± 1.3. Significant differences ($F_{(1,68)} = 4.42$, $p = 0.03$) in neophobic traits according to age were found, with higher scores provided by subjects >26 years old (42.9 ± 1.7) compared with younger subjects (37.5 ± 1.9). No gender and gender × age effects were found on FTNS scores ($F_{(1,68)} = 0.22$, $p = 0.64$; $F_{(1,68)} = 0.62$, $p = 0.43$, respectively).

As regards the influence of food technology neophobia level on liking scores, no effect was found ($F_{(1420)} = 0.72$, $p = 0.48$)

4. Discussion

In the present study, the use of chickpea and green pea flour and related bran in extruded snack formulations was investigated considering both sensory and texture properties. Sensory attributes influencing consumer preferences were characterized. Moreover, food neophobia and food technology neophobia were considered to define whether these behavioral attitudes could impact on hedonic perception.

Even though the use of legumes as a high-fiber and high-protein ingredient in food formulation has been widely investigated [28], to our knowledge this is one of the first studies that has evaluated consumer responses to extruded snacks containing different percentages of chickpea and green pea bran as sustainable food ingredients.

Samples developed with 100% chickpea and green pea, as well as samples with different percentages of legume bran, obtained significantly higher liking scores compared with the control sample made only with rice. These results suggest that the legume-based formulations developed here have a better market potential compared with the more traditional rice-based snacks. Legume-based snacks represent a promising gluten-free alternative not only for subjects with gluten allergy or intolerance but also for those who follow gluten-restricted diets for health reasons [29]. A gluten-free diet is actually one of the most popular diets, with a greater number of people avoiding gluten for nonmedical reasons than those who are dealing with a gluten-related disorder [30]. Moreover, due to their high-fiber content, the consumption of the legume-based snacks could help consumers reach their daily recommended intake of dietary fiber, which could have a potentially positive health effect. Indeed, despite the proven beneficial effects associated with a fiber-rich diet, the average intake of such components in adults is lower than the recommended daily intake [11]. In this context, food products, such as minimally processed snacks and ready-to-eat foods, with a low fat and salt, high fiber, and high-value proteins could be part of a balanced diet and lead to a consequent good health status [31]. Cereal-based snacks are mainly produced by extrusion-cooking, i.e., a relatively cheap, easy, and versatile technology that allows the production of a variety of textures and shapes that appeal to consumers [32]. The positive effects of extrusion on nutritional traits, including the decrease in antinutritional factors and the increase in soluble dietary fiber and in protein and starch digestibility, have been widely discussed [32–34]. On the other hand, extrusion might cause the loss of heat-labile vitamins and the reduction of the nutritional value of proteins, due to the Maillard reaction between protein and sugars.

The results reported in this paper agreed with the study of Balasubramanian and collaborators (2012) [35] who found that extruded samples made with black gram, green gram, lentil, and peas were well accepted. However, since previous sensory data on extruded snacks with legumes were obtained involving a small number of consumers, and thus not leading to robust and reliable results, the comparison between our hedonic data and previous results is not indicative. Generally, the replacement of cereals with legumes leads to a general trend toward decrease in food acceptability as the percentage of legumes increases [36]; however, it greatly depends on the food matrices used and how the process conditions are adapted with respect to the change in formulation. Indeed, legume flour in some products, such as biscuits and pasta, can enhance food acceptability [37].

It should also be pointed out that encouraging the legume chain represents an important sustainable action that can help to reduce greenhouse gas emissions, break the cycle of pests and diseases with crop diversification in agroecosystems, and contribute to protein production [38]. Moreover, using legume bran as a value-added ingredient for new food formulations reduces the environmental impact of this food chain [39]. Descriptive analyses revealed that some sensory evaluations were more affected by the type of legumes used in snack formulations rather than by the quantity of bran added. This is in line with evidence that changes introduced by the addition of bran are much more significant in wheat flour products than in gluten-free products that do not have such a complex and functional matrix as a gluten network has. To corroborate this hypothesis, it has been reported that fiber addition generally reduces acceptability in terms of consistency, flavor, and appearance, although when initial acceptability is low, as for gluten-free products, fiber addition can improve consumer preference [40–42].

Among sensory attributes, texture was found to be the most interesting. Indeed, sensory descriptive analysis revealed that, besides mild flavor, the other sensory attributes that positively affected overall hedonic responses were related to texture properties. Although texture has been referred to as the "forgotten attribute" due to the little attention it has received for several years [43], it is a complex sensory dimension including tactile, visual, and auditory sensations, playing an important role in defining consumer responses [44]. The present findings indicated that crumbliness of the products was an important driver of consumer preference. Interestingly, three out of four attributes responsible for the negative scores were related to texture. Our results are in line with previous research that found texture to be a critical factor for consumer acceptance of many kinds of food products [45].

In accordance with the sensory data, instrumental data showed chickpea snacks to have the greatest hardness, whereas green pea products were found to be less hard. Sensory and instrumental texture parameters were related to each other with the term "hard" being the most often mentioned when describing the chickpea sample. Differences in chemical composition might account for differences in texture. Specifically, the higher lipid content in chickpea might have favored amylose–lipid complex formation during extrusion, thus limiting starch swelling and gelatinization and accounting for a firmer structure. The addition of different percentages of legume bran led to an increase in hardness values. These results are corroborated by evidence reporting that the integration of fiber- and protein-rich plant by-products generally results in dense, hard extrudates due to several factors. Apart from starch dilution, fiber can interrupt the starch matrix and disrupt the bubble cells, leading to poorer texture (i.e., great hardness) [34]. Moreover, both proteins and fiber may compete with starch for free water, thus decreasing the occurrence of starch gelatinization. Our results suggest that reformulating snacks with 15% of legume bran will have no effect in limiting starch gelatinization, leading to products with textural features similar to those of rice snacks.

The type of bran seems to play a role only at high enrichment levels (i.e., 30%), with green pea bran and chickpea bran impacting the snack texture in an opposite way. Pea bran—being higher in fiber—could absorb water during processing, limiting its availability for starch gelatinization, thus resulting in a more compact structure with high hardness values. Besides differences in the chemical composition and, eventually, in the structural and functional characteristics of fiber, interactions between rice starch and legume fiber might also be considered.

Although the impact of either legume or plant-food processing by-products has been investigated [34,46], a direct comparison of our data with those found by other researchers is difficult. Indeed, snack features depend on several factors including moisture content, temperature, screw speed, die dimension, and screw profile. Adjusting such processing parameters would enable the creation of a wide variety of extruded food products with different structure–texture properties. Specifically, the snack produced in the present study is a co-extruded snack characterized by an extrusion-cooked outer shell that is later filled with either a savory or sweet filling. To the best of our knowledge, there are no studies dealing with the textural features (measured by instrumental analysis) of this kind of product.

Moving on to the behavioral attitudes that could have a role in the acceptance of high-fiber products, food neophobia data indicated that subjects scoring low to medium for neophobia gave higher liking scores to all samples compared to subjects scoring high. Generally, it is widely reported that neophobic subjects prefer less vegetable-based foods, with high fiber amount, compared with neophilic ones [47]. The present data are in line with a previous finding that demonstrated—in a large sample of children from five different European countries—that subjects more prone to try and eat new/unfamiliar food appreciated more experimental samples enriched in fiber [48]. Accordingly, it is well established that food-neophobic subjects are diffident in trying and buying novel foods, while neophilic ones tend to have a wide and varied diet [49]. No food technology neophobia effect was found regarding sample acceptability, while recent findings showed that most adolescents with a low level of food technology neophobia appreciated a flat bread with mushroom powder rich in ß-glucans compared with a control sample containing only wheat flour [50]. These contrasting results could be associated with the consumer sample involved in the study. Indeed, in the present research, people with knowledge about food science and technology were recruited as subjects, and this should be mentioned as a limitation of the study, whereas the adolescents involved in the previous mentioned research were more naïve consumers.

5. Conclusions

Snack products with legume flour and bran represent an interesting food formulation for two reasons. From a nutritional standpoint, these products incorporating milling by-products at a high percentage represent an interesting source of fiber, as well as a valuable food alternative in the worldwide increasing demand for high-fiber and gluten-free products. From a sustainable point of view, the exploitation of milling by-products could reduce the environmental impact of this food category. All legume-based products containing bran in our study were accepted by the consumers involved, even if the hedonic scores were rather low. Crumbliness and mild flavor attributes positively influenced hedonic scores, whereas stickiness, dryness, hardness, and to a lesser extent, visual aspect affected them negatively. As future perspectives, it could be interesting to involve a larger sample population to obtain more representative data about consumer responses to pulse snacks. Moreover, it could be useful to compare the present snacks with a savory or sweet filling and to involve a commercially available product type (e.g., rice-based snack with filling) to better understand the acceptance level of the prototype products

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foods

Article

Consumer Acceptance of Brown and White Rice Varieties

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Abstract: Rice is consumed as a staple food by more than half of the world's population. Due to a higher fibre and micronutrient content, brown rice is more nutritious than white rice, but the consumption of brown rice is significantly lower than that of white rice, primarily due to sensory attributes. Therefore, the present research aimed to identify the sensory attributes which drive liking of Australian-grown brown and white rice varieties. Participants (n = 139) tasted and scored (9-point hedonic scale) their liking (i.e., overall liking, aroma, colour and texture) of brown and white rice types of Jasmine (Kyeema), Low GI (Doongara), and Medium grain rice (Amaroo). In addition, participants scored aroma, colour, hardness, fluffiness, stickiness, and chewiness, on Just About Right Scales. A within-subjects crossover design with randomised order (William's Latin Square design) was used with six repeated samples for liking and Just About Right scales. Penalty analyses were applied to determine the relative influence of perception of sensory attributes on consumer liking of the rice varieties. Across all varieties, white rice was liked more than brown rice due to the texture and colour, and Jasmine rice was preferred over Low GI and Medium Grain. Rice texture (hardness and chewiness) was the most important sensory attribute among all rice varieties and aroma was important for driving of liking between white rice varieties.

Keywords: brown rice; white rice; sensory; consumer acceptance; Just About Right scale; JAR; penalty analysis

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1. Introduction

Rice is consumed as a staple food by more than 4 billion people around the globe [1–3]. Rice is a significant source of dietary nutrients such as carbohydrates, vitamins, and minerals [4,5]. For populations that rely on rice as a staple food, it delivers approximately 21% of the consumed energy and 15% of the consumed protein [6].

Australia produces high quality rice from different varieties, which are categorised as aromatic Thai jasmine origin and non-aromatic rice [7]. Aromatic rice varieties have distinctive popcorn like flavour notes due to the presence of 2-acetyl-1-pyrroline [7–10]. Furthermore, rice can be classified based on the milling process. The milling of the whole grain results in brown rice, and a further removal of bran and germ results in white rice. [11]. Although white rice is more commonly consumed, brown rice is considered healthier due to nutritional components such as lipids, proteins, dietary fibre, and polyphenols [12,13].

The sensory profile of rice is an important driver of consumer acceptance. Sensory attributes have a strong influence on product selection, consumption, and purchase decisions [14,15]. Sensory attributes such as physical appearance (i.e., uniformity, cleanliness, brightness, glossiness and translucency of the rice grain) [16], taste (e.g., sweetness, bitterness), and aroma (e.g., floral notes) are drivers of liking [17] that affect consumer acceptance of rice.

Furthermore, rice texture (i.e., cohesiveness, softness) has been suggested to be of high importance for consumer acceptance of rice. A previous study reported that brown rice texture was less liked compared to white rice and there was variation in liking of the various textures of different brown rice varieties [18]. Along the same lines, Suwansri et al. suggested that an increase in the hardness of rice is associated with a lower consumer acceptability [19]. The importance of texture has also been emphasised by Maleki et al., who suggests that consumers can be segmented based on their preference for different rice textures [20]. In their study, fluffiness was a driver of liking for the majority of consumers (44%), whereas for smaller segments of consumers, liking was mainly driven by flavour attributes.

Within each rice variety, the milling process (e.g., white vs. brown rice) alters the nutrient composition and sensory attributes [21]. For example, brown rice has a higher lipid content compared with white rice. The lipid context affects the sensory profile due to lipid oxidation in the bran layer of brown rice [22]. Lipid oxidation leads to the development of off flavours [23], which potentially impact consumer perception and acceptance. In short, differences in the acceptance of white and brown rice are likely caused by differences in sensory profiles, which are related to differences in nutrient composition [24].

In Australia, 90% of rice is consumed as white rice, whereas only 10% is consumed as brown rice [25], which is similar to global rice consumption patterns [25,26]. Brown rice is considered a healthier option than white rice [27]. To understand what drives the difference in consumption of brown and white rice, it is important to investigate the sensory differences of brown and white rice.

The objective of this study was to identify the drivers of liking of Australian grown brown and white rice varieties. It will provide important information for rice industry and breeding programmes for the development of new rice varieties to meet consumer needs.

2. Participants, Materials, and Methods

2.1. Study Design

A within-subjects crossover design with randomised order (William's Latin Square design) for liking and Just About Right scales with six repeated samples was used in the present study. To determine the required participant sample size, G*power [Version 3.1.9.2, Franz Faul, Universitat Kiel, Kiel, Germany] was used. Based on six measurements (six rice samples) comparisons within subjects with alpha level 0.05, power of 0.8, and a small effect size (f = 0.10), the minimum sample size was 109. To account for potential dropouts, 140 participants from Consumer Analytical Safety Sensory (CASS) Food Research Centre database were recruited. Participants were excluded if they had food allergies, dietary restrictions, and/or were pregnant or lactating. Participants were asked to refrain from eating, drinking, or brushing their teeth one hour prior to testing. The rice consumer study was approved by the research ethics committee Deakin University (HEAG-H 29_2018).

2.2. Measurements

Participants were asked to complete two questionnaires concerning (1) demographics (age, gender, education, and marital status), and (2) rice consumption (type of rice (brown or white), number of times they eat rice daily, weekly or fortnightly, and awareness of brown rice health benefits). To assess the liking and sensory perception of the rice samples before and after tasting the rice samples, participants filled out 9-point hedonic scales (1 = extremely dislike and 9 = extremely like) [28] for overall liking, aroma, colour, and texture. In addition, participants completed Just About Right scales for aroma intensity, colour, hardness, fluffiness, stickiness, and chewiness, similar to previous published research [29]. A Just About Right scale, is a bipolar labelled attribute scale [30], which has an anchored mid-point that corresponded to Just About Right for each attribute [31]. The Just

About Right scales provided the participants with 3 answer options per sensory attribute (1 = not enough, 2 = Just about Right, 3 = too much) [32].

2.3. Materials

Three most commonly consumed Australian rice varieties (Jasmine rice (Kyeema), Low GI (Doongara) and Medium grain (Amaroo) (Table 1)) with both brown and white rice types were sourced from Sunrice (Ricegrowers Ltd., Leeton, Australia) Australia [33].

Table 1. Selected Australian rice varieties.

Rice Varieties	Samples (Types)	Water to Rice Ratio
Jasmine (Kyeema)	Brown rice	2:1
Jasmine (Kyeema)	White rice	1.5:1
Low GI (Doongara)	Brown rice	2:1
Low GI (Doongara)	White rice	1.5:1
Medium grain (Amaroo)	Brown rice	2:1
Medium grain (Amaroo)	White rice	1.5:1

Rice samples were washed 2 to 3 times in cold running water until the water ran clear. Rice samples were cooked in dedicated rice cookers ("Grain Master" HD4514/72_ UM_ US_v1.0, Philips, China), to avoid cross flavour contamination, according to manufacturer's instructions with specific water to rice ratios (Table 1). Rice samples and water quantities were measured by a measuring cup. Rice was cooked at quick rice cooking mode and kept warm at 600 C (as measured by an infrared thermometer Xintest HT-88A; Dongguan Xintai Instrument Co., Guangdong, China) in the rice cooker for no longer than the duration of the sensory test (approximately 45 min).

2.4. Testing Procedure

Sensory testing took place in a sensory laboratory, which consisted of partitioned booths and a high capacity air filtration system, of the CASS Food Research Centre, Deakin University, Melbourne, Australia. On arrival, participants were instructed to carefully read the Plain Language Statement and sign the consent form. Ten participants participated in each one hour session. Rice samples were served to the participants in 30 mL clear plastic medicine cups that were labelled with three digit unique codes. Each cup contained 10 g of rice and participants were instructed to consume at least one teaspoon of rice. The rice samples were randomly presented one at a time directly from the rice cooker at a temperature of 55 ± 3 °C. The participants were instructed to rinse their mouth with filtered water for five seconds and use crackers between tasting the different rice samples.

The test consisted of two parts (i.e., before tasting, after tasting). In the first part, the participants received the following instruction: "do not eat the rice samples, only look, feel (e.g., hold the rice between your fingers) and smell the rice". Next, participants were asked to rate overall liking and their liking for aroma and colour on a 9-point hedonic scale, and fluffiness, stickiness, hardness, and aroma intensity on Just About Right Scales.

In the second part, the participants were instructed to taste the rice samples (one by one) and rate on 9-point hedonic scales, their overall liking, and texture for each rice sample. In addition, participants rated their perceived intensity of flavour, fluffiness, hardness and chewiness on Just About Right scales. There was a one minute break after the tasting of each sample to avoid tasting fatigue of the participants.

The data were collected on computers using Compusense Software Academic Consortium (Compusense, Inc., Guelph, ON, Canada). Gift vouchers (50AUD) were served to each participant on completion of the rice consumer test.

2.5. Statistical Analysis

All rice consumer study data were exported from Compusense Cloud into Microsoft Excel version 1708 (Microsoft Corporation) for data cleaning. For the statistical analysis of liking, the program Stata/IC 15.0 (StataCorp LLC, 4905 Lakeway Drive, College Station, TX 77845, USA) was used. Descriptive statistics (mean, standard deviation and correlation coefficient) were calculated for overall liking scores and all sensory attributes. Box plots and scatter plots were extracted for overall liking and for other sensory attributes. Linear mixed model approach was used to analyse repeated measure Analysis of Variance (ANOVA) data to determine the effect of rice varieties (Jasmine, Low GI and medium grain rice samples) and rice types (brown, white) on overall liking, aroma, colour, and texture linking. This approach accounts for within subject autocorrelation via a random intercept in the model. The combined effect of rice varieties and types of rice was tested through a model that contained the main effects of rice type (brown and white) and varieties (Jasmine, Low GI and Medium Grain) as well as the two-way interaction between varieties, and types of rice. The post-hoc pairwise comparison (Bonferroni adjusted) was conducted to identify the significant difference in sensory attributes among rice varieties and rice types.

The descriptive statistics for Just About Right attributes, overall liking, and penalty analysis ($p < 0.05$) of brown and white rice from the three varieties were conducted in XLSTAT Sensory version 2020.3 (Addinsoft, New York, NY, USA). The penalty was a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together) [32]. Spearman's correlation coefficients were calculated. Mean drop plots were extracted to identify the effect of JAR attributes on overall liking of rice. The mean drops were plotted against the percentage of consumers. For penalty analysis and mean drop plots, 20% consumers were considered as the threshold level for each JAR attribute [30].

3. Results

3.1. Participants

The participants ($n = 140$, female 52%, male 48%) from different age groups participated in the consumer study, one participant was excluded during data cleaning because of incomplete rice tasting session. The participants were rice consumers and mostly thought they were aware of the health benefits of brown rice. The demographics are shown in Table 2.

Table 2. Demographics of the participants for the rice tasting study.

	Demographics	Participants
Age groups	Age 18–30 years	56%
	Age 31–45 years	28%
	Age 46 years and above	16%
Rice consumers	Brown rice	10%
	White rice	37%
	Brown and white rice	53%
Brown rice health benefits_perceived knowledge	Aware enough	67%
	Not aware enough	33%
Education	High school certificate/Diploma	21%
	Bachelor and above	79%

3.2. Liking (9-Point Hedonic Scale) of Brown and White Rice Varieties before Tasting

In the result section, rice variety refers to the different varieties which were tested (i.e., Jasmine white, Jasmine brown, Low GI white, Low GI brown, Medium grain white, and Medium grain brown) and rice type refers to brown and white rice. The results (Table 3) indicate that there was a main effect of rice varieties and their types (i.e., brown vs. white) on overall liking before tasting the rice samples ($p < 0.05$). However, there was no statistically significant interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type. This means that white rice was preferred over brown rice, regardless of the rice variety ($p < 0.05$) (see Figure 1). Pairwise comparisons show that Jasmine white rice was more liked than any of the other rice varieties ($p < 0.05$), while liking of Low

GI white and Medium grain was not statistically significantly different (represented with shared letter "C"). Likewise, no difference was observed between the overall liking of brown rice varieties.

Table 3. Linear mix model (repeated measures) ANOVA table for brown and white rice varieties before tasting.

	Overall Liking		**Aroma Liking**		**Colour Liking**	
	Mean (95% CI)	**Mean (95% CI)**	**Chi-Square (df) *p* Value**	**Mean (95% CI)**	**Chi-Square (df) *p* Value**	
Rice variety						
Jasmine (ref)	6.6 (6.4–6.8)	26.50 (2) $p < 0.0001$	6.7 (6.5–6.9)	53.84 (2) $p \leq 0.0001$	6.6 (6.4, 6.8)	20.08 (2) $p \leq 0.0001$
Low GI	6.2 (6.0–6.4) [1]		6.1 (5.9–6.3) [1]		6.2 (6.1, 6.5) [1]	
Medium Grain	6.3 (6.1–6.5) [1]		6.1 (5.9–6.3) [1]		6.5 (6.3, 6.7)	
Rice type						
Brown (ref)	5.9 (5.6–6.2)	45.50 (1) $p < 0.0001$	6.1 (5.8–6.3)	13.93 (1) $p \leq 0.0002$	5.9 (5.6–6.2)	50.85 (1) $p \leq 0.0001$
White	6.9 (6.7–7.0) [1]		6.5 (6.3–6.7) [1]		7.0 (6.9–7.3) [1]	
Pairwise comparisons of variety and rice type (Bonferroni groups) [2]						
Jasmine White	7.2 (6.9, 7.4)D	1.69 (2) $p = 0.43$	7.0 (6.9, 7.3)D	6.94 (2) $p = 0.03$	7.3 (7.1, 7.5)C	1.21 (2) $p = 0.55$
Low GI White	6.7 (6.5, 6.9)C		6.2 (5.9, 6.4)AB		6.9 (6.7, 7.1)B	
Medium Grain White	6.7 (6.5, 7.0)C		6.3 (6.1, 6.6)AB		7.0 (6.9, 7.2)BC	
Jasmine Brown	6.1 (5.8, 6.4)B		6.4 (6.1, 6.7)B		6.0 (5.7, 6.3)A	
Low GI Brown	5.7 (5.3, 6.0)A		6.0 (5.7, 6.3)AB		6.0 (5.7, 6.3)AB	
Medium Grain Brown	5.9 (5.6, 6.2)AB		5.8 (5.5, 6.1)A		5.8 (5.5, 6.1)A	

[1] Statistically significant ($p < 0.001$) from the reference (ref). [2] rice variety with different letters are statistically significant different ($p < 0.05$).

For aroma liking, there was a significant difference (Table 3) between rice varieties and their types (i.e., brown vs. white) before tasting the rice samples. The differences in mean values of Low GI and Medium Grain were −0.6, 95% CI (−0.8, −0.5) and −0.7, 95% CI (−0.9, −0.5), respectively, when compared with Jasmine rice (a reference sample). The interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type was also statistically significant, meaning that the aroma of white rice was preferred over brown rice, regardless of the rice variety ($p < 0.05$) (see Figure 1). Pairwise comparisons show that the aroma of Jasmine white rice was more liked than any of the other rice varieties (i.e., Jasmine white rice has the highest mean 7.0, 95% CI (6.9, 7.3) and Medium Grain brown has lowest mean 5.8, 95% CI (5.5, 6.1)). On the other hand, liking of Low GI white and Medium grain was not statistically significantly different (represented with shared letter "AB"). Similarly, no difference was observed between the aroma liking of Low GI and Medium Grain brown rice varieties.

The rice varieties and their types (i.e., brown vs. white) were significantly associated with colour liking before tasting the rice samples. The differences in mean values of Low GI and Medium Grain for colour liking were −0.4, 95% CI (−0.5, −0.2) and −0.1, 95% CI (−0.3, −0.04) respectively when compared with Jasmine rice (a reference sample). However, the interaction between rice variety (i.e., Jasmine, Low GI, Medium Grain) and rice type was not statistically significant. That is, the colour of white rice was liked more than the colour of brown rice, regardless of the rice variety (see Figure 1). Pairwise comparisons show that there was no difference in colour liking of Jasmine white and Medium Grain white rice (represented with shared letter "C"). Likewise, no difference was observed in colour liking of Jasmine brown, Low GI brown and Medium Grain brown (represented with shared letter "A").

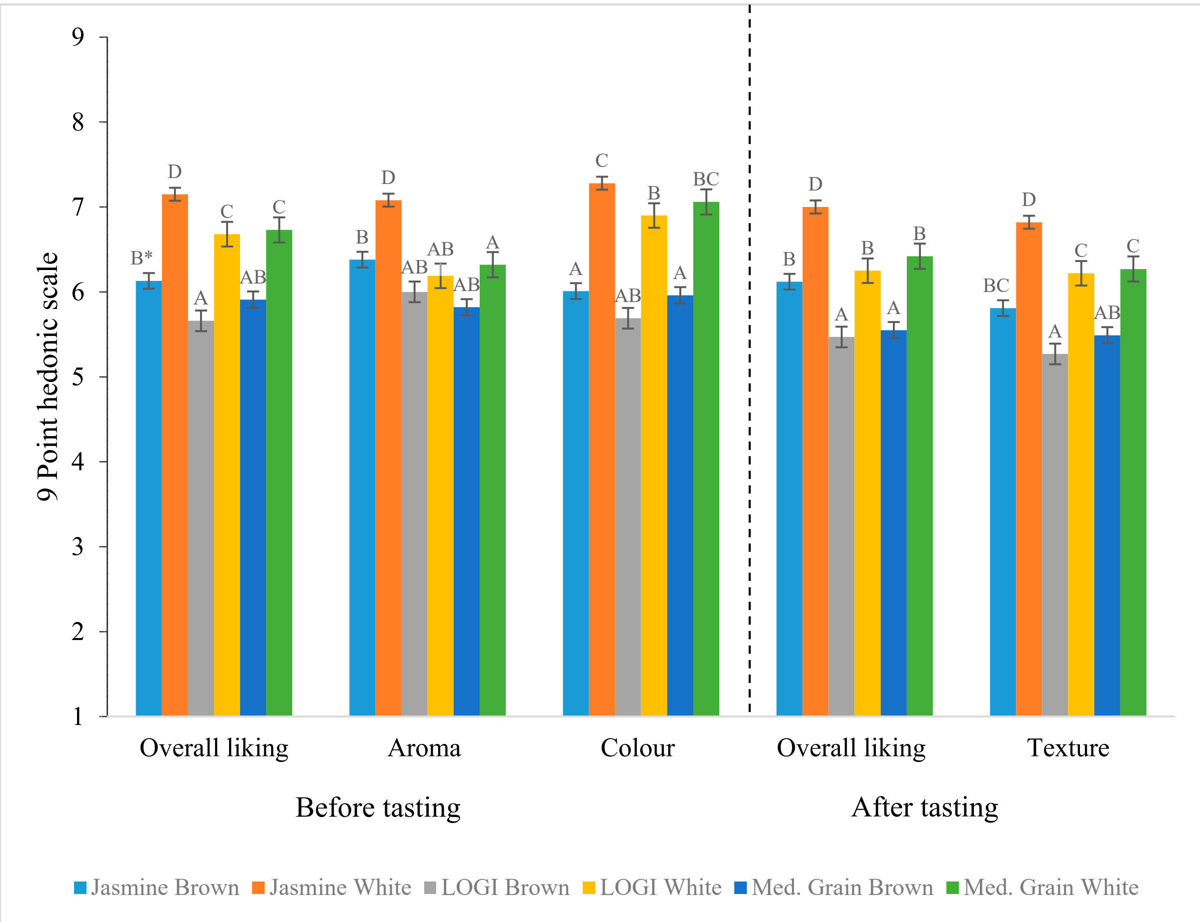

Figure 1. Mean liking (9-point hedonic scale, 1 = extremely disliked to 9 = extremely liked) of sensory attributes for rice varieties. * Different letters, shown as A–D, within attribute are statistically significantly different ($p < 0.05$).

Liking (9-Point Hedonic Scale) of Brown and White Rice Varieties after Tasting

The results show rice variety and rice type (i.e., brown and white) after tasting significantly affect liking (see Table 4). Jasmine rice was liked more than Low GI and Medium Grain rice. For all rice varieties, white rice was preferred over brown rice (mean difference = 0.8, 95% CI (0.6, 1.1). The significant interaction between rice varieties and rice types (i.e., brown and white) shows that Jasmine white rice was liked more than any of the other brown and white rice varieties (see Figure 1). The pairwise comparisons show that no difference was observed between Low GI white rice, Medium Grain white rice and Jasmine brown rice in overall liking after tasting.

There was a significant correlation between rice variety and rice type on texture liking ($p < 0.05$) after tasting rice samples (Table 4). This means that the texture of Jasmine rice was liked more than the texture of Low GI and Medium Grain. The mean liking of Low GI and Medium Grain rice were reduced by −0.6, 95% CI (−0.8, −0.4) and −0.4, 95% CI (−0.7, −0.2), respectively, when compared with Jasmine rice (a reference sample). Likewise, the texture of white rice was preferred over brown rice, regardless of rice varieties (mean difference = 0.91, 95% CI (0.6, 1.2). The significant interaction between rice varieties and rice types also indicates that the texture of Jasmine white rice was liked more than the texture of any of the other brown and white rice varieties (see Figure 1). The pairwise comparisons show that no difference was observed between Low GI white rice, Medium Grain white rice, and Jasmine brown rice in texture liking after tasting. However, the texture liking of brown rice varieties was not statistically different.

Table 4. Mix model (repeated measures) ANOVA table for brown and white rice varieties after tasting.

	Overall Liking	**Texture Liking**	
	Mean (95% CI)	**Mean (95% CI)**	**Chi-Square (df)** ***p*** **Value**
Rice variety			
Jasmine (ref)	6.5 (6.3, 6.8)	6.3 (6.1, 6.6)	25.67(2) $p \leq 0.0001$
Low GI	5.9 (5.6, 6.1) [1]	5.7 (5.5, 6.1) [1]	
Medium Grain	6.0 (5.8, 6.2) [1]	5.9 (5.6, 6.1) [1]	
Rice type			
Brown (ref)	5.7 (5.4, 6.0)	5.5 (5.2, 5.8)	35.25(1) $p \leq 0.0001$
White	6.6 (6.4, 6.8) [1]	6.4 (6.2, 6.6) [1]	
Pairwise comparisons of variety and rice type (Bonferroni groups) [2]			
Jasmine White	7.0 (6.7, 7.3)D	6.8 (6.5, 7.1)D	1.11(2) $p = 0.57$
Low GI White	6.3 (6.0, 6.5)B	6.2 (5.9, 6.5)C	
Medium Grain White	6.4 (6.2, 6.7)B	6.3 (6.0, 6.6)C	
Jasmin Brown	6.1 (5.8, 6.4)B	5.8 (5.5, 6.1)BC	
Low GI Brown	5.5 (5.2, 5.8)A	5.3 (5.0, 5.6)A	
Medium Grain Brown	5.5 (5.2, 5.9)A	5.5 (5.1, 5.8)AB	

[1] statistically significant ($p < 0.001$) from the reference (ref). [2] rice variety with different letters are statistically significant different ($p < 0.05$).

3.3. Just About Right Attributes and Penalty Analysis

3.3.1. Penalty Analysis of Jasmine Brown and White Rice before Tasting

Penalty analysis shown in Table 5 indicates that the overall penalty is significant ($p < 0.05$) for all attributes of Jasmine brown rice. This means that the rice was not perceived at optimum level for all attributes tested. The Jasmine brown rice was rated as being too low in aroma, too dark in colour, too hard in texture, too low in fluffiness, and/or too low in stickiness. For Jasmine white rice, the overall penalty (Table 5) was not significant for any of the attributes. This means that across all tested attributes, a deviation from JAR did not have a significant influence on overall liking. The mean drop plot against consumers for each attribute of Jasmine brown and white rice is shown in Figure 2A,B, which visually represents the results of the penalty analysis.

Table 5. The Penalty analysis and JAR variables (before tasting) for Jasmine brown and white rice.

Rice	Attribute	Sensory Test	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Jasmine Brown	Aroma	Smell	0.12	Too low	17.99	5.28	1.25	
				JAR	53.24	6.53		0.85 **
				Too high	28.78	5.93	0.60	
	Colour	Visual	−0.35	Too light	10.79	5.87	1.0	
				JAR	51.08	6.87		1.52 *
				Too dark	38.13	5.21	1.67	
	Hardness	Handling	−0.22	Not hard enough	13.67	6.0	0.62	
				JAR	52.52	6.62		1.03 *
				Too hard	33.81	5.43	1.19	
	Fluffiness	Handling	0.16	Too low	35.97	5.70	0.81	
				JAR	48.20	6.50		0.73 **
				Too much	15.83	5.96	0.55	
	Stickiness	Handling	0.01	Too low	13.67	5.0	1.57	
				JAR	49.64	6.57		0.87 **
				Too much	36.69	5.96	0.60	
Jasmine White	Aroma	Smell	0.02	Too low	20.86	7.24	−0.05	
				JAR	48.92	7.19		0.08
				Too high	30.22	7.02	0.17	
	Colour	Visual	−0.09	Too light	17.27	7.25	−0.06	
				JAR	70.50	7.19		0.15
				Too dark	12.23	6.77	0.43	
	Hardness	Handling	−0.12	Not hard enough	28.06	7.41	−0.27	
				JAR	61.87	7.14		−0.30
				Too hard	10.07	6.50	0.64	
	Fluffiness	Handling	0.13	Too low	17.99	7.08	−0.05	
				JAR	65.47	7.03		−0.34
				Too much	16.55	7.70	−0.66	
	Stickiness	Handling	−0.04	Too low	2.88	8.0	−0.72	
				JAR	41.01	7.28		0.22
				Too much	56.12	7.01	0.27	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level α = 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples [34]. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

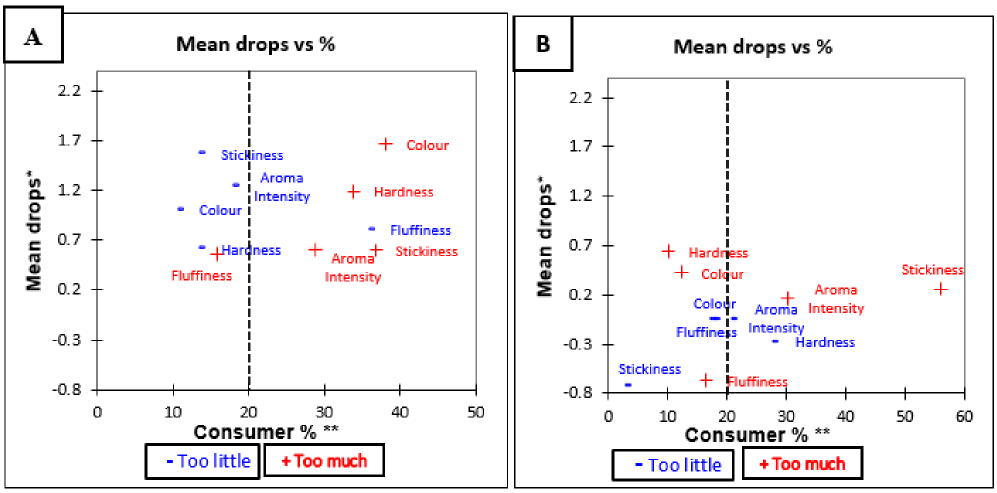

Figure 2. Mean drop plots for Jasmine rice variety before tasting (**A**) Jasmine Brown, and (**B**) Jasmine White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

3.3.2. Penalty Analysis of Low GI Brown and White Rice before Tasting

The overall penalty analysis for Low GI brown rice was significant ($p < 0.05$) for all attributes except "hardness" ($p = 0.18$) (see Table 6). This means that the hardness of Low GI brown rice was the only attribute which was rated as being optimal. The penalty analysis (Table 6) showed that the overall penalty for Low GI white rice was significant for fluffiness ($p < 0.05$). This means that the rating of liking was significantly negatively influenced when participant rated Low GI white as low in fluffiness. Specific changes in liking due to suboptimal attributes are shown in Figure 3A,B which visually represents the penalty analysis of Low GI rice.

Table 6. The Penalty analysis and JAR variables (before tasting) for Low GI brown and white rice.

Rice	Variable	Sensory Test	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Low GI Brown	Aroma	Smell	−0.15	Too low	24.46	5.79	0.22	
				JAR	43.88	6.02		0.63 **
				Too high	31.65	5.07	0.95	
	Colour	Visual	−0.38	Too light	15.83	5.68	0.87	
				JAR	46.04	6.55		1.64 *
				Too dark	38.13	4.59	1.96	
	Hardness	Handling	−0.18	Not hard enough	12.23	5.94	−0.04	
				JAR	44.60	5.90		0.44
				Too hard	43.17	5.33	0.57	
	Fluffiness	Handling	0.14	Too low	41.01	5.33	0.68	
				JAR	43.88	6.01		0.63 **
				Too much	15.11	5.52	0.49	
	Stickiness	Handling	0.16	Too low	28.06	4.90	1.22	
				JAR	48.92	6.12		0.89 **
				Too much	23.02	5.63	0.49	
Low GI White	Aroma	Smell	0.06	Too low	31.65	6.66	−0.09	
				JAR	46.76	6.57		−0.22
				Too high	21.58	6.97	−0.40	
	Colour	Visual	0.08	Too light	14.39	6.25	0.53	
				JAR	73.38	6.78		0.34
				Too dark	12.23	6.65	0.13	
	Hardness	Handling	0.02	Not hard enough	12.95	6.78	−0.11	
				JAR	61.15	6.67		−0.03
				Too hard	25.90	6.67	0.004	
	Fluffiness	Handling	0.17	Too low	18.71	6.0	0.88	
				JAR	65.47	6.88		0.57 **
				Too much	15.83	6.68	0.20	
	Stickiness	Handling	0.06	Too low	19.42	6.37	0.41	
				JAR	61.15	6.78		0.24
				Too much	19.42	6.70	0.07	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level $\alpha = 0.05$). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

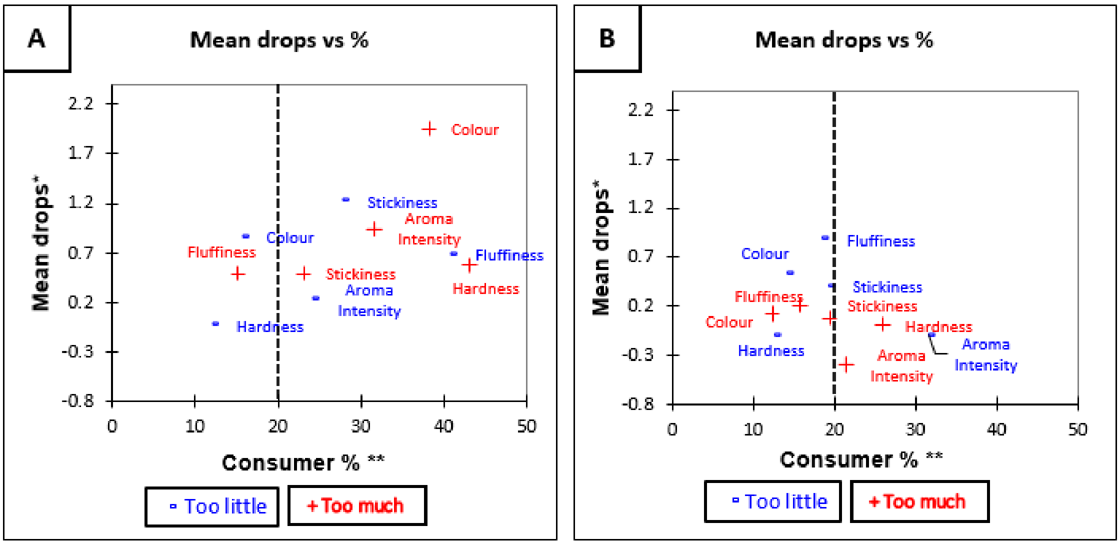

Figure 3. Mean drop plots for Low GI rice variety before tasting (**A**) Low GI Brown and (**B**) Low GI White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

3.3.3. Penalty Analysis of Medium Grain Brown and White Rice before Tasting

The results of the penalty analysis (Table 7) for Medium Grain brown rice show that the overall liking was significantly ($p < 0.05$) influenced when the majority of the participants considered that aroma, colour, and hardness were not at optimum level, the attributes were too high in aroma, too dark in colour, and too hard in texture. Similarly, the overall penalty (Table 7) for Medium Grain white rice was significant for fluffiness ($p = 0.02$). That means that for fluffiness, the deviations from the Just about right level have a significant impact on overall liking. The impact on liking of each attribute is shown in Figure 4A,B.

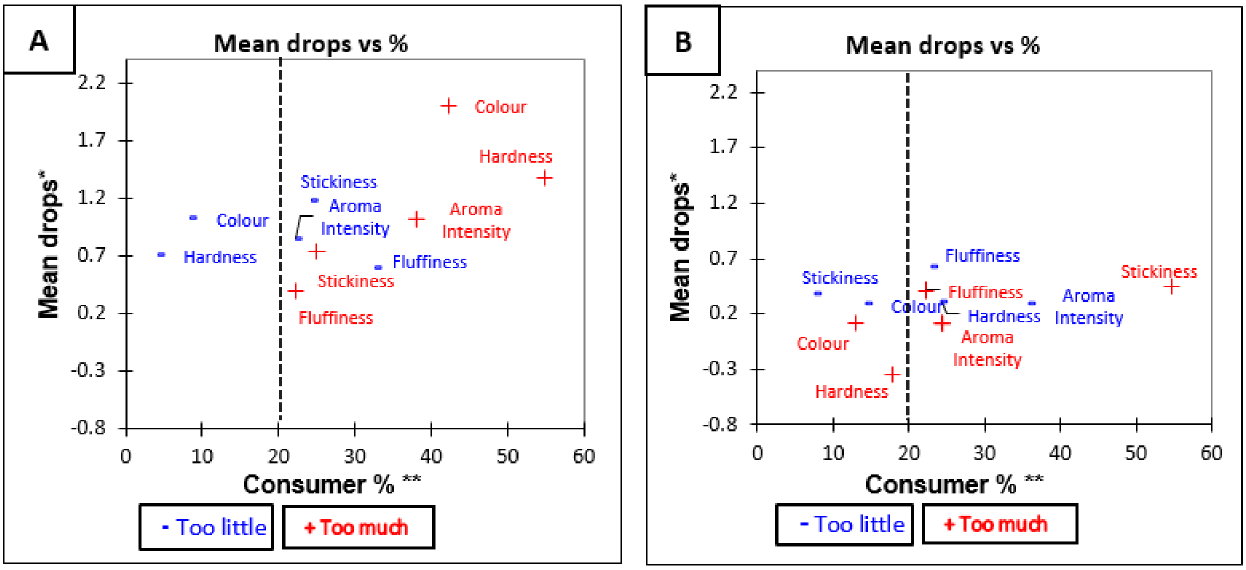

Figure 4. Mean drop plots for Medium Grain rice variety before tasting (**A**) Medium Grain Brown and (**B**) Medium Grain White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

Table 7. The Penalty analysis and JAR variables (before tasting) for Medium grain brown and Medium grain white rice.

Rice	Variable	Sensory Test	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Medium Grain Brown	Aroma	Smell	−0.11	Too low	22.30	5.65	0.85	
				JAR	39.57	6.49		0.96 **
				Too high	38.13	5.47	1.02	
	Colour	Visual	−0.44	Too light	8.63	5.83	1.02	
				JAR	48.92	6.85		1.84 *
				Too dark	42.45	4.85	2.01	
	Hardness	Handling	−0.39	Not hard enough	4.32	6.0	0.70	
				JAR	41.01	6.70		1.34 *
				Too hard	54.68	5.32	1.39	
	Fluffiness	Handling	0.12	Too low	33.09	5.61	0.59	
				JAR	44.60	6.19		0.51
				Too much	22.30	5.81	0.39	
	Stickiness	Handling	0.07	Too low	24.46	5.21	1.18	
				JAR	50.36	6.39		0.95 *
				Too much	25.18	5.66	0.73	
Medium Grain White	Aroma	Smell	0.04	Too low	35.97	6.58	0.28	
				JAR	39.57	6.86		0.21
				Too high	24.46	6.74	0.12	
	Colour	Visual	0.05	Too light	14.39	6.50	0.28	
				JAR	72.66	6.78		0.20
				Too dark	12.95	6.67	0.12	
	Hardness	Handling	0.14	Not hard enough	24.46	6.44	0.30	
				JAR	57.55	6.74		0.26
				Too hard	17.99	7.08	−0.34	
	Fluffiness	Handling	0.08	Too low	23.02	6.34	0.62	
				JAR	54.68	6.96		0.52 **
				Too much	22.30	6.55	0.41	
	Stickiness	Handling	−0.13	Too low	7.91	6.64	0.36	
				JAR	37.41	7.0		0.44
				Too much	54.68	6.55	0.45	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level $\alpha = 0.05$). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

3.3.4. Penalty Analysis of Jasmine Brown and Jasmine White Rice after Tasting

Penalty analysis (Table 8) indicate that the overall liking was significantly ($p < 0.05$) influenced when participants rated the Jasmine brown rice as not being ideal for flavour, fluffiness, hardness, or chewiness. For Jasmine white rice, the overall penalty (Table 8) was only significant for hardness and not significant for all other attributes after rice tasting. This means that most of the participants considered Jasmine white rice "not hard enough" in texture. The mean drop plot against participants for each attribute by tasting of Jasmine brown and Jasmine white rice is shown in Figure 5A,B.

Table 8. The Penalty analysis and JAR variables (after tasting) for Jasmine brown and Jasmine white rice.

Rice	Variable	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Jasmine Brown	Flavour	0.02	Too low	25.90	5.83	0.62	
			JAR	53.96	6.45		0.72 **
			Too high	20.14	5.61	0.85	
	Fluffiness	0.27	Too low	30.22	5.17	1.45	
			JAR	56.83	6.62		1.15 *
			Too much	12.95	6.17	0.45	
	Hardness	−0.26	Not hard enough	8.63	5.25	1.59	
			JAR	54.68	6.84		1.59 *
			Too hard	36.69	5.26	1.59	
	Chewiness	−0.20	Too low	8.63	5.67	1.06	
			JAR	46.76	6.73		1.13 *
			Too much	44.60	5.58	1.14	
Jasmine White	Flavour	0.20	Too low	30.22	6.69	0.42	
			JAR	52.52	7.11		0.23
			Too high	17.27	7.21	−0.10	
	Fluffiness	0.25	Too low	21.58	6.13	1.04	
			JAR	58.99	7.17		0.42
			Too much	19.42	7.44	−0.27	
	Hardness	0.27	Not hard enough	24.46	6.00	1.37	
			JAR	69.06	7.37		1.18 *
			Too hard	6.47	6.89	0.48	
	Chewiness	−0.03	Too low	18.71	6.81	0.34	
			JAR	58.99	7.15		0.36
			Too much	22.30	6.77	0.37	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level α = 0.05). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice-versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

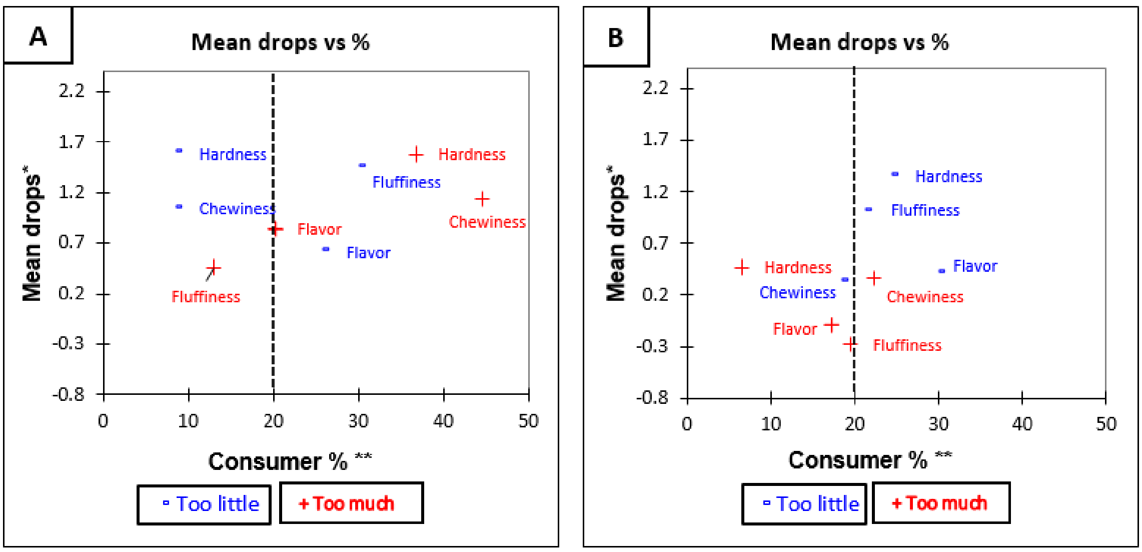

Figure 5. Mean drop plots for Jasmine rice variety after tasting (**A**) Jasmine Brown and (**B**) Jasmine White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

3.3.5. Penalty Analysis of Low GI Brown and Low GI White Rice after Tasting

The penalty analysis (Table 9) of Low GI brown rice by tasting shows that the overall liking was significantly ($p < 0.05$) influenced when most of the participants judged that flavour, hardness, and fluffiness were not optimal in Low GI brown rice. For Low GI white rice, the overall penalty (Table 9) was significant ($p < 0.05$) for all attributes tested. This means that the overall liking was significantly influenced, when the majority of the participants rated Low GI white rice as being not ideal for flavour, fluffiness, hardness, or chewiness. The influence on liking of sensory attributes is shown in Figure 6A,B.

3.3.6. Penalty Analysis of Medium Grain Brown and White Rice after Tasting

For Medium Grain brown rice, the penalty analysis (Table 10) showed that the overall liking of Medium Grain brown rice was significantly ($p < 0.05$) influenced when participant rated flavour, fluffiness, and hardness were not at optimum level. Similarly, the overall penalty of Medium Grain white rice was significant for flavour intensity, fluffiness, and chewiness. This means that significant participants perceived Medium Grain white as too low in flavour and fluffiness, and too high in chewiness. The mean drop plots against participants for each attribute of Medium Grain brown rice shown in Figure 7A,B.

Table 9. The Penalty analysis and JAR variables (after tasting) for Low GI brown and Low GI white rice.

Rice	Variable	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Low GI Brown	Flavour	−0.16	Too low	33.81	5.55	0.50	
			JAR	39.57	6.06		0.96 **
			Too high	26.62	4.51	1.54	
	Fluffiness	0.19	Too low	35.97	5.0	0.83	
			JAR	51.80	5.83		0.74 **
			Too much	12.23	5.35	0.48	
	Hardness	−0.33	Not hard enough	5.76	5.38	0.81	
			JAR	35.25	6.18		1.10 *
			Too hard	58.99	5.06	1.12	
	Chewiness	0.02	Too low	12.95	5.39	0.01	
			JAR	34.53	5.40		−0.12
			Too much	52.52	5.55	−0.15	
Low GI White	Flavour	0.21	Too low	44.60	5.82	0.92	
			JAR	44.60	6.74		0.89 *
			Too high	10.79	6.0	0.74	
	Fluffiness	0.12	Too low	20.86	5.31	1.39	
			JAR	64.03	6.70		1.24 *
			Too much	15.11	5.67	1.03	
	Hardness	−0.11	Not hard enough	15.83	5.68	0.97	
			JAR	60.43	6.66		1.02 *
			Too hard	23.74	5.61	1.05	
	Chewiness	0.04	Too low	23.02	5.94	0.56	
			JAR	59.71	6.49		0.60 **
			Too much	17.27	5.83	0.66	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level $\alpha = 0.05$). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

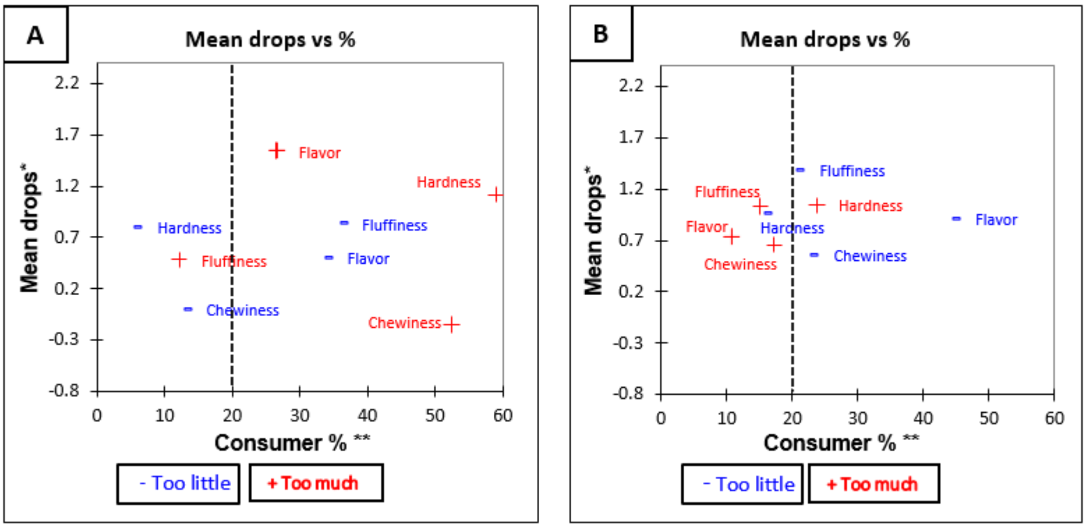

Figure 6. Mean drop plots for Low GI rice variety after tasting (**A**) Low GI Brown and (**B**) Low GI White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

Table 10. The Penalty analysis and JAR variables (after tasting) for Medium Grain brown and white rice.

Rice	Variable	Correlation Coefficient [a]	Level	Selection% [b]	Mean [c]	Mean Drop [d]	Penalty [e]
Medium Grain Brown	Flavour	−0.11	Too low	25.18	5.23	1.02	
			JAR	46.76	6.25		1.31 *
			Too high	28.06	4.67	1.58	
	Fluffiness	0.34	Too low	33.09	4.35	1.89	
			JAR	53.24	6.24		1.49 *
			Too much	13.67	5.74	0.50	
	Hardness	−0.52	Not hard enough	5.04	6.71	0.05	
			JAR	38.85	6.76		1.98 *
			Too hard	56.12	4.60	2.16	
	Chewiness	−0.07	Too low	12.95	6.06	−0.62	
			JAR	34.53	5.44		−0.17
			Too much	52.52	5.49	−0.05	
Medium Grain White	Flavour	0.22	Too low	48.20	6.06	0.75	
			JAR	41.01	6.81		0.65 **
			Too high	10.79	6.60	0.21	
	Fluffiness	0.13	Too low	23.02	5.75	0.99	
			JAR	58.99	6.74		0.78 **
			Too much	17.99	6.24	0.50	
	Hardness	0.11	Not hard enough	5.04	6.29	−0.03	
			JAR	38.85	6.26		−0.27
			Too hard	56.12	6.55	−0.29	
	Chewiness	−0.07	Too low	16.55	6.17	0.53	
			JAR	53.96	6.71		0.61 **
			Too much	29.50	6.05	0.66	

[a] The impact of JAR variables for Jasmine brown and white rice on the overall liking (Spearman's correlation coefficient with a significance level $\alpha = 0.05$). The correlation coefficients (between JAR attributes and overall liking) show how much JAR attributes have impacted ("low" or "high") on overall liking for rice samples. When the correlation is positive, the "too little" has a bigger impact than the "too much", and vice versa for the negative correlations. If correlation is "0" for a JAR attribute, then that attribute would have a strong impact on overall liking [35]. [b] Selection % is the percentage of consumers who rate the rice as too low, JAR, or too high on a given attribute. [c] Mean is the mean overall liking (9-point hedonic scale) of consumers who rated a given attribute as too low, JAR, or too high. [d] Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. [e] Penalty is a weighted difference between means (mean liking of JAR category minus the mean of liking for other two levels (too low and too high) taken together). * $p \leq 0.001$, ** $p \leq 0.05$.

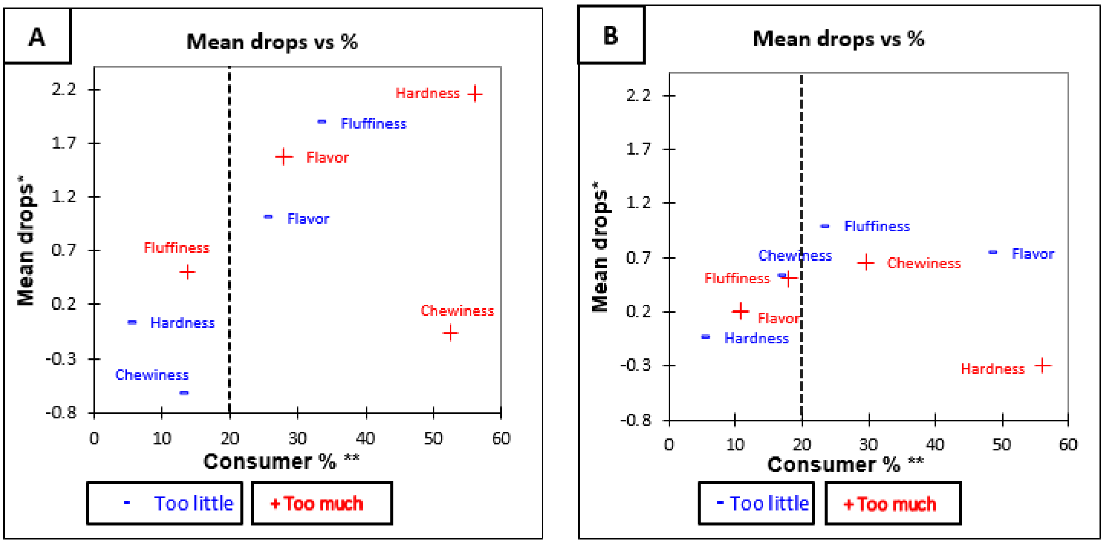

Figure 7. Mean drop plots for Medium Grain rice variety after tasting (**A**) Medium Grain Brown and (**B**) Medium Grain White. * Mean drop is the decrease in liking compared to the mean liking of those who rated the attribute as JAR. ** Consumer % are the consumers which judged an attribute as not ideal (Just About Right). The attributes with large percentages of consumers and penalties are in top right quadrant of the plot, which illustrates the critical points of the product [34].

4. Discussion

This study aimed to identify the consumer liking, sensory attributes, and drivers of liking of brown and white rice varieties. The results suggest that, overall, participants liked Jasmine rice varieties more than Low GI and Medium grain rice varieties. This was also reflected in a higher liking of the aroma, colour, and texture of Jasmine rice, compared to Low GI and Medium grain rice varieties. However, white rice was preferred over brown rice regardless of rice varieties.

The present study suggests, in line with previous studies [19,24,36,37], that texture, colour, and aroma are important drivers of consumer liking for rice. However, these drivers of liking do not seem to equally explain the differences in liking of white and brown rice. Indeed, differences in aroma mainly explain the difference in liking for white rice varieties and the aroma of Jasmine white rice was liked more than any of the other rice varieties. The most liked white rice (Jasmine rice), contains more of the compound 2-acetyle-1-pyrroline [10] which is known to elicit a distinctive popcorn/pandan aroma [3,38–40] that has a strong impact on consumer acceptance of rice [41]. On the other hand, the other white rice (non-fragrant) varieties contain less 2AP [42–44] that may have an impact on liking of non-fragrant white rice varieties. This is also reflected in the sensory data of the present study that aroma of Jasmine white rice is an important sensory attribute in predicting consumer liking and acceptance of white rice varieties. Therefore, the aroma of Jasmine white rice was preferred over all other white and brown rice varieties. In contrast to aroma being able to explain liking differences for white rice varieties, aroma does not fully explain differences in liking for brown rice.

Differences between brown rice varieties can be explained by texture (hardness and chewiness). This means that brown rice is considered as too hard and chewy in texture, which is driving the difference between brown rice varieties, whereas Jasmine brown rice was preferred over Low GI and Medium grain brown rice. The results are in line with a previous study conducted on ready-to-eat rice in Korea which concluded that the brown rice was scored less in overall acceptability due to being high in hardness, chewiness, and yellowness [18]. Brown rice hardness in texture is associated with dietary fibre that is present in bran layer [45] whereas, in white rice, polishing removes bran and germ during rice processing [46]. This significantly improves texture liking and consumer acceptance of white rice. In contrast to previous studies, which used a combination of descriptive analysis and hedonic scaling [16,18–20], the current study investigated consumer acceptance of rice by utilising 9-Point hedonic scales, JAR scales, and penalty analysis. Penalty analysis is a powerful tool to analyse the decreases in acceptability associated with sensory attributes which are perceived by consumers as being not optional [47,48]. This study also compared a range of brown and white rice varieties which enabled to compare brown and white rice, but also identify the drivers of liking between brown rice varieties as well as the drivers of liking within white. In addition, it is interesting to note that rice texture (hardness) is more important for the consumer acceptance and overall liking of Australian brown rice varieties. This study suggests that the decrease in hardness and chewiness will increase the overall liking of Australian brown rice varieties, which can eventually increase brown rice acceptance and consumption.

Brown rice texture (hardness and chewiness) and colour are the sensory attributes that are driving the difference between white and brown rice varieties. Thus, the texture of brown rice is less liked as compare to white rice regardless of rice varieties, because the majority of participants rated brown rice varieties as too hard and too chewy. However, differences in texture seem to be more important when comparing liking between white and brown rice. This is in line with a study conducted on consumer acceptance of parboiled brown and white rice which reported that white rice was preferred to brown rice because of texture and colour [24]. The results are also in agreement with the study that reported consumer acceptance of white rice varieties in Thailand, in which the participants preferred cooked white rice because of the soft texture [36]. Suwansri and Meullenet (2004) reported that Asian consumers preferred rice with white appearance (colour) and less sticky texture [49]. Similarly, the consumers from South Asia and Middle East did not prefer the brown rice texture [50]. In the present study, the sensory results also suggest that brown rice texture (hardness and chewiness) is the most important sensory attribute that is driving the liking and consumer acceptance of brown rice.

Although this was the first study which investigated consumer acceptance of Australian brown and white rice varieties, there are some limitations which need to be taken into consideration. The participants were mainly living in urban areas and were well educated, with 79% of participants holding undergraduate degree or higher. That may have affected their liking because of their awareness of the brown and white rice varieties which may cause bias in evaluation of rice attributes. For future investigation, the sample (participants) could be recruited from different geographical areas to predict the preference of Australian brown and white rice varieties. It is suggested to conduct future studies with a greater focus on the texture attributes of brown rice. To identify the variability in the texture of brown rice, different cooking methods and water to rice ratios are recommended. In addition, the instrumental analysis (colour and texture analyser) can be considered for the better understanding of texture attributes of brown and white rice varieties.

5. Conclusions

Texture is the most important sensory attribute which explains the difference in liking between brown and white rice, whereas differences in aroma best explain the variation in liking of white rice. Therefore, to increase the acceptance and consumption of brown rice, development needs to mainly focus on the improvement of the texture acceptance of brown rice. Future research is needed to investigate if an increased water absorption, milling process, packaging, and storage of brown rice can positively improve the texture and subsequently increase consumer acceptance.

Author Contributions: T.A.G.: Conceptualization, Methodology, Writing, and original draft preparation. R.S.J.K.: Conceptualization, Supervision, Reviewing and Editing. R.A.S.: Writing—Reviewing and Editing. S.R.J.: Supervision, Writing—Reviewing and Editing. S.G.: Supervision, reviewing and editing. M.M.: statistical analysis. D.G.L.: Conceptualisation, Methodology, Supervision, Writing—Reviewing and Editing. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Deakin University (HEAG-H29_2018, date of approval 28 February 2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare that they have no competing interests.

Ethics Approval and Consent to Participate: The rice consumer study was approved by the research ethics committee Deakin University (HEAG-H 29_2018). The participants were asked to read Plain Language Statement (PLS) and all participants signed their consent forms.

Abbreviations

JAR	Just About Right
IRRI	International Rice Research Institute
CASS	Centre for Analytical Sensory and Safety
ANOVA	Analysis of Variance
XLSTAT	Name of Statistical Sensory Software
CI	Confidence Interval
Ref	Reference

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foods

Article

Food Consumption and Emotions at a Salad Lunch Buffet in a Multisensory Environment

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Abstract: The food experience is multisensory and multisensory external stimuli may affect food choice and emotions. The objective of this study was to evaluate the effect of a multisensory eating environment on food choice, intake and the emotional states of the subjects in a salad lunch buffet setting. A total of 30 female subjects consumed a salad lunch twice in the multisensory laboratory. The two test conditions (control and multisensory condition with environmental stimuli) were randomized and the visits were scheduled one week apart. Subjects selected and ate a meal from a salad buffet including 14 food items and the intake of each item was weighed. They answered an online questionnaire about the meal and their emotional states (20 different emotion terms) after the lunch. There was no significant difference in the food consumption between the control and multisensory conditions. The subjects were very satisfied with their lunch for both study visits but the pleasantness of the eating environment was rated higher under the multisensory condition. In emotional terms, the subjects selected the term “happy” significantly more frequently under the multisensory condition compared with the control. In conclusion, the multisensory eating environment in this study was not related to food intake but may be associated with positive emotions. The effect of the eating environment on food choice and experience deserves further study with a larger study population in a real lunch restaurant setting.

Keywords: lunch buffet; vegetables; food intake; multisensory; emotion terms

1. Introduction

The workday lunch is an important part of Finnish food culture [1] and lunchtime salad buffets are common at restaurants and worksite canteens in Finland. Lunch is typically eaten around noon in Finland and on workdays the lunch break is half an hour. Healthy lunch choices, especially consumption of vegetables may promote public health [2] and, when replacing less sustainably produced food items in diet, also sustainable food system. Recently, different nudging techniques have been used to increase vegetable intake [3]. Lunch breaks spent in pleasant environments may be associated with positive emotions and further with wellbeing and recovery from stress [4]. Customers value peaceful eating environments but they may have different expectations for interior colors, background music and desired emotional sensations in relation to the restaurant menus [5].

Food perception is multisensory, integrating taste, smell, vision, touch and hearing. Food items have various internal sensory attributes. For example, the perception of vegetable quality combines many sensory characteristics [6,7]. External sensory stimuli, such as visual or sound, in the eating environment may modulate the multisensory experience [8]. The eating context, for example at home, a lunch restaurant or snack bar, may provide various external stimuli affecting food choices and perception. Traditionally, sensory evaluations have been performed in standard sensory laboratory conditions. Recently, different multisensory, immersive or virtual reality applications have been tested in consumer research [9]. Most previous studies involved the evaluation of single foods or beverages in virtual or multisensory conditions such as cookies [10], coffee [11], beer [12] or non-alcoholic beer [13]. Zandstra et al. reported a consumer study of tomato soup comparing tasting sessions in three different contexts: in a laboratory, an immersive simulated café and a real café [14]. A virtual reality eating environment was used in consumer studies evaluating snack products and emotions [15] as well as chocolate products and emotions [16]. To our knowledge, food consumption at a salad buffet in a multisensory environment has not been studied previously.

The emotions elicited by different food products have also been a research focus recently but the entire eating situation has seldom been evaluated using emotional terms. Various methods have been used to evaluate emotions evoked by food experiences including questionnaires with emotion, mood or wellness terms [17,18]. Recently, new types of methods such as a language-independent graphical tool with emoji have been developed for the assessment of food-elicited emotions [19]. Emotion questionnaires have been used in addition to sensory tests to identify the differences between tested products and even to predict food choice [20,21]. Different eating environments have been associated with different emotions [22] and thus may be related to the consumer's experience of the meal.

The main aim of the present study was to evaluate the effect of a multisensory eating environment on food intake, especially vegetable and fruit intake, in a salad lunch buffet setting. A further aim was to compare subjects' reported emotional states under control and multisensory conditions.

2. Methods

2.1. Subjects

The subjects had previously participated in extensive sensory tests [23] and further taste testing in a multisensory laboratory. Invitations to participate in this study part were sent to 62 female subjects. Two sets of data were collected in this study: food consumption and emotions as well as eye-tracking data, which were used to record the lunch sessions in this study and are reported in more detail in another article (submitted manuscript). Celiacs and pregnant or breastfeeding women were excluded and subjects with smell hypersensitivity were not recommended to participate. Due to eye-tracking data collection, normal vision was required (below −1.0 diopter). Wearing contact lenses was allowed but wearing glasses was not permitted during food selection and eating. Wearing reading glasses was allowed when answering the online questionnaire. Food allergies and intolerances of the subjects were enquired about before the study visit and just before the meal. A total of 32 subjects attended the first visit but one did not attend for the second and one subject was excluded due to noncompliance with the study protocol (having lunch elsewhere and taking only a small portion of salad). Thus, 30 subjects attended the required two sessions and provided complete data for analysis. The study protocol was approved by the Ethical Committee of the University of Turku and all subjects provided written informed consent. The lunch was free for the subjects and no other compensation for participation was offered.

2.2. Buffet Foods

The lunch buffet included 14 different food items. The foods, their preparation and serving sizes are described in Table 1. Food items were ordinary foods generally included in lunch salad buffets in Finland. Food was selected based on visual appearance with mainly color pairs (red, green, orange, black, white, beige) so that they formed a colorful buffet. Foods also had different dominant taste qualities (salty, sweet, sour, bitter). Fresh vegetables and fruits were the main options. Two different lactose-free cheeses, chickpeas and peanuts were provided as protein sources. Pasta with two different sauces (pesto or aioli mayonnaise) was served to supply energy (carbohydrate and fat) for the lunch.

Table 1. Foods served and serving size.

Food Color	Foods	Type, Preparation	Serving Size (g)
Black	Kalamata olive	canned, strained	150
	Black grape	rinsed	240
Green	Broccoli	frozen, defrosted	180
	Ice lettuce	rinsed, ripped to pieces	100
Red	Cherry tomato	rinsed	240
	Red bell pepper	rinsed, chopped	200
Beige	Chickpeas	canned, rinsed, strained	240
	Salted peanuts		140
Orange	Orange	peeled, cut	250
	Cantaloupe melon	peeled, cut	200
White	Mozzarella cheese	cut into slices	240
	Feta-type cheese	cubes, strained	210
Pasta	Pesto pasta	cooked pasta, cooled, mixed with pesto sauce 1:7	205
	Aioli pasta	cooked pasta, cooled, mixed with aioli mayonnaise 1:7	205

Food items were delivered weekly by the same local supermarket and the quality of the vegetables and fruit was carefully monitored daily. The food was prepared fresh daily in the kitchen of the sensory laboratory just before the session for each participant. After finishing the preparation, the serving trolley was kept in the cold storage room at +8 °C. The weights of the served and consumed amount of the foods were measured with a scale (Mettler Toledo PB3002-S, Mettler Toledo International Inc., Columbus, OH, USA), to 1 g accuracy. The foods were served in square-shaped 15 × 15 cm glass bowls. The bowls were placed on the serving trolley on three different levels (Figure 1). The order of the serving bowls was randomized for every subject.

Figure 1. Serving trolley with the buffet foods.

The serving sizes were selected based on similar volume appearance in the bowls and so that the subjects felt that they could take enough. Serving tools were ordinary tablespoons, except using a salad server for lettuce. The plates were white porcelain with a diameter of 22 cm. In addition to the salad buffet, rye and oat bread as well as margarine were served. Olive oil with a lemon flavor and French dressing were also offered. Water was served as a drink with the meal and coffee or tea with biscuits were offered after the meal.

2.3. Multisensory Laboratory Conditions

Multisensory conditions with different landscapes, sounds and odors were pilot-tested beforehand. Of the pilot-tested options, the forest landscape with birdsong and orange scent were selected for the multisensory condition and the other condition was a plain control. These two different conditions (control vs. multisensory) were randomized between the first and second study visit for each subject. Thus, all participants attended in both conditions but in a randomized order.

The multisensory laboratory equipment included an odor diffuser (Pump unit BB-200, @aroma GmbH, Berlin, Germany) and controlled illumination (five bulbs on the wall and three bulbs in a floor lamp, Hue, Philips, Amsterdam, Netherlands). The audio-visual multimedia system included an 80-inch Apple-tv (Apple Inc., Cupertino, CA, USA) and an audio system with two speakers (Genelec Oy, Iisalmi, Finland). In the control condition, the neutral room lighting system was used. In addition, there was no sound, no scent and no visual landscape on the screen. In the multisensory condition, there was a landscape of a pine forest and lake during summertime and bright lighting, matching the color tones of the landscape on the screen (Figure 2). The soundscape was birdsong in a Finnish summertime forest with various species of bird (recorded in Kortesjärvi in June). Orange scent (Orange Oil Sweet Brazil Pera, @aroma GmbH, Berlin, Germany) was diffused to the room with an odor diffuser for 30 s before a subject entered the room and then for 5 s in 3 min intervals until the subject had finished eating.

Figure 2. Lunch under a multisensory condition.

2.4. Questionnaire

Subjects also answered an online questionnaire (Webropol Oy, Helsinki, Finland) on an iPad (Apple Inc., Cupertino, CA, USA). Before the lunch, the questions asked about how hungry they felt (four options from not at all to very hungry) and the time (hours and minutes) since their previous meal. After the meal, the questions included how full they felt (four options, not at all to very full) and if they were satisfied with the salad meal (four options, not at all satisfied to very satisfied). The liking of the test environment in the multisensory room was also evaluated (9-point scale). The emotion terms were selected and modified from emotion questionnaires [24,25]. The term selection was pretested with Finnish consumers in a previous study setting focusing on ambient odors in the multisensory room. Altogether, 19 emotion terms, both positive and negative, as well as an open question option (something else) were presented and the subjects could choose as many options as they liked (check all that apply) based on how they felt at that moment. After the second study session, a few background questions (education, weight, height, how often they have salad for lunch) were asked.

2.5. Procedure

The test sessions were organized at the multisensory laboratory of the Functional Foods Forum (University of Turku, Finland) at usual lunch times in Finland. Subjects were asked to attend two study sessions at the same time of day (either at 10:45 a.m. or 12:30 p.m.) at least one week apart. The sessions lasted approximately 30–45 min. Session conditions (control vs. multisensory) in the multisensory room occurred in randomized order. Subjects were also instructed to have the same kind of breakfast on both study days and they were asked to avoid the use of scented cosmetic products before visits.

Subjects were first asked to view the trolley for 20 s while the researcher stood next to her. Next, the researcher left the room and closed the door and the subject collected a meal from the buffet. The subjects were instructed to take as much as they wanted and have all the foods at once. The researcher then removed the trolley from the room. Subjects were seated alone in the multisensory room, ate their meal at their own pace and knocked on the door when they had finished eating. After the meal they were served coffee or tea with biscuits. Subjects answered the online questionnaire while having coffee or tea.

The test session was recorded with a head-mounted eye-tracker (Tobii Pro Glasses 2, Tobii AB, Danderyd, Sweden). The subject wore the wireless eye-tracking glasses and gaze data were sent to a laptop in another room in live video format. This allowed the researcher to monitor the session behind a closed door and no other video cameras were needed. The subject knew that she was being monitored and that she herself was not visible on the video since it only recorded her first-person view of the laboratory. The eye-tracker was removed when the subject began to answer the online questionnaire. For this study, the eye-tracking recording was used for monitoring the session and calculating the time spent on eating the self-selected salad. The eating time was measured from the time the participant sat down to eat until she knocked on the door and let the researcher know she had finished. The detailed description of the eye-tracking methodology and analyses are reported in another article; this paper focuses on the food intake and emotional measures.

2.6. Statistics

The basic results of the intake of foods are presented as means (SD). The same subject attended under both conditions and the intakes in control vs. multisensory conditions were compared using the Wilcoxon signed-rank non-parametric test for repeated measurements. For paired nominal data, McNemar's test was applied. The statistical software used was IBM SPSS Statistics 26 (IBM Corporation, Armonk, NY, USA).

3. Results

The mean age of the participants (n = 30) was 53 years (SD 14 years) and their mean BMI was 26.8 kg/m^2 (SD 6.9). The educational background was high; 50% had a university education and 30% had a university education with an applied sciences degree. Half of the subjects (50%) reported having salad for lunch one to three times per week and 27% one to three times per month. There was no difference in the time since the previous meal for the two study visits: control of 3.9 (SD 2.1) vs. multisensory of 4.0 (SD 2.8) hours. The state of hunger did not differ significantly either as 77% in the control and 73% in the multisensory condition felt very or fairly hungry before the lunch.

The number of food items taken altogether from the salad bowls varied; the range was 7 to 14, mean 11 (SD 1.5) but we found no significant differences between the control and multisensory conditions. The mean (SD) weights of foods and the total portion weight in the control and multisensory conditions are presented in Table 2. The sum variables of the food groups (vegetables, fruit, cheese and pasta) were calculated and analyzed but the intakes of these groups did not differ between the two conditions. Because the total weight of the portions differed between subjects, proportions (%) of the foods in the total portion weight were calculated. However, no significant differences in these variables were observed between study conditions.

Table 2. Foods consumed (mean, SD grams) at different conditions (control vs. multisensory).

Food	Food Intake Control (g) Mean (SD)	Food Intake Multisensory (g) Mean (SD)
Kalamata olive	14 (13)	14 (14)
Black grape	25 (18)	29 (16)
Broccoli	32 (21)	31 (22)
Ice lettuce	22 (13)	21 (14)
Cherry tomato	38 (24)	35 (22)
Red bell pepper	20 (17)	19 (17)
Chickpeas	17 (24)	15 (19)
Salted peanuts	7 (8)	7 (7)
Orange	38 (30)	33 (27)
Cantaloupe melon	43 (25)	38 (19)
Mozzarella cheese	36 (22)	32 (22)
Feta-type cheese	30 (20)	28 (18)
Pesto pasta	34 (27)	35 (29)
Aioli pasta	14 (17)	16 (25)
Total weight of the portion	372 (98)	354 (100)

The multisensory condition included a forest landscape on screen, birdsong and orange scent. *p*-values all non-significant (Wilcoxon signed-rank test).

The eating time did not differ significantly between the two conditions (control 12.8 min vs. multisensory 13.0 min). Considering fullness after the meal, the proportions of responses were exactly the same for both conditions: 47% reported feeling very full and 50% fairly full. Contentment with the salad was also good for both conditions. In the multisensory condition, 83% were very satisfied with the salad compared with 77% in the control condition (non-significant difference). Liking ratings of the testing environment differed (Figure 3). Overall, the multisensory condition was significantly more pleasant than the control ($p < 0.001$).

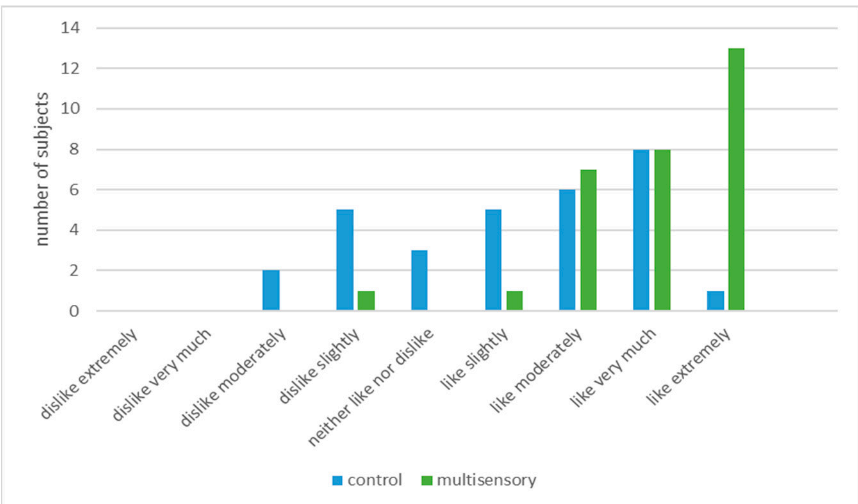

Figure 3. Liking of the test environment.

The selected emotion terms under the control and multisensory conditions are presented in Figure 4. Most of the selected terms were positive for both conditions. Over two-thirds of the participants felt healthy in both test environments. No one stated that they felt stressed, cold or tired in either condition. Respondents chose the term "happy" more often in the multisensory condition ($n = 13$) compared with the control ($n = 5$); $p = 0.02$, McNemar's test. The subjects also tended to select the terms "relaxed" ($p = 0.09$) and "strong" ($p = 0.07$) more often for the multisensory condition.

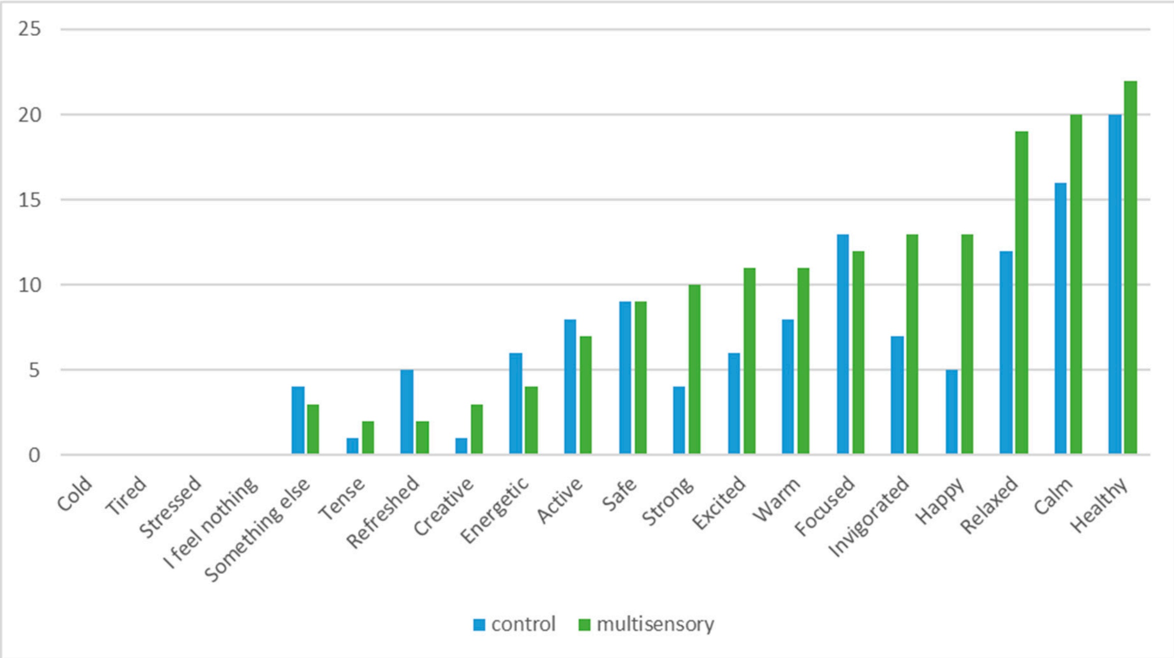

Figure 4. Selection of the emotion terms (n) in different conditions.

4. Discussion

In the present study, no general effect of the multisensory environment on food choice or intake at a salad lunch buffet was observed. Therefore, changing individual food preferences and consumption patterns simply with external multisensory stimuli appears to be challenging. The selected foods, portion sizes and eating times were surprisingly similar for the same person under both conditions. This finding may reflect the overall stability of individual eating habits or a more situated tendency to repeat their first-time choices in the second session with exactly the same offerings. However, the multisensory condition was evaluated as very pleasant by the participants and positive emotional effects were reported based on the selection of emotion terms. In general, the feedback from participants regarding the whole experiment was positive; they valued the free, fresh and appealing buffet service and most were very satisfied with their meal.

Comparison with previous studies is challenging as we are not aware of studies using the same type of real-life but controlled lunch buffet settings in multisensory conditions. Previous studies used different study protocols, populations, buffet food selection and sensory primers. The buffet setting studies evaluated, for example, food choices of normal weight and overweight subjects [26]. Buffet meal intakes by different bitter taste sensitivity groups [27] or taste receptor genotype groups [28] were compared. In a multisensory study setting in Italy [29], consumers evaluated tomatoes and wild rocket in an immersive environment using countryside landscapes and sounds as well as natural herbs as olfactory cues. The liking scores were reported to be higher in the immersive environment compared with the traditional sensory laboratory setting [29]. In a self-service buffet setting, a priming experiment consisted of creating a leafy environment with green plants and an odor of herbs. The priming condition reduced the total energy intake [30]. Most previous studies have evaluated single foods or beverages in immersive conditions whereas this study provides new information about food consumption at a salad buffet in a multisensory environment.

Priming with food odor has been hypothesized to affect food selection but the results are controversial. Exposure to a fruity odor (pear) was found to increase the likelihood of selecting a fruity dessert [31]. Mors et al. [32] reported that priming with a bread or cucumber odor did not affect lunch choices but odor condition was associated with a self-reported positive mood. In the present study, exposure to the orange odor did not increase the selection or consumption of orange in the salad buffet; the trend seemed to be slightly the opposite. The auditory contribution to food perception was reviewed by Spence et al. [33]. Most previous studies have focused on the effect of music genre on the perception of a single flavor or food [34] but what kind of background sounds are most appropriate for lunch room conditions is not known. Different nature sounds, including birdsong, have been related to stress recovery and restorative benefits although restorative perceptions may vary between different bird species [35].

The buffet food selection in the present study was colorful and consumers were previously reported to value visually attractive and colorful salads [36]. External visual stimuli including colors of the food package, plates or cups may be associated with food perception [37]. Individuals differ in their associations of the color of liquid samples with taste qualities, pleasantness or healthiness [38]. In the present study, the tablecloth on the serving trolley was white while the color hue of the lighting and the color of the landscape were greenish in the multisensory condition. The color of the lighting may also have affected the color perception of food items offered in the salad buffet. Schifferstein et al. [39] reported that colored backgrounds affected the perceived attractiveness of vegetables but optimal background colors differed substantially for various vegetables. According to Hasenbeck et al. [40], yellow lighting increased the willingness to eat bell peppers. Because our buffet included food items with various colors, evaluating which colors of lighting would most effectively increase the attractiveness of vegetables and fruit was difficult. Complex landscape scenes present various colors and the effects of various pictures or scenes may be difficult to interpret. Investigating the effects of single sensory stimuli provides important information but in the multisensory context several aspects are combined. Real-life studies in restaurant settings also combine many sensory stimuli both in the food and in the environment. Therefore, the multisensory approach on consumer behavior and experience are challenging research topics.

Comparing study results focusing on emotions is difficult as the emotion terms vary and the results may be specific to the study population, study setting and the tested products. Few studies have related emotions specifically to the eating or meal situation [41,42]. In this study, the subjects selected the terms related to the whole meal situation and we do not know if their emotions were more related to the food eaten or the multisensory eating environment. We did not ask for opinions separately about different components (odor, lighting and sound) in the multisensory room. The reactions may be individual and some people may report unpleasant emotions associated with musical or pictorial stimuli [43]. Some consumers report adverse effects such as headaches related to fragrances [44]; thus, room odors should be used with caution. More research is needed on what kinds of sensory stimuli, as well as their combinations in different eating environments and with different consumer groups, can support pleasant eating experiences. Emotion questionnaires rely on self-reported subjective ratings of emotions and other measures would also be useful in food research settings. The review by Kaneko et al. [18] recommended combining various instruments, including physiological, behavioral and cognitive measures, for evaluating emotions evoked by food experiences.

The strength of this study was that real intake with real foods was studied and not just food pictures or fake food models [45,46]. In comparison with self-estimated portions of food intake in many nutrition studies, here the food intake was accurately weighed [47]. The same subjects attended two visits in a randomized order. Recording the sessions with a head-mounted eye-tracker overcame the need to set up external video cameras in the laboratory and we think this made the session monitoring feel less intrusive for the subjects. The possible limitation may be the short exposure time to the multisensory environment while taking the food. However, we wanted to create a situation resembling the normal food selection phase in a lunch restaurant setting and not to have the subjects wait before selecting the food. The subjects were seated alone whereas in real restaurants there may be many other external stimuli present and other customers. Only women were included in this study and men may have different preferences for lunch buffet foods as well as greater energy needs, requiring larger portions. The number of subjects was rather small but comparable with other buffet setting studies [26]. Only one subject was attending at a time and the preparation, serving and weighing of various fresh food items was rather laborious and time consuming. In future, real lunch restaurant buffets with a larger study population including both sexes could be studied.

In conclusion, the multisensory room conditions in this study did not change the food intake of the subjects. Fresh, colorful and a varied vegetable selection at lunch is appealing and could promote the consumption of vegetables and sustainable eating habits. In addition to fresh vegetables and fruit, salad buffets usually include other components and thus the overall nutrient composition and healthiness of the lunch depends on individual consumer choices. A pleasant and relaxing ambience may elicit positive feelings and thus enhance meal satisfaction and wellbeing [48]. The promotion of positive eating situations among various consumer groups deserves further study.

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foods

Article

Does the 'Mountain Pasture Product' Claim Affect Local Cheese Acceptability?

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Abstract: This paper aims to explore the impact of "mountain pasture product" information on the acceptability of local protected designation of origin (PDO) cheese produced from the raw milk of cows grazing in mountain pastures (P) or reared in valley floor stalls (S). A total of 156 consumers (55% males, mean age 41 years) were asked to evaluate their overall liking on a 9-point hedonic scale of four samples: Cheeses P and S were presented twice with different information about the origin of the milk (cows grazing on mountain pasture or reared in a valley floor stall). Demographics, consumer habits, and opinions on mountain pasture practice (MPP), attitudes towards sustainability, and food-related behaviours (i.e., diet, food waste production, organic food, and zero food miles products purchase) were recorded and used to segment consumers. The cheeses were all considered more than acceptable, even though they were found to be significantly different in colour and texture by instrumental analyses. In the whole consumer panel, the cheese P was preferred, while in consumer segments less attentive to product characteristics, this effect was not significant. External information had a strong effect: Overall liking was significantly higher in cheeses presented as "mountain pasture product", both in the whole panel and in consumer segments with different attitudes (except for those with a low opinion of MPP).

Keywords: mountain cheese; acceptability; conjoint analysis; external information; consumer segmentation; food sustainability

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1. Introduction

Mountain dairies—which, in the alpine territories, are placed in contexts with a high naturalistic value, in most cases—play key roles in the promotion of local tourism, the preservation of biodiversity and the environment, and the maintenance of cultural and historical traditions [1]. They also find themselves in a position of increasingly seeking a compromise between production and conservation needs, as well as trying to respond convincingly to consumer requests regarding food safety and compliance with ethical farming principles. While animal husbandry, in general, has been subjected to criticism due to the excessive intensification and poor efficiency of production processes, mountain activity has gained growing interest from both tourists and consumers who associate this activity with greater sustainability, being able to combine production, environmental, and social needs on a small scale [2]. Nevertheless, mountain farming is less competitive and has higher costs than intensive production, with the consequent abandonment of such activities in the most remote areas in recent decades [3,4]. The EU has recognized, for some years, the need to prevent the abandonment of these mountain areas by focusing on the promotion and development of mountain food production as a way to promote sustainable development and to reduce the disadvantages of these areas [5]. With this objective, the EU has recently introduced a new labelling system for mountain products [6], which is an important step toward taking into account that there is a strong correlation between the perception of EU quality signs and the attitude towards food origin [7].

1.1. Mountain Products and Consumer Perception

The quality of dairy mountain products starts from the animals, which are moved from indoor feeding with conserved forage to fresh herbage (i.e., feeding on pasture), according to the traditional transhumance system [8]. Several studies have focused on the effects of summer grazing on dairy product characteristics, demonstrating that mountain products are different from indoor feeding products, in terms of sensory attributes [9–13], volatile organic compounds (VOCs)' profile [8,14–16], and fatty acid composition [11,17,18]. The quality of dairy mountain products is also a key aspect for consumers [19], for whom the production of high-quality dairy products is the most important ecosystem service among those provided by summer farms [20].

1.2. Influence of Information and Attitudes

When the quality of a food product is evaluated, we have to take into account that consumer perception is based both on intrinsic characteristics (mainly related to product physical properties) and extrinsic properties (i.e., any information provided to the consumer about the product) [21]. Among the external factors, those linked to product credibility, such as labels, brands, origin, organic and production method-related, health, and ethics, are those of high interest for product enhancement in the market [22].

For food products of animal origin, some studies have investigated the effect of information about the production method, demonstrating that information about cow grazing versus information about indoor system increased consumer preference for meat [23,24] and generated the highest willingness to pay or positive effect, in terms of liking milk [25–28]. Romanzin et al. [28] have reported similar results for cheese, even if the literature on this food matrix is scarce. A recent review on consumer perception, preferences, and behaviours regarding pasture products did not report any study on cheese [29].

External factors generate expectations about food products and influence the choices of consumers, having a role in both their perception and liking [30,31]. In spite of this, the magnitude of these effects on food choice depends on how well the consumer is informed, aware, and prepared towards the concepts associated with the external information transmitted [32–34]. Studies have demonstrated that consumers associate sustainability-related attributes, such as environmental friendliness, animal welfare, local, and small-scale production, with mountain pasture products [2,35]. Nevertheless, it is important to measure consumer engagement with respect to the mentioned aspects, in terms of knowledge, awareness, and attitude. Some examples in the literature have proposed self-assessed measures or questionnaires for estimating the individual environmental sustainability [36], the low-carbon consumption scale [37], and knowledge of food sustainability [38]. Poortinga and Darnton [39] developed a screening tool to segment consumers, according to their attitude towards environmental, economic, and social aspects of sustainability. The developed tool has been proven to be valid in differentiating the Welsh population, even though it lacks a domain that measures the aspect linked to food sustainability.

1.3. Objective of the Study

In this study, we explored the impact of "mountain pasture product" information on the acceptability of a local cheese, with the final aim to enhance the value of dairy products obtained from milk produced in mountain pastures, thus promoting the multiple positive externalities connected to them. In order to identify the profiles of consumers differently involved with the mountain pasture world and differently inclined towards environmental and food sustainability, we developed and proposed new questionnaires as screening tools for this precise purpose. Then, we verified whether consumer segments with different attitudes toward these quality characteristics experienced a different impact of external information about mountain pasture products.

2. Materials and Methods

2.1. Cheese Samples

A protected designation of origin (PDO) cheese (Puzzone di Moena) was the product chosen for the consumer test. Puzzone di Moena is a semi-hard cheese with characteristic washed rind, produced from raw bovine milk of animals reared in the mountain area of Trentino Alto Adige (Italy) from a minimum height of 1000 m (valley floor stalls) up to 2000 m of altitude (mountain pasture). Puzzone di Moena is generally sold at 100 days of maturation, but the ripening period varies from a minimum of 3 up to a maximum of 16 months. Puzzone di Moena "malga cheese" is a Slow Food presidium [40], sold with the label "Sapori di malga" (which means "Mountain hut flavours"). It is exclusively produced from alpine pasture milk during the summer pasturing period, from June to September.

The samples given to the consumers were obtained from two different wheels of Puzzone di Moena PDO produced in Predazzo dairy (Trento, Italy): One made from milk collected in valley floor stalls (S) and aged 100 days, and the other one from alpine pasture milk (P) and aged 200 days. The two cheeses were considered representative of the two types of Puzzone present in the local market: The mountain pasture product is sold with greater maturation, in order to enhance its distinctive characteristics (min 120 days) [41], while the valley bottom cheese is mostly sold with a minor seasoning (min 60 days) [42].

Sample Preparation

Cheese wheels were stored at 15 °C until the moment of portioning, which took place the day before the test. To obtain homogeneous samples, the whole wheel was first cut in half, then into two quarters. From each quarter, eight 1.5-cm thick slices were cut. From each slice, after removing the rind, a parallelepiped was obtained, which was further divided into 16 smaller parts (3 × 1.5 cm × 1.5 cm). The cheese pieces were then stored in vacuum-sealed containers at 10 °C until the next day. On the day of the test, each piece of cheese was placed in a transparent bio-plastic cup, covered with a lid, coded with a three-digit number, and stored at 15 °C until tasting.

2.2. Physical and Rheological Properties

For each cheese (P and S), 32 cheese parallelepipeds randomly selected from those cut were collected (one piece for each cheese slice) and submitted first to instrumental measurements of colour and then of texture characteristics. Colour measurements were recorded at room temperature on freshly cut cheese slices using a tri-stimulus CR-400 colorimeter supported by the CM-S100wSpectraMagicTM colour data software (Konica Minolta Sensing, Inc., Tokyo, Japan) and calibrated with a white standard plate. The L*-, a*-, and b*-parameters of the CIEL*a*b* colour space model (see [43]) describe visual lightness (as values increase from 0 to 100), redness to greenness (positive to negative values, respectively), and yellowness to blueness (positive to negative values, respectively) of the samples.

Texture properties were then measured using a TA-XT texture analyser, equipped with an acoustic envelope detector device (Stable MicroSystem Ltd., Godalming, UK). A 4-mm probe was used to compress the samples. Nine mechanical parameters were calculated from the recorded curves, following the method described by Costa et al. [44].

2.3. Consumer Study

The consumer test was conducted in the Trento Expo exhibition spaces (Trento, Italy), on the 16 and 17 March 2019, in "La Casolara 2019", the traditional Slow Food presidium fair dedicated to the best cheese and dairy production from all over the country, attracting not only local visitors.

The responses of 156 consumers were collected in a mobile sensory laboratory compliant with EN ISO standards 8589 [45], equipped with four mobile individual booths using the FIZZ 2.46A software (Biosystemes, Couternon, France).

The test consisted of an experiment that was evaluated in 'informed' conditions, combining conjoint analysis with the tasting of the two Puzzone di Moena PDO cheeses (described in Section 2.1). Each consumer received four cheese samples in total, according to a complete factorial design with two milk productions and two information levels. The two cheeses (P and S) were presented twice, each time with different external information: 'Produced from milk of cows reared on mountain pasture' (Claim_P) or 'Produced from milk of cows reared in valley floor stalls' (Claim_S). These two claims were submitted to consumers on the computer screen (Figure 1), just before tasting the sample. Consumers rated their overall liking of the four cheeses on a nine-point scale, from 1 = "Dislike extremely" to 9 = "Like extremely". The four samples were presented in a random and balanced order for each participant, who evaluated them under white light.

(**a**) (**b**)

Figure 1. Examples of the screen used in the conjoint study: (**a**) The information about mountain pasture cheese; and (**b**) the information about cheese made with milk from cows reared in valley floor stalls.

All subjects were not paid and voluntarily joined the test. Prior to participation, the experimental procedure was explained to all participants and written informed consent was obtained from each, according to the European Data Protection Regulation (UE 679/2016). The consumers were asked to pay attention and to carefully read all the instructions provided during the test. We provided participants with noise-proof earmuffs, in order to help them concentrate in the noisy fair environment, and asked them to follow a rinse procedure with water and unsalted crackers to avoid possible carry-over effects between the products tested.

2.4. Questionnaires

After tasting, by means of a series of questionnaires, participants provided information about a list of different topics, from socio-demographic data to self-reported behaviours and habits related to food, sustainability, and mountain pasture perception (Table 1). They were asked about their food diet, in order to identify the omnivore, flexitarian (people reducing or limiting their meat consumption), and vegetarian/vegan distribution in the panel, using 9 items adapted from De Backer and Hudders [46], which have already been used in Italian [47,48]. Consumers reported their percentage of weekly food waste, as well as organic and zero food mile products weekly purchased (<5%, 5–10%, 11–20%, 21–30%, 31–40%, >40%). To assess interest towards natural products, the Natural Product Interest

(NPI) sub-scale of the Health and Taste Attitude Scales (HTAS), developed by Roininen et al. [49] and validated by Saba et al. [50], was used. Participants rated their degree of agreement with a series of positive and negative statements on a 9-point scale (1 = totally disagree; 9 = totally agree), rather than the original 7-point scale, in order to be consistent with the other questionnaires submitted to the participants. In the Supplementary Materials, the original and the Italian version of the NPI sub-scale is reported (Table S1).

Table 1. Demographics, food behaviour questions, attitude questionnaires, and their relative acronyms, number of items, rating scale, response options, and references.

Topic	Questionnaire/ Question	Items	Scale and Response Options	References
Demographic	Age	4	Completed years (open answer)	Developed by the authors
	Educational qualification		None, Primary, Lower secondary, Upper secondary, Bachelor/Master degree, Post-graduate degree	
	Family		Alone, In family, Other	
	Number of children		From 0 to 3 or more	
Food behaviour and life style	Smoking habit	6	Never tried, gave up, occasionally, regularly	Developed by the authors
	Sport		No, Up to twice a week, More than twice a week	
	Food Diet		Omnivores, flexitarians, vegetarians and vegans; classification based on the eating diet chosen out of a list of ten	Adapted from De Backer & Hudders [46]
	Organic food weekly purchased		<5%, 5–10%, 11–20%, 21–30%, 31–40%, >40%	Developed by the authors
	Zero food miles food weekly purchased		<5%, 5–10%, 11–20%, 21–30%, 31–40%, >40%	
	Food waste weekly throw it away		<5%, 5–10%, 11–20%, 21–30%, 31–40%, >40%	
	HTAS *—Natural product Interest domain (NPI)	6	9-point Likert scale (1 = totally disagree; 9 = totally agree)	Roininen et al. [49] (Table S1)
Sustainability	Attitude Towards Sustainability (ATS)	15	9-point Likert scale (1 = totally disagree/not at important/not at all concerned; 9 = totally agree/very important/very concerned, depending on the item)	Poortinga & Darnton [39] (Table S2)
	Food Consumption Sustainability (FCS)	18	9-point Likert scale (1 = totally disagree; 9 = totally agree)	Developed by the authors (Tables 2 and S3)
Mountain	Area of residence	7	Urban (>150 inhabitants/km^2), Rural (<150 inhabitants/km^2)	Developed by the authors
	Altitude of residence		>600, 300–600, <300 m a.s.l.	
	Mountain hiking		Never, rarely, often, always	
	Hiking zone		Trentino, Alto-Adige, out of region	
	Mountain pasture (MP) product purchasing		Never, rarely, often, always	
	MP products purchased		Fresh cheese, mature cheese, butter, yogurt, milk, more	
	MP cheese sold at supermarket (knowledge)		Yes, No	
	MP Practice Values (MPP)	6	9-point Likert scale (1 = totally disagree; 9 = totally agree)	Developed by the authors (Tables 3 and S4)

* HTAS health and taste attitude scale.

2.4.1. Attitude towards Sustainability and Food Sustainability

Furthermore, participants provided information regarding their attitude towards sustainability (ATS), rating their degree of importance, agreement, and concern on the response option expected by each statement of the 15-item Welsh screening tool for sustainability [39]. The original scale was back-translated in Italian by a native bilingual, following the procedure suggested by Brislin [51]. In this case, a 9-point scale (1 = not important at all/totally disagree/not concerned at all; 9 = extremely important/totally agree/extremely concerned, depending on the statement), rather than the original 6-point scale with the escape answer "don't know", was used. In the original Welsh questionnaire, there were no statements investigating sustainability, in terms of food consumption. Given the importance for a study like this to collect this information, a list of 18 positive and negative statements investigating attitudes towards local food, green restaurants, and domestic food waste were developed, in order to cover the food consumption sustainability domain (FCS; Table 2). In the Supplementary Materials, the original Welsh questionnaire, its translation in Italian (ATS), and the Italian version of FCS scale are reported (Tables S2 and S3).

Table 2. Mean (M) and Standard Deviation (SD) values for each statement of the Food Consumption Sustainability scale.

Item	Food Consumption Sustainability	M	SD
1	It is better to buy local foods because they cost less	6.24	2.30
2	It is better to buy foreign foods because they are cheaper ^{R}	2.03	1.35
3	It is better to buy local food because it pollutes less	7.65	1.51
4	It is better to buy local food because local labour is employed	7.83	1.40
5	It is better to buy foreign food to have more choice ^{R}	2.72	1.67
6	It is better to buy local foods because they are better	6.84	1.82
7	It is better to buy foreign foods because they are better ^{R}	2.56	1.67
8	There are no advantages to buying local foods over foreign ones ^{R}	2.40	1.79
9	I try to buy seasonal fruit and vegetables so I pollute less	7.46	1.85
10	It is better to buy seasonal fruit and vegetables because there is no need to transport them from afar	7.63	1.65
11	I buy the fruit and vegetables I want regardless of the season ^{R}	3.65	2.25
12	In my opinion, eating only seasonal fruit and vegetables is unhealthy ^{R}	1.93	1.53
13	I would be willing to pay more for environmentally friendly catering services	6.57	1.92
14	I would choose one food product over others if labelled as "green" ^{R}	6.69	1.95
15	When I buy food, my priority is taste and value for money before "green" aspects	4.81	2.13
16	When I eat out, I would like to be offered local food and drink if possible	7.64	1.54
17	Rather than throwing away food, I eat it even if it is 1–2 days out of date	7.00	2.34
18	When I do the shopping, I always buy more than I need ^{R}	3.66	2.06

^{R} Negative statements recoded for the final score calculation.

2.4.2. Mountain Pasture Practice Values

Six further statements on the values and habits of mountain pasture practice (MPP) were developed, in order to explore the knowledge level and perception of the mountain pasture world and its products of consumers (Table 3). These statements were previously developed by a focus group of researchers involved in different fields related to mountain pasture and food (i.e., sensory, nutrition, chemistry, food technologies, animal husbandry, agricultural economics, and statistics). In the Supplementary Materials, the Italian version of the MPP scale is reported (Table S4).

Table 3. Mean (M) and Standard Deviation (SD) values for each statement of the Mountain Pasture Practice scale.

Item	Statements about Mountain Pasture Practices	M	SD
1	The mountain pasture practice helps to maintain pleasant high mountain landscapes [52]	7.92	1.37
2	Both stable and pasture management have the same impact on climate change [53]	3.38	2.48
3	The mountain pasture practice contributes to the welfare of the animals [1,2]	8.12	1.17
4	The mountain pasture practice produces high quality dairy products [10,54]	8.04	1.14
5	The mountain pasture practice increases tourist activity [55]	7.85	1.39
6	The mountain pastures maintain a high natural animal and plant biodiversity [56,57]	7.89	1.35

2.5. Data Analysis

Data analysis was performed using the STATISTICA v. 13.1 software (Dell Inc., Tulsa, OK, USA, 2016).

In order to confirm the differences between the two cheeses (P and S), the product effect (fixed factor) on colour and texture instrumental parameters was estimated using one-way analysis of variance (ANOVA). In all statistical tests, we consider a significant difference as $p < 0.05$ after Bonferroni correction.

2.5.1. Analysis of Questionnaire Data

As a preliminary pre-treatment, the scores for the negative statements of NPI questionnaire [49], of the ATS scale [39], and of the developed scales on FCS and statements on MPP were reversed. For the NPI scale, the statements suggested by the authors were considered negative while, for the ATS scale, we considered four statements (8–11) of the original scale negative, as they were found to be opposite to the others in an explorative principal component analysis (PCA) map (data not shown). Following the same procedure, of the 18 statements developed for FCS, eight were considered negative (Table 2); while the MPP statements were all considered positive, being true statements extracted from the literature.

Subsequently, the internal validity for each scale was tested using the standardized Cronbach's alpha [58]. Cronbach's alpha values above 0.60 are considered acceptable and values above 0.70 are considered good to optimal [59]. Then, for each of the four scales, the sum scores were calculated for each participant by adding the score of each item, according to the procedure described by Roininen et al. [49]. Based on these scores, the participants were classified in three groups (low, moderate, and high interest/attitude), according to the 33rd and 66th percentiles.

A two-way analysis of variance (ANOVA) was carried out to test how gender and age (three age classes were considered: Age_1, 18–30; Age_2, 31–50; and Age_3, 51–75) affected the sum scores of the attitude scales. One-way ANOVA was instead used to estimate the effect of food diet (omnivorous, flexitarian, or vegetarian/vegan), percentage of weekly food waste, organic, and zero food mile products weekly purchased (<5%, 5–10%, 11–20%, 21–30%, 31–40%, >40%) on attitude scale sum scores. For significant effects after Bonferroni correction (corrected $p < 0.05$), the Tukey–Kramer post-hoc honestly significant difference (HSD) test for unequal sample size was applied, whenever appropriate.

2.5.2. Analysis of Conjoint Data

The liking data were analysed using a three-way ANOVA mixed model, considering both product and external information as main fixed factors and consumer as the random main factor, together with their second-order interactions. For significant effects after

Bonferroni correction (corrected $p < 0.05$), the post-hoc HSD Tukey's test for multiple comparison was applied, whenever appropriate.

In order to identify which groups of people were more sensitive to intrinsic or extrinsic factors, the same ANOVA model was recalculated in sub-groups of consumers, identified by gender, age (Age_1, 18–30; Age_2, 31–50; Age_3, 51–75 years of age), place of residence altitude (Alt_1, >600; Alt_2, 600–300; Alt_3, <300 m a.s.l.; [60]), residence zone (Urb_1, >150 inhab/km^2; Urb_2, <150 inhab/km^2; [61]), interest towards natural products (NPI_1, low; NPI_2, moderate; NPI_3, high), attitude towards sustainability (ATS_1, low; ATS_2, moderate; ATS_3, high), attitude towards food consumption sustainability (FCS_1, low; FCS_2, moderate; FCS_3, high), and attitude towards mountain pasture practice values (MPP_1, low; MPP_2, moderate; MPP_3, high).

3. Results

3.1. Instrumental Analysis

Overall, five instrumental parameters—two for colour and three for texture—showed significantly different mean values in the two cheeses (Table 4). Cheese produced with pasture milk and a longer ripening period was more yellow, having a higher b* index, whereas cheese produced with stall milk was lighter, having a higher L* index. Three out of nine texture parameters showed significantly different mean values between the two cheeses. Cheese produced with pasture milk and a longer ripening period was harder, resistant, and more elastic, showing greater values for linear distance force (computation of the force curve length), delta force (difference between yield force and final force), and elasticity modulus, computed as the ratio between stress and strain.

Table 4. Instrumental characterisation of pasture (P) and stall (S) cheese: Means, standard deviations (in parenthesis), and *p*-values for colour and texture parameters.

Parameters	P	S	*p*-Value *
Lightness (L *)	71.9 (1.3)	75.6 (1.0)	0.001
Redness (a *)	−2.5 (0.2)	−2.4 (0.1)	0.116
Yellowness (b *)	25.8 (0.9)	17.8 (0.5)	0.001
Yield Force (F1)	3.8 (1.1)	3.0 (1.9)	0.199
Max Force (F2)	4.7 (0.6)	5.0 (0.6)	0.266
Final Force (F3)	4.6 (0.7)	4.9 (0.6)	0.234
Number of Force Peaks (FP)	1.2 (0.9)	0.8 (0.7)	0.965
Area (A)	350.3 (51.8)	321.0 (47.8)	0.259
Linear Distance Force (LDF)	91.0 (0.5)	90.6 (0.1)	0.001
Elasticity modulus (E)	0.4 (0.1)	0.2 (0.1)	0.001
Mean Force (F4)	4.1 (0.6)	4.1 (0.6)	7.259
Delta Force (DF)	−0.8 (1.1)	−1.9 (1,4)	0.011

* Bonferroni corrected *p*-values.

3.2. Consumer Panel Profile

A total of 156 subjects (55% men) aged between 18 and 75 took part in the test (Table 5). From the analysis of socio-demographic data, it was found that the participants had a high level of education: 50% declared a secondary school and 31% a bachelor's/master's degree. Furthermore, 73% reported to live with their families, mainly in urban areas (60%), and 48% did not have children. With regard to lifestyle and behavioural habits, it emerged that consumers adopted an average healthy lifestyle: 63% claimed they had never smoked and 53% practiced sports up to twice a week.

Table 5. Percentage distribution of socio-demographic characteristics by gender of respondents recruited in the consumer study.

	Males % (n = 85)	Females % (n = 71)	Total (n = 156)
Age (years)			
18–30	24.7	29.6	26.9
31–50	47.1	43.7	45.5
50–75	28.2	26.8	27.6
Educational level			
None	0.0	1.4	0.6
Primary	2.4	1.4	1.9
Lower secondary	10.5	7.0	9.0
Upper secondary	49.4	50.7	50.0
Bachelor/Master degree	31.8	29.6	30.8
Post-graduate	5.9	9.9	7.7
Who do you live with?			
Alone	14.1	18.3	16.0
In family	77.6	67.6	73.1
Other	8.2	14.1	10.9
N° of children			
None	47.1	47.9	47.4
One	16.5	14.1	15.4
Two	29.4	32.4	30.8
Three or more	7.1	5.6	6.4
Area of residence			
Urban (>150 inhabitants/km^2)	61.2	57.7	59.6
Rural (<150 inhabitants/km^2)	38.8	42.3	40.4
Altitude of residence			
>600 m a.s.l.	25.9	22.5	24.4
300–600 m a.s.l.	30.6	29.6	30.1
<300 m a.s.l.	43.5	47.9	45.5
Smoking			
Not smoking (never tried)	57.6	69.0	62.8
Not smoking (quit)	31.8	8.5	21.1
Occasionally	3.5	15.5	9.0
Regularly	7.1	7.0	7.1
Sport			
No	10.6	22.5	16.0
Up to 2 times a week	55.3	50.7	53.2
More than 2 times	34.1	26.8	30.8
Diet			
Omnivores	77.6	59.1	69.2
Flexitarians	22.4	33.8	27.6
Vegetarians	0.0	7.0	3.2

Regarding eating habits, the majority of the participants (69%) were omnivorous, 28% flexitarian (60% of them mainly lead a diet in which the consumption of meat was limited), and 3% vegetarian. As the tested product was of animal origin, vegans did not participate in the study.

With regard to attention to organic food, only 10% of the participants stated that organic products comprised more than 40% of their weekly shopping. Consumers, on the other hand, were attentive to the purchase of zero food miles products and to limiting food waste: The majority (76%) declared throwing away less than 5% of their weekly shopping.

A total of 44% of the consumer panel quite often organized excursions to the mountain huts (malga), mainly in Trentino province (87%). On these occasions, among the dairy products locally produced, they chose to buy fresh (33%) and mature cheese (33%), butter (16%), yogurt (10%), and milk (4%). The list of statements on mountain pasture practices and relative average scores and standard deviations are shown in Table 3. All statements obtained a high average score, demonstrating how the consumers associated positive opinions with mountain pasture practices. The only exception was the second statement ("Both stable and pasture management have the same impact on climate change"), which divided the opinion of the participants. However, only 33% of participants were aware of the possibility of buying cheeses with the "Sapori di Montagna" label directly from the supermarket.

3.3. Consumer Segmentation

Before classifying the consumers, according to the scales, the internal validity of each scale was verified (Table 6). All scales were reliable, showing standardized Cronbach's alfas higher than 0.6 [59]. The NPI scale revealed a lower, but still comparable, internal validity, in comparison with that originally described by Roininen et al. [49] (Cronbach's alpha = 0.76). In Table 6, the percentages of people in the three groups (low, moderate, and high interest/attitude), calculated for each scale according to the 33rd and 66th percentiles, are reported.

Table 6. Means (M), standard deviations (SD), percentile cut-points (33rd and 66th), percentage of participants in each group (L = low attitude; M = moderate attitude; H = high attitude), and reliability of attitude scales: Natural product interest (NPI), attitudes toward sustainability in general (ATS), food consumption sustainability (FCS), and mountain pasture practice scale (MPP).

Scale	M	SD	33rd	66th	L (%)	M (%)	H (%)	Cronbach's α	Standardized α
NPI	37.3	8.4	33	41	29	34	37	0.66	0.66
ATS	91.8	11.0	88	96	30	38	32	0.57	0.64
FCS	124.0	13.3	118	131	31	34	35	0.69	0.73
MPP	43.2	5.8	42	46	30	28	42	0.68	0.79

We found some associations with gender and age: Women ($p = 0.033$) and older respondents ($p = 0.035$) rated FCS items higher than men or younger respondents, respectively. Similar results for older consumers were obtained in the NPI and MPP knowledge scales ($p < 0.05$).

Additionally, those who showed a higher NPI declared a higher weekly purchase of organic and zero food miles products ($p = 0.0004$ and $p = 0.006$, respectively), and declared to be mainly flexitarians and vegetarians ($p = 0.002$). Participants who showed a higher attitude towards FCS declared less than 5% of weekly food waste ($p = 0.003$), more than 40% of weekly purchase of zero food mile products ($p = 0.006$), and limited or no meat consumption ($p = 0.09$).

In the first row of Table 7, the results of the ANOVA mixed model for the whole consumer panel are reported. The main factors of product and external information had significant effects on consumer liking scores. Among the interaction effects, only that between consumer and product (C $\times$ P) was significant; showing that, among all consumers, people with different liking for products were present. External information had the strongest effect (MS = 76.16), with products claimed as "mountain pasture product" (Claim_P; M = 7.0, SD = 1.4) being statistically more preferred than those claimed as "valley floor stall product" (Claim_S; M = 6.3, SD = 1.6), regardless of the cheese effectively tasted (Figure 2a). Product effect was the second strongest (MS = 42.06), with more seasoned and pasture cheese (P; M = 6.9, SD = 1.5) being statistically different and more preferred than the stall one (L; M = 6.4, SD = 1.6); see Figure 2b.

Table 7. The p-values of ANOVA mixed model on the effects of consumer, conjoint factors and their second order interactions (*) on liking. Mean squares are reported in parentheses. Statistically significant effects after Bonferroni correction (p-value < 0.0022) are reported in bold.

Groups	N	Consumer (C)	Product (P)	Information (I)	P*C	I*C	P*I
All	156	0.014 (4.18)	**0.0001 (42.1)**	**0.0001 (76.2)**	**0.0001 (2.6)**	0.059 (1.3)	0.467 (0.5)
M	85	0.019 (3.8)	0.001 (30.6)	**0.0001 (36.9)**	**0.0001 (2.4)**	0.815 (0.9)	0.838 (0.1)
F	71	0.163 (4.7)	0.039 (12.7)	**0.0001 (39.6)**	**0.0001 (2.6)**	**0.001 (1.7)**	0.36 (0.7)
Age_1	42	0.409 (3.9)	0.042 (13.7)	**0.0001 (25.9)**	**0.0001 (3.1)**	0.013 (1.0)	0.057 (1.9)
Age_2	71	0.056 (4.7)	**0.001 (33.3)**	**0.0001 (35.9)**	**0.001 (2.7)**	0.078 (1.7)	0.628 (0.3)
Age_3	43	0.039 (3.5)	0.362 (1.7)	**0.0001 (15.1)**	0.022 (2.0)	0.812 (0.8)	0.508 (0.5)
Alt_1	38	0.464 (3.5)	**0.002 (33.2)**	**0.0001 (19.9)**	**0.0001 (3.0)**	0.11 (1.2)	0.066 (2.9)
Alt_2	47	0.005 (5.2)	0.007 (13.3)	**0.0001 (24.6)**	0.021 (1.7)	0.029 (1.6)	0.543 (0.3)
Alt_3	71	0.16 (5.9)	0.163 (5.9)	**0.0001 (31.8)**	**0.0001 (3.0)**	0.443 (1.1)	0.078 (3.4)
Urb_1	93	0.027 (3.7)	0.005 (20.8)	**0.0001 (42.7)**	**0.0001 (2.6)**	0.09 (1.3)	0.247 (1.3)
Urb_2	63	0.137 (4.5)	0.006 (21.7)	**0.0001 (33.6)**	**0.0001 (2.7)**	0.193 (1.3)	0.803 (0.1)
NPI_1	45	0.104 (4.3)	0.078 (8.9)	**0.0001 (20.0)**	0.012 (2.7)	0.922 (1.9)	1 (0.0)
NPI_2	53	0.09 (4.3)	0.378 (1.9)	**0.0001 (31.7)**	**0.0001 (2.4)**	**0.002 (1.4)**	0.118 (1.5)
NPI_3	58	0.103 (3.6)	**0.0001 (44.8)**	**0.0001 (24.9)**	**0.0001 (2.6)**	0.1 (1.5)	1 (0.0)
ATS_1	47	0.038 (4.4)	**0.0001 (42.3)**	**0.0001 (29.9)**	0.024 (1.9)	0.078 (1.6)	0.234 (1.5)
ATS_2	59	0.215 (4.3)	0.89 (9.8)	**0.0001 (23.2)**	**0.0001 (3.3)**	0.242 (1.0)	0.887 (0.1)
ATS_3	50	0.127 (3.6)	0.252 (3.1)	**0.0001 (23.8)**	0.004 (2.3)	0.308 (1.3)	0.84 (0.1)
FCS_1	49	0.569 (2.3)	0.651 (0.1)	**0.0001 (12.3)**	0.003 (3.0)	0.972 (0.8)	0.951 (0.1)
FCS_2	53	0.157 (4.2)	0.043 (10.4)	**0.0001 (37.4)**	**0.0001 (2.4)**	0.013 (1.7)	0.513 (0.4)
FCS_3	54	**0.002 (6.0)**	**0.0001 (50.1)**	**0.0001 (29.6)**	**0.0001 (2.2)**	0.032 (1.3)	0.446 (0.5)
MPP_1	48	0.552 (4.0)	0.092 (11.0)	0.003(14.1)	**0.0001 (3.7)**	0.124 (1.4)	0.387 (0.8)
MPP_2	43	0.019 (4.2)	0.115 (5.2)	**0.0001 (15.7)**	0.004 (2.0)	0.47 (0.9)	0.418 (0.6)
MPP_3	65	0.022 (4.0)	**0.001 (28.5)**	**0.0001 (50.0)**	**0.001 (2.2)**	0.123 (1.4)	0.228 (1.5)

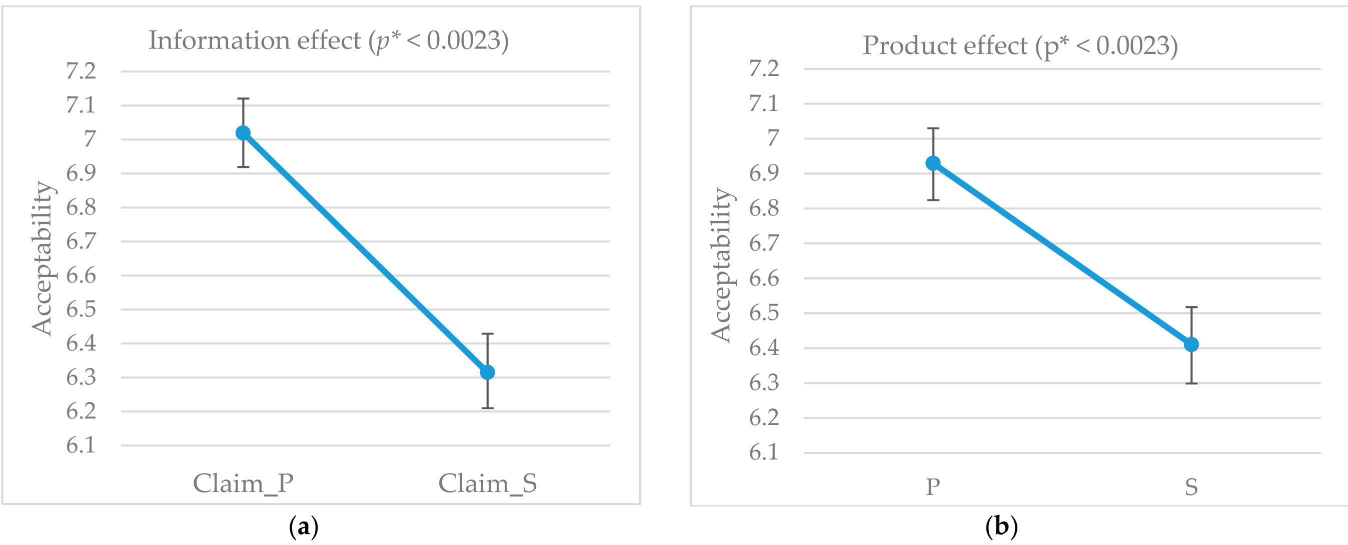

Figure 2. Effects of main factors in the conjoint study for the whole panel: (**a**) Information effect; and (**b**) Product effect. Bonferroni corrected p^* is reported.

The results of the ANOVA mixed model, recalculated for specific sub-groups of consumers identified by gender, age, altitude and urbanization of their place of residence, ATS, FCS, NPI, and opinion about MPP are reported in Table 7. Findings concerning the sub-groups of men, of people between 31 and 50 years old, of those who live in mountain areas, of those who had low ATS, high NPI, and positive opinions on MPP confirmed those observed for the overall panel of consumers (first row of Table 7). The random main consumer effect was not significant for any of the sub-groups, except for the group of people with high FCS attitude.

The most interesting results concerned the main effects of product and external information. The effect of the information was significant for all consumer groups: Men and women, people with different ATS, and so on, always evaluated the cheeses presented with the claim "mountain pasture product" with higher liking scores. The only exception lay in those who had a low opinion of MPP, who were not influenced by this information. The product effect was significant for a few sub-groups of consumers, in which mountain pasture cheeses showed higher liking scores, in comparison with valley floor stall cheeses. Mountain pasture cheese was more appreciated in the group of men, people aged between 31 and 50 years old, and those who had a very positive opinion on mountain pasture practices, although the effect of information remained the most important (Table 7, in parenthesis). Furthermore, mountain cheese was also more appreciated by those who lived above 600 m a.s.l. than those at lower altitude, as well as by those who had higher FCS attitude and NPI than those who were less attentive to these food aspects: In these groups, the product effect was a more important factor than information (Table 7, in parentheses). Furthermore, living in a more urban area or having a different attitude towards the social, economic, and environmental aspects of sustainability did not influence the significant effect of information on mountain production. Surprisingly, in the group of those who were less attentive to sustainability aspects, the product effect was the most important factor, showing a significant preference for mountain pasture cheese. Furthermore, there were changes in the significance of interaction effects between consumer and design factors on liking, which varied depending on the sub-group. In any case, the significant presence of these effects meant that, even within consumer sub-groups, different opinions were possible, both in the evaluation of the product and of the information.

4. Discussion

4.1. Mountain Cheese Acceptability

In the present paper, the acceptability of typical local cheeses produced in the same dairy from either mountain pasture or valley floor stall milk was investigated. Overall, both cheeses achieved good consumer acceptability, obtaining average liking scores ranging from 6.0 to 7.3. These results confirm what previous studies have stated, even without a real product tasting, as the quality of dairy products is an important aspect for both tourists and local farmers in the perception of summer mountain farms [3,20]. The significant effect of the product found for the whole panel (first row of Table 7) demonstrated that pasture cheese was significantly preferred over the stall one. This is in line with the results of Romanzin et al. [28], who reported that consumers expressed a higher actual liking for mountain pasture Montasio cheese. However, the cheeses evaluated here had different ripening and were different (as demonstrated by instrumental analyses), both in terms of colour and texture, with the pasture cheeses being harder and more yellow. Colour and texture generally change with the aging of dairy products [62,63], even if the yellow colour in milk and cheese also highly depends on their carotenoid content, which is generally higher in spontaneous pasture [64]. Our finding confirms that mountain pasture dairy products are recognizable and distinguishable from valley floor stall products [17,18]. Nevertheless, product sensory differences due to different milk production were probably influenced by differences induced by maturation [65], as the pasture cheeses were ripened 100 days more than the stall ones.

4.2. Information Effect

For the whole consumer panel, cheese acceptability was influenced by external information about the milk used for cheese manufacturing, showing that the "mountain pasture product" claim generated higher liking scores. This effect remained true for all the consumer segments investigated, except for people with a less positive opinion of mountain pasture practices (MPP1), who seemed not to be influenced by this information. Moreover, there were no effects due to gender, age, different area of residence, or different level of interest to natural products or different awareness of sustainable aspects (i.e., neither environmental nor food).

The strength and persistence of the external information effect on acceptability in the various groups of consumers surprised the authors, who expected a non-significance for the overall sample and significant effects in the groups of consumers who were more aware or sensitive to the information given [32,66]. This, in itself, is an important result; perhaps being due to the more detailed way in which the information was transmitted (i.e., a short sentence on the origin of the milk, accompanied by an image of the animal grazing or in the stable, depending on the level of information; Figure 1). Osburg et al. [67] reported, in fact, that more detailed information on the product increases both the purchase intention and the trust in eco-friendly products.

It is also possible that the image itself, in addition to reinforcing the concept already expressed in the claim, carries other concepts connected to the main information, such as animal welfare, naturalness, and sustainability issues that, when connected to food, also indicates a local, organic, and traditional product [68]. It is also known that visual imagery is an effective way to inform consumers and capture their interest, but also to increase the perceived product benefits [69]. Furthermore, the image linked to the mountain pasture cheese message used in this study was predominated by the colour green, which has been demonstrated to be associated with environmental friendliness and is the most effective for producing positive attitudes [70]. Previous studies that have examined consumer perception on verbal versus pictorial claims reached opposite conclusions on which modality is most effective [71,72]. Hence, further studies in this sense are necessary, in order to deepen the understanding of the message actually perceived by the consumer and to establish the most effective modality, passing from the evoked concept to a claim on packaging.

4.3. Segmentation Effect

The segmentation scales used in the present work—both those developed for this study and those developed by other authors—proved to be sufficiently reliable and with good external interpretability. The FCS scale, developed to measure attitudes towards sustainable food-related behaviours, was effective in assigning higher scores to people producing less domestic waste, purchasing a greater percentage of zero food miles and organic products, and people following a diet that limits or refuses meat consumption. The MPP scale, developed to investigate consumer opinions and knowledge about mountain pasture practices, was efficient in identifying consumers with different sensitiveness to external information about mountain pasture cheese.

Gender and age effects were found for the FCS, MPP, and NPI scales: Women and older consumers had higher scores with respect to food sustainability, mountain pasture practices aspects, and natural food interest. This finding was in line with our expectations: Women and older consumers are generally more attentive to the ecological aspects of food [36,73–75]. Cavaliere and Ventura [68], instead, argued that millennials are the most sustainable and environmentally friendly generation, even if their study did not include comparisons with groups of respondents aged over 30 years. The gender effect is also controversial. Muratore and Zarba [76] found that environmental aspects are more important to males, whereas other studies did not find any gender influence [77]. In our case, both genders were sensitive to information given; the difference was perhaps due to the different evaluative cues used by the two groups. Rahman et al. [78] saw that, in the evaluation of the sustainable aspects related to the production of garments, females were more sensitive to aspects of animal welfare, while males were more attentive to environmental aspects, such as air quality or the quantity of water used in production.

For mountain-related factors, those who lived in mountain areas (more than 600 m a.s.l) showed significant effects for both information and product factors; the latter was also the most important factor in this group of people. This may be due to the fact that inhabitants of mountain areas, compared to those who live in the plains or hills, are more familiar with the mountain pasture products, recognizing their sensory characteristics and associating them as local and zero food miles products.

The segmentation between those who lived in urban and rural areas did not lead to differences: There was no significant preference for one cheese over the other, while information on the mountain pasture product had a significant effect on liking in both groups. These results are contrary to those found by Zuliani et al. [2], who revealed a gap between urban consumer conception of mountain farming and the actual farming practices. The authors would have expected a non-significant effect of information in this group of consumers, with less knowledge of farming practices. This aspect is in line with the results obtained by segmenting consumers on the basis of their opinions on mountain pasture practices: Those with a less positive opinion were not influenced by external information, while those with a moderately positive opinion were. Those who had a highly positive opinion of MPP were not only sensitive to information given but also recognized the mountain pasture product as a better product, even if the information factor remained the most important one.

It is well-known that consumers are willing to pay a premium price to support local and organic food [24,79–83]. In our findings, segmentations based on FCS and NPI—which investigate attitudes towards organic and local products—did not show any difference in terms of external information influence. Instead, there was a difference in terms of product influence: Those with a high FCS and NP attitude actually preferred mountain pasture cheese and, thus, were more attentive to the aspects related to the product, which was also the most important factor.

Consumer segments with different attitudes towards socio-economic and environmental sustainability showed the same sensitivity to information. People presenting moderate or high attitudes seemed less attentive to the products: Those less engaged with sustainability were those who preferred mountain pasture cheese over the stall one. These results can be partly explained by the fact that, although concern and awareness of environmental problems are decisive for individual choices, the correlation between these aspects and actual behaviour is weak [84]. Furthermore, possessing environmental values, being aware of environmental problems, and having a correct perception of one's own ecological footprint are necessary, but not sufficient, conditions to generate pro-environmental behaviour [19,36,85,86]; and, perhaps, not even to recognize these positive externalities in a food product.

4.4. Limitations and Future Perspectives

Our sample size of 156 subjects can be seen as a limitation. However, in the field of sensory sciences, the size of the consumer sample for an acceptability test is commonly recognised as adequate at around 100 consumers [87], even though the sample size from previously published research in the field commonly exceeds 100–120 subjects [88]. Thus, a consumer panel of 156 consumers can be considered an acceptable sample size, also because participants shared a core common feature (i.e., being potential consumers of dairy products), which represents the target demographic under investigation. In addition, our sample was balanced for gender and age classes.

All participants attended the cheese fair "La Casolara", which is both an advantage and a limitation for the purposes of this study. If, on one hand, it is possible to reach a large number of cheese consumers in a short time; on the other hand, despite the ability of these events to attract not only local visitors, the majority of the consumers came from the same region. The external validity of our findings would surely be enhanced by considering a more representative sample of consumers coming from various regions. Furthermore, the preference for local food products—and, thus, mountain pasture products—could be related to the regional ethnocentrism of consumers [89], due to the close connection between local traditional practices and regional origin. We tried to measure this connection by classifying the subjects by area of origin, in terms of altitude and degree of urbanization, assuming a closer link for those who lived in a rural or mountain area.

Some of the variables included in this study were directly or indirectly measured using scales, while others were self-reported. It should be noted that the self-reported variables could be inaccurate, due to memory recall and subject bias [90]. Thus, in order to avoid the distortion of responses to different test instruction presentations, all the instructions were not given verbally but submitted on a screen, being the test anonymously administrated on a computer.

The study could be replicated by increasing the sample size and screening for regular cheese consumption. Future research could generalize the results obtained here into a national context, in order to identify the drivers promoting the introduction of these products into new markets. It would be interesting to repeat the test using other, more well-known types of cheese, such as parmesan, or some other types for which the sign of quality of "mountain product" is sought. Furthermore, the liking of other mountain products, such as butter or yogurt, which are sold directly in the mountain hut could be investigated. Finally, future research could also be dedicated to the study of the images and claims used to evoke the concept of valley floor stall and mountain pasture products, identifying the most effective ones in a large validation study.

5. Conclusions

The present study showed that the impact of "mountain product" information on the acceptability of local cheese generated an overall positive response in the consumers, who assigned it extra value. The importance of this extrinsic characteristic exceeded the intrinsic value of the tasted product, which, however, was globally recognized, even if to a lesser extent. The positive effect of information persisted even within groups of consumers with different socio-environmental characteristics and different levels of interest and attitude. This study also showed that the consumers generally associated positive opinions with mountain pasture practices; it was precisely the lack of this positive association that made the claim lose its effectiveness. Furthermore, the consumers who lived in mountainous areas, who had a high opinion of mountain pasture practice, and who were predisposed towards local and organic food products and sustainable food-related behaviours were able to identify mountain pasture cheese as a product of higher quality than the valley floor stall cheese. This study contributes to revealing that the foundations exist for mountain pasture products to become mainstream products for all consumers. Nevertheless, effort is needed to promote the product in places other than mountain huts or dairy vendors.

Supplementary Materials: The following are available online at https://www.mdpi.com/2304-8158/10/3/682/s1. Table S1: List of the original statements of the Natural Product Interest domain of the Heath and Taste Attitude Scale (HTAS) (a) and the translation in Italian (b). Table S2: List of the original statements of the Welsh Sustainability Segmentation Screening Tool (a) and its adaptation in Italian (b). Table S3: List of the statements of the Food Consumption Sustainability scale in Italian. Table S4: List of the statements of the Mountain Pasture Practice scale in Italian.

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Institutional Review Board Statement: Ethical review and approval were waived for this study as the experimental protocol did not expose the participants to particular psychological, social or physical risks other than those conventionally defined as minimum. Participants voluntarily attended the study, provided their written consent, and had the right to withdraw the consent at any time and for any reason. Moreover, the present study did not include the collection or analysis of data that could directly be used to define the identity of participants, any risk of discomfort or inconvenience to participants, any risk of psychological distress to participants or their families, the involvement of vulnerable groups of participants whose capacity to consent to participation may be challengeable, and international data collection. The authors declare that the experimental protocol was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study, according to the European Data Protection Regulation (UE 679/2016).

Data Availability Statement: The data generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Article

Consumer Acceptability and Sensory Profile of Sustainable Paper-Based Packaging

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Abstract: Sustainability appears to be increasingly important to consumers. In order for companies to reach their sustainability targets and offer more environmentally friendly solutions to consumers, food producers and retailers have begun to change their packaging to more recyclable, bio-based and biodegradable packaging. This study evaluated the sensory characteristics of paper-based prototype packages developed for two product categories (biscuit and meat packages) using a trained sensory panel. Consumer liking, preference and purchase intent were assessed by 130 participants. For the biscuit packages, no significant differences were observed for the liking of any of the four dimensions assessed (appearance, design, feel or overall liking). However, consumer segmentation identified three relatively homogeneous groups of consumers exhibiting differences in the hedonic reaction to the three packages. For the meat packages, significant differences and preference were observed between the original and paper-based packages. For both categories, the purchase intent was low, indicating that further work needed to be done to improve several quality characteristics (e.g., design, size and strength of the package), which would lead to better consumer acceptability.

Keywords: paper-based packaging; sensory attributes; consumer acceptability; biscuit packages; meat packages

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1. Introduction

Packaging is essential in providing adequate protection to foodstuffs during transport, distribution and storage, thus reducing food loss and waste. Packaging that has a comparatively low environmental impact as assessed by life-cycle assessment models can be considered to be sustainable packaging [1]. From a consumer point of view, a packaging design that evokes explicitly or implicitly the eco-friendliness of the packaging can be considered to be sustainable packaging [2]. Since sustainability appears to be increasingly important to consumers [3,4], market interest in alternative forms to plastic packaging has increased drastically in recent years [5]. In order for companies to reach their sustainability targets and offer more environmentally friendly solutions to consumers, food producers and retailers have started to change their packaging to more recyclable, bio-based and biodegradable packaging. As paper fulfils these requirements and is easily understood by consumers, there is a high market interest for paper-based solutions [5].

Paper and cardboard packaging were the most recycled packaging in the UK and Europe in 2018, with recycling rates of 74.4% and 82.9%, respectively [6]. This has motivated companies toward the use of paper-based packaging. In addition, recyclable materials generally give the impression that the packaging is environmentally friendly [7–9]. Paper/cardboard is associated with positive emotions and attributes such as trust, biological/natural [10], homely and fresh products [11]. It is generally preferred over plastic because plastic is associated with emotions and attitudes such as unnecessary, expensive or bad for the environment [11].

There is limited research looking at sustainable paper-based packaging while analytically exploring the sensory characteristics of the packaging and consumers' perceptions.

Magnier & Schoormans [12] estimated the effects of visual appearance and verbal sustainability claims on purchase intent and found that consumer responses to the visual appearance and verbal sustainability claims of the package depended on their level of environmental concern. The study showed that consumers with low environmental concerns evaluated conventional-looking packages with a verbal sustainability claim more negatively. In a subsequent study, Magnier et al. [13] investigated the effect of packaging sustainability on consumers' perceived quality of three product categories and found a more positive perceived quality of a food product when it was packed in a sustainable rather than conventional way. Steenis et al. [14] showed how packaging sustainability influenced consumer perceptions, inferences and attitudes toward packaged products. They demonstrated that consumers often rely on misleading and inaccurate beliefs when judging packaging for sustainability. Most studies acknowledge how the expectations and responses of consumers vary based on the design (shape, orientation, alignment of graphical forms), branding, visual appearance, colour, verbal claims and quality of products [13,15–19].

Research has shown that consumers decide what to purchase based on extrinsic product characteristics and appearance [20]. Consumer perception of extrinsic product cues such as packaging material and brand name differs from intrinsic product cues such as aroma, flavour and texture [21]. Packaging and branding as extrinsic product cues have been shown to have an influence on how consumers evaluate food products [22] and can determine consumers' expectations [23]. Thus, it is important that careful attention is given to the design of a package because of its dual role: attracting consumers' attention and creating expectations of the sensorial properties of the product [21].

According to a recent systematic review by Ketelsen et al. [24], there were only two studies [25,26] focusing on consumers' affective liking of environmentally friendly packaging, so research in this area has been quite limited. The study conducted by Koenig-Lewis et al. [25] explored consumers' emotional and rational evaluations of pro-environmental packages for beverages. Sijtsema et al. [26] investigated consumers' perceptions of 'bio-based' products and found that while participants were unfamiliar with 'bio-based' as a concept, they associated the word 'bio-based' with both positive and negative sustainability attributes. Therefore, our study (a) evaluated the sensory characteristics of the newly developed paper-based packages for two product categories (biscuit and meat packages), as per Oloyede & Lignou [27] and (b) investigated consumer acceptability, liking and preference of the developed packages and also explored purchase intent.

2. Materials and Methods

2.1. Materials

Innovative, 3-dimensionally formed paper-based packages were developed for two product categories (biscuits/confectionery and meat/chilled products) using either 3D press forming or deep drawing technology.

2.1.1. Biscuit Packages

Two paper-based prototypes were developed as an alternative to the traditional polyethylene terephthalate (PET) tray in flow wrap packaging for Strauss Ad Hazot chocolate-coated biscuits. A package of two formed cavities holding three cookies each were individually sealed and easily separable. Sample B1 had a smooth tray surface, whereas sample B2 had an embossed surface. Both versions (B1 and B2) were sealed with a printed lidding film, and trays were cut by twos, with individual trays connected to each other by perforation (Table 1).

Table 1. Biscuit and meat packages.

Samples			
Biscuit packages B0: preformed polymer multicavity tray, polymer flow pack (horizontal) 	B1: form-fill-seal paper-based tray with paper-based lidding film 		B2: form-sill-seal paper-based tray with paper-based lidding film 
Meat packages M0: preformed polymer tray with polymer lidding film 	M1: preformed paper-based tray with polymer lidding film 	M2: form-sill-seal paper-based tray with polymer lidding film 	M3: form-fill-seal paper-based tray with paper-based lidding film 

2.1.2. Meat Packages

Three paper-based prototypes were developed to replace an expanded polystyrene (EPS) tray for meat products for Colruyt Group. Sample M1 had an identical shape to the original tray and was formed by deep drawing, sample M2 was press formed with a smooth surface and less-steep side walls, and sample M3 was based on sample M2 with embossing in the bottom area and improved stiffness in the side walls. Samples M1 and M2 had a transparent polymer lidding film with the possibility to see the product, whereas sample M3 had a non-transparent paper-based lidding film (Table 1).

Life cycle assessment conducted on the paper-based trays with PET coating showed a lower environmental impact compared to plastic crystalline polyethylene terephthalate (CPET) trays and recycled plastic recycled polyethylene terephthalate (rPET) trays [21].

2.2. Sensory Evaluation of the Packages

Sensory evaluation was carried out using quantitative descriptive analysis (QDA^{TM}) to determine the sensory characteristics of the various prototype packages, and the characteristics were estimated quantitatively. A screened and trained sensory panel (n = 12; 11 female and 1 male) was used, and each member had a minimum of 1 years' experience with expertise in profiling techniques. The panellists received 5 h specific training (1 h per day) over a period of 5 days for each category of packages (biscuits and meat packages) (a total of 10 days for both categories). During the development of the sensory profile, the panellists were asked to describe the appearance and feel of the package and then open the package and describe the interior in order to produce as many descriptive terms as seemed appropriate. The terms were discussed by the panellists as a group, with the help of the panel leader, and this led to a consensus vocabulary of 15 and 16 attributes for biscuit and meat packages, respectively, as outlined in Tables 2 and 3 in Section 3. The quantitative sensory assessment was carried out in a temperature-controlled room (22 °C) under artificial daylight and in isolated booths, each equipped with an iPad. All panellists scored in duplicate for each sample in separate sessions (30 min each) over two days for each product category. Compusense Cloud Software (Version 21.0.7713.26683, Compusense, Guelph, ON, Canada) was used to acquire the sensory data. In total, 7 samples were evaluated (3 biscuit packages and 4 meat packages in separated sessions). Samples, coded with three-digit random numbers, were provided in a monadic balanced order, with sample sets randomly allocated to panellists within each product category. Panellists were instructed to evaluate the appearance attributes first and then open the package and evaluate the remaining attributes related to the interior of the package. The intensity of each attribute for each sample was recorded on a 100-point unstructured line scale.

Table 2. Mean panel scores for sensory attributes of the three biscuit packages.

Code	Attributes [Anchors 0–100)]	Scores [1]			LSD [2]	*p*-Value [3]
		B0	B1	B2		
	Appearance					
a1	Complexity of design (top and bottom) [simple to complex]	65.5a	28.3b	37.1b	8.9	<0.0001
a2	Amount of text [low to high]	72.5a	25.1b	25.4b	6.9	<0.0001
a3	Ease of holding [easy to difficult]	25.6ab	34.9a	21.2b	10.1	0.0313
a4	Sharp edges [not to very]	2.0b	35.6a	30.6a	13.1	0.0001
a5	Level of slipperiness [not to very]	42.7a	38.7a	21.3b	12.0	0.0032
a6	Noise of package [quiet to noisy]	68.3a	5.0b	6.2b	6.5	<0.0001
a7	Brightness of colour [light to dark]	63.8a	29.1b	30.7b	11.7	<0.0001
a8	Roughness of bottom surface [smooth to rough]	17.0b	10.2b	47.2a	15.8	0.0002
a9	Shininess of outer package [matt to shiny]	48.7a	10.1b	13.3b	9.2	<0.0001
a10	Rigidity before opening the package [flimsy to rigid]	69.2a	43.7b	50.8b	9.4	<0.0001
	After opening the package					
o1	Difficulty of opening [easy to difficult]	31.0b	47.3a	22.1b	12.7	0.0018
o2	Tearing [none to lots]	44.3a	0.0b	0.0b	10.5	<0.0001
o3	Rigidity of the tray after opening the package [not to very]	73.3a	30.8b	39.1b	10.9	<0.0001
o4	Shininess of the inner tray [matt to shiny]	52.8b	72.8a	73.8a	11.7	0.0017
o5	Shininess of the inner lid [matt to shiny]	79.1a	69.9b	69.7b	6.5	0.0097

[1] Means not labelled with the same letters are significantly different ($p < 0.05$); means are from two replicate samples, measured on an unstructured line scale (0–100). [2] Fisher's least significance difference (LSD) at $p = 0.05$. [3] Probability, obtained from ANOVA, that there is a difference between the means.

Table 3. Mean panel scores for sensory attributes of the four meat packages.

Code	Attributes [Anchors 0–100)]	Scores [1]				LSD [2]	*p*-Value [3]
		M0	M1	M2	M3		
	Appearance						
a1	Depth of tray [not to very]	72.6a	54.5b	28.1c	18.8c	9.4	<0.0001
a2	Ability to hold [easy to difficult]	16.4b	42.7a	37.0a	17.8b	11.3	<0.0001
a3	Level of slipperiness [not to very]	24.1b	56.2a	48.9a	19.8b	16.1	0.0001
a4	Colour of the tray [white to cream]	1.0b	84.7a	84.6a	82.4a	13.8	<0.0001
a5	Roughness of bottom surface [smooth to rough]	47.4b	6.7d	23.2c	63.7a	12.3	<0.0001
a6	Shininess of outer package [matt to shiny]	51.5a	5.4b	2.4b	5.0b	10.1	<0.0001
a7	Rigidity before opening the package [flimsy to rigid]	94.6a	31.3c	30.2c	66.0b	9.7	<0.0001
a8	Transparency of lid [not to very]	99.7a	97.0a	98.3a	0.0b	2.9	<0.0001
a9	Tightness of lid [not to very]	97.2a	50.2b	51.9b	90.7a	13.4	<0.0001
a10	Sitting of tray on the table [not stable to stable]	96.7a	26.8c	58.0b	95.3a	12.1	<0.0001
	After opening the package						
o1	Difficulty of opening [easy to difficult]	14.4c	93.4a	68.2b	65.2b	17.3	<0.0001
o2	Tearing [none to lots]	30.5ab	43.8a	15.2bc	12.5c	16.6	0.0018
o3	Rigidity of the tray after opening the package [not to very]	93.2a	19.5c	23.8c	43.7b	10.8	<0.0001
o4	Thickness of the lid [thin to thick]	18.5b	59.0a	54.3a	60.5a	9.7	<0.0001
o5	Shininess of the inner tray [matt to shiny]	51.4c	71.5b	72.4b	87.2a	9.4	<0.0001
o6	Difficulty of separating barrier [easy to difficult]	36.8c	79.7a	53.8b	31.1c	16.2	<0.0001

[1] Means not labelled with the same letters are significantly different ($p < 0.05$); means are from two replicate samples, measured on an unstructured line scale (0–100). [2] Fisher's least significance difference (LSD) at $p = 0.05$. [3] Probability, obtained from ANOVA, that there is a difference between the means.

2.3. Consumer Evaluation of the Packages

The study was conducted at the Sensory Science Centre at the University of Reading (UK). One hundred and thirty people were recruited across the University of Reading and Berkshire area (male and female, aged 18 years and above, without allergies or intolerances to wheat, gluten and/or dairy). Consumers who took part in the qualitative part of the study [27] were not allowed to sign up. Participants attended a single, 45-min session. Samples were presented to the participants, and after observing the samples, they were asked to rate their liking (appearance, design, feel, overall) on a 9-point hedonic scale (where 1: dislike extremely, 5: neither like nor dislike, 9: like extremely) for all samples. They also indicated the appropriateness of attribute level on a 5-point Just-About-Right (JAR) scale for the following attributes: strength of the package (where 1: much too weak, 3: JAR and 5: much too strong) and naturalness (where 1: not much too natural, 3: JAR and 5: much too natural). Finally, consumers were asked to indicate their preference (ranking: most-preferred to least-preferred package for each category—biscuit or meat packages), purchase intent for the packages (5-point scale, where 1: definitely will not buy, 3: may or may not buy and 5: definitely will buy) and whether they regularly purchased or consumed biscuit or meat (pate) products. Participants were given the opportunity to leave additional comments after evaluating each package if they wanted to. In total, 7 samples were evaluated (3 biscuit packages and 4 meat packages in one session, but with a break between the two product categories). Samples were presented to consumers in a monadic balanced order using Williams design, with sample sets randomly assigned to consumers within each product category. The assessment took place in sensory booths as described in Section 2.2. Consumers were asked to not open the package during assessment. Data was collected using Compusense Cloud Software. The study was conducted in November 2019 and approved by the School of Chemistry, Food and Pharmacy Research Ethics Committee, University of Reading (study number: 51/19). Informed consent was obtained from all participants prior to the study.

2.4. Statistical Analysis

SENPAQ version 5.01 (Qi Statistics, Kent, UK) was used to carry out ANOVA of sensory panel data, wherein the main effects (sample and assessor) were tested against the sample by assessor interaction, with sample as a fixed effect and assessor as a random effect. For those attributes exhibiting significant difference in the one-way ANOVA, Fisher's least significant difference (LSD) test was applied to determine which sample means differed significantly ($p < 0.05$).

XLSTAT 2019.3.2 version (Addinsoft, Paris, France) was used to carry out the following analyses: (i) principal component analysis of the sensory panel data, (ii) one-way ANOVA (and Fisher's LSD test) for the consumer liking and purchase intent data (iii) analysis of the preference (ranking) data using Friedman's test; (iv) agglomerative hierarchical clustering (AHC) for overall liking and (v) penalty analysis of the JAR data for strength and naturalness attributes. In more detail, for the AHC, dissimilarity of responses was determined by Euclidean distance, and agglomeration using Ward's method (set to automatic truncation). For the penalty analysis, the influence of consumer perception of appropriateness of attribute level rating (JAR) on consumer liking was evaluated by calculating the mean drop in liking rating (scale 1–9) compared with mean liking of consumers that rated the attribute as JAR (JAR 3 on a 1–5 scale), determining whether this drop in liking score was significant.

3. Results

3.1. Sensory Evaluation of the Packages

3.1.1. Biscuit Packages

Table 2 summarises the mean panel scores of the sensory attributes for the three samples (B0, B1 and B2). All 15 attributes were significantly different between the original package (B0) and the two prototypes (B1, B2). Discrimination, repeatability and consistency were checked for all assessors (Supplementary Data, Table S1). In terms of the appearance attributes, B0 was evaluated as having a more complex design with more amount of text present on the packages because the two prototypes (B1 and B2) had no labels at the back of the package. B0 was quite slippery to hold and the sound of it was very noisy in comparison to B1 and B2. The colour of B0 was dark red and shiny, and the package was very rigid overall. After opening the packages, B0 had many more tears compared to B1 and B2, the inner lid was very shiny and the tray was very rigid, too. Panellists found B1 easier to hold but more slippery to hold compared to the B2 package. Both the B1 and B2 packages did not make any noise and had a matte outer package appearance. B1 was found easier to open compared to B0 and B2. Both B1 and B2 had very shiny inner trays but a less shiny inner lid compared to B0.

Principal component analysis was carried out on the correlation matrix of all samples and all attributes in order to graphically visualise the differences between the samples. The first two principal components accounted for all the variation in the data (Figure 1). The first axis (76.26%) mainly separated B0 from the two prototypes, whereas the second axis separated the two prototypes—B1 and B2 (23.74%). The majority of the attributes were positively correlated with the first axis and thus associated with B0. Important attributes included the complexity of the design, the amount of text, the brightness of the colour of the package, the noise of the package and the rigidity of the tray before and after opening the package. On the other hand, the two prototypes had a shinier inner tray and sharp edges. The B2 package had a rougher bottom surface, whereas B1 was easier to open.

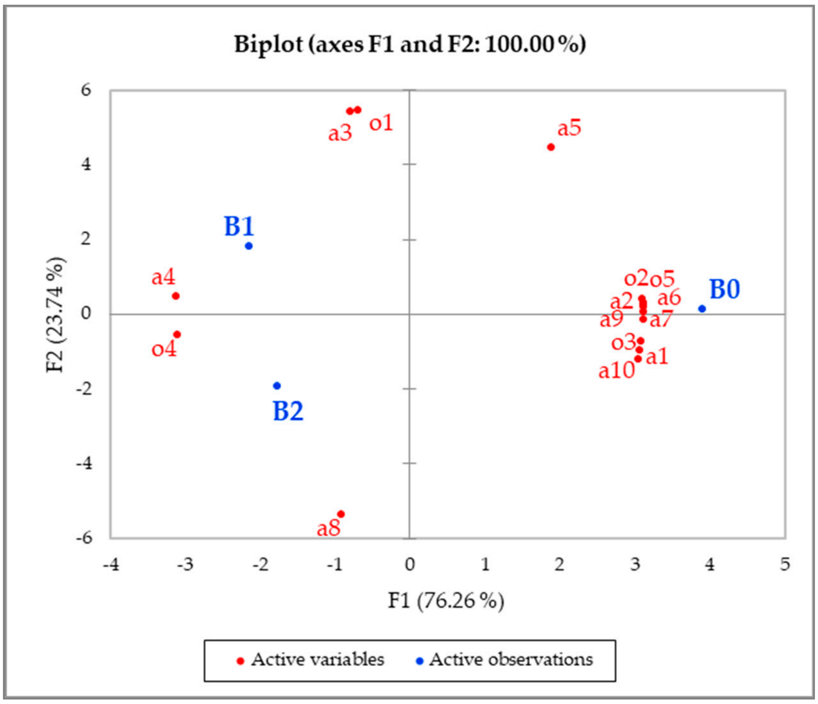

Figure 1. Principal component analysis of biscuit packages (B0, B1 and B2) showing correlations with sensory attributes (codes on plot refer to sensory attribute codes in Table 2).

3.1.2. Meat Packages

Table 3 summarises the mean panel scores of the sensory attributes for the four meat packages (M0–M4). All 16 attributes were significantly different among the original package and the three prototypes. It could be observed that the M0 was quite deep with a very shiny and rigid tray. The lid was quite tightly sealed on the top of the package, and overall, the package was quite stable when placed on a table. After opening the packages, M0 was quite easy to open but tears developed on the lid. The tray was still quite rigid even after removing the lid, and the inner tray was found to be less shiny compared to the other packages (M1–M3). The three paper-based prototypes (M1–M3) were less deep compared to the original package, had a cream colour and were not shiny. M3 was quite rigid before opening the package and exhibited similar scores to M0 in terms of the tightness of the lid and stability when placed on a table.

Similar to biscuit products, principal component analysis was carried out in order to graphically visualise the differences between the meat packages. The first two principal components accounted for 96.3% of the variation in the data (Figure 2). The first axis mainly separated M1 and M2 from M0, whereas the second axis separated M3 from the rest of the packages. Attributes positively correlated with the first axis, and thus associated with the M0 package, were the rigidity of the tray before and after opening the package, the shininess of the outer tray, the depth of the package, the tightness of the lid and sitting of the tray on the table. On the other hand, attributes negatively correlated with the first axis and thus associated with the M1 and M2 packages were the difficulty of separating the barrier and the difficulty of opening the package as well as the ability to hold the package and the level of slipperiness when holding the package. Transparency of the lid attribute positively correlated with the second axis and was negatively correlated with M4 packages because the lid was not transparent at all.

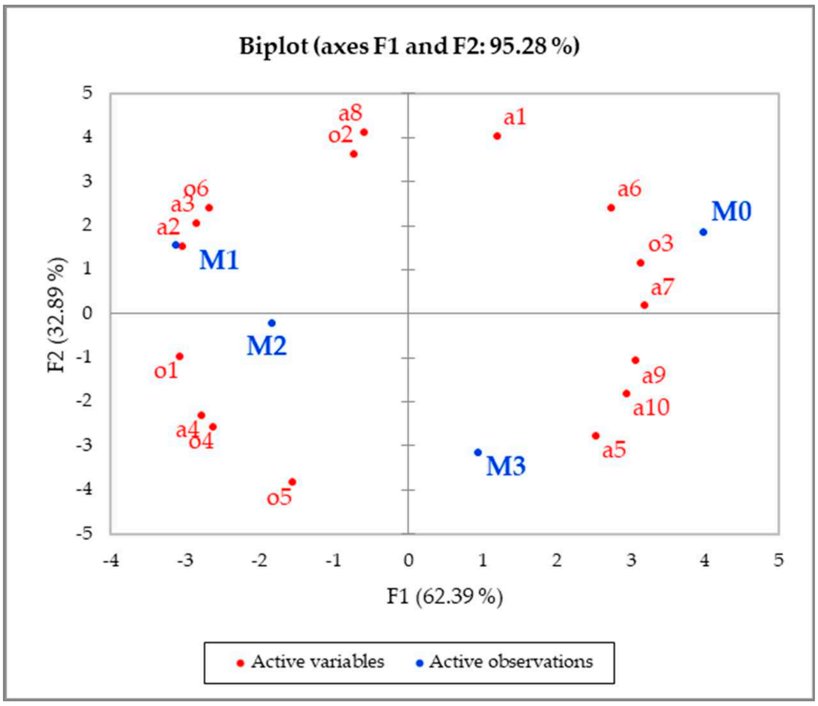

Figure 2. Principal component analysis of meat packages (M0, M1, M2, and M3) showing correlations with sensory attributes (codes on plot refer to sensory attributes codes in Table 3).

3.2. Consumer Evaluation of the Products

Table 4 summarises the demographic data for the consumers. One hundred and thirty consumers evaluated the samples. A higher proportion of the consumers were female (72.3%), and the mean and median ages were 32.8 and 29, respectively. More than one-third of the consumers were working (36.9%), and 58.5% were students. In total, 47.7% of the consumers that took part were people connected with the food, nutrition or sensory sector. The largest ethnic group to participate were White British (40%). The majority of the participants consumed or purchased biscuits sometimes or frequently (78.5%), whereas for the meat packaging, and particularly for pate (as this was the meat product inside the package), only 33.8% of the participants consumed or purchased it sometimes or frequently.

Table 4. Consumer demographics and characteristics of consumer panel.

Consumers	**Number**	**Percentage (%)**
Total number of volunteers	130	
Age		
mean	32.8	
median	29	
min	18	
max	66	
Gender		
male	36	27.7
female	94	72.3
Working status		
working	48	36.9
unemployed	0	
student	76	58.5
other	6	4.6
working in food/nutrition/sensory sector	62	47.7
Ethnic group		
White British	52	40.0
White other	35	26.9
Mixed	1	0.8
Indian, Pakistani, Bangladeshi	8	6.2
Chinese	11	8.4
African, Caribbean	3	2.3
Arab	6	4.6
Other	13	10.0
Not declared	1	0.8
Frequency of biscuit consumption/purchase		
Frequently (approx. once per week)	42	32.3
Sometimes (approx. once per month)	60	46.2
Rarely (less than once per month)	25	19.2
Never	3	2.3
Frequency of pate consumption/purchase		
Frequently (approx. once per week)	12	9.2
Sometimes (approx. once per month)	32	24.6
Rarely (less than once per month)	51	39.2
Never	35	26.9

3.2.1. Biscuit Products

The mean liking scores of the packages are presented in Table 5. The results show that there were no significant differences in the appearance, design, feel and overall liking for all the samples tested, with all results ranging between like slightly and like moderately. While consumers did not like any of the packages very much, the results showed that both original and new packages were liked at a similar level, which can be seen as a positive for the new paper-based packages, to some extent.

In order to identify relatively homogeneous groups of consumers, agglomerative hierarchical cluster analysis was conducted, and three clusters of consumers were identified (Table 6). Consumers in cluster 1 (40.8%) liked slightly the original package of the biscuits and less the paper-based packages (B1 and B2). Cluster 2 (50%), the largest cluster, liked all three samples, whereas cluster 3 (9.2%), did not like B0 but liked moderately the paper-based packages.

Consumers were also asked to rank the samples in order of overall liking with 1-most liked and 3-least liked (Table 5). The results from the Friedman's test showed that there was no significant difference in preference ranking of overall liking of all the three packages, a result that it is in agreement with the non-significant result obtained for overall liking.

Table 5. Liking scores, preference ranking and purchase intent for biscuit and meat packages.

Code	Liking [1]				Ranking [2]	Purchase Intent [3]
	Appearance	Design	Feel	Overall		
Biscuit packages						
B0	6.7	6.5	6.5	6.6	1.9	3.62b
B1	6.4	6.3	6.6	6.5	2.1	3.41ab
B2	6.3	6.4	6.4	6.4	2.0	3.35a
p-value	0.099	0.558	0.657	0.540	0.299	0.096
Meat packages						
M0	6.3a	6.4a	5.6a	6.1a	1.7a	3.33a
M1	4.8b	4.7b	5.0b	4.9b	3.0c	2.79b
M2	4.2c	4.5c	5.4ab	4.5bc	2.2b	2.35c
M3	4.0c	4.0c	4.4c	4.2c	3.0c	2.35c
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[1] Means not labelled with the same letters are significantly different ($p < 0.05$); means are from 130 consumers on a 9-point hedonic scale (from dislike extremely to like extremely). [2] Mean rank (1: most preferred to 3: least preferred). [3] Measured on a 5-point scale (1: definitely will not buy to 5: definitely will buy).

Table 6. Overall liking of the biscuit packages for the clusters of consumers obtained from agglomerative hierarchical clustering.

Cluster/Percentage of Consumers	Samples [1]			*p*-Value
	B0	B1	B2	
1 (40.8%)	6.3a	5.1b	4.7b	<0.0001
2 (50.0%)	7.4b	7.7a	7.7a	0.057
3 (9.2%)	4.2b	7.1a	7.3a	<0.0001
Overall liking	6.6	6.5	6.4	0.540

[1] Means not labelled with the same letters are significantly different ($p < 0.05$); means are from 53 consumers for cluster 1, 65 consumers for cluster 2 and 12 consumers for cluster 3, respectively. The mean for overall liking is from 130 consumers.

Penalty analysis was used to relate JAR data to liking scores and explain drivers of liking in relation to strength and naturalness, and the results are presented in Table 7. There was no significant difference in the JAR strength of the packages, and all three packages were perceived very close to Just-About-Right (JAR = 3). However, a significant difference was observed for the JAR naturalness, with packages B1 and B2 considered closer to Just-About-Right compared to B0.

When the attributes are not at the optimum level for a consumer this may have an effect on the overall liking. The penalty analysis showed that for samples B1 and B2 there was a negative impact on the overall liking when the strength of the package was considered too low. Similarly, for naturalness, there was a significant drop in the liking of all the packages when the naturalness of the package was considered to be 'too little' by the consumers with B1 considered to be the least natural of all the packages.

Finally, consumers were asked about their purchase intent of these packages (5-point scale: 1-definitely will not buy, 2-probably will not buy, 3-might or might not buy, 4-probably will buy and 5-definitely will buy). The mean scores of the purchase intent for all three packages ranged between 3.3-3.6 (Table 5), and a significant difference was observed ($p = 0.039$), with consumers more likely to buy B0 than B2. There were no significant differences between B1 and B2 ($p = 0.636$) or B0 and B1 ($p = 0.110$). Additional comments on the packages provided by the participants were both positive and negative. Some examples of those comments are shown in Table 8.

Table 7. Mean Just-About-Right ratings and influence on overall liking ratings.

Packages	Overall	Significance of Sample (p-Value)	Penalty Analysis Too Little Mean Drop	Too Little Frequency (%)	Too Much Mean Drop	Too Much Frequency (%)
Biscuit Packages						
	JAR Strength					
B0	3.03b	0.107	0.57	10.0	0.11	11.5
B1	2.87a		1.49 *	25.4	0.64	13.9
B2	2.91ab		2.08 *	22.3	1.03	14.6
JAR Naturalness						
B0	2.18a	<0.0001	1.05 *	63.9	−0.16	3.9
B1	2.82b		1.25 *	22.3	−0.24	9.2
B2	2.77b		2.49 *	24.6	0.69	6.9
Meat Packages						
	JAR Strength					
M0	3.14a	<0.0001	2.17	7.7	0.40 *	20.8
M1	2.47b		1.61 *	60.8	1.42	6.9
M2	2.37b		2.03 *	49.2	1.41	5.4
M3	2.31b		1.53 *	53.1	1.14	3.1
JAR Naturalness						
M0	2.12c	<0.0001	1.84 *	64.9	−0.39	4.6
M1	2.42b		2.19 *	54.6	1.1	7.7
M2	2.90a		1.99 *	53.9	0.82	6.9
M3	2.35b		2.04 *	24.6	0.37	17.7

* Represents a significant difference ($p < 0.05$) within a sample in overall liking compared with mean liking rating when the sample was considered Just-About-Right. Frequency (%) is the % of participants within each group.

Table 8. Examples of participants' comments (one positive and one negative comment) relating to the various packages.

Sample	Comments and Participants Details
Biscuit packages	
B0	*This package looks so common (IP60, female, aged 24). I would avoid this one if I was trying to reduce my waste and carbon footprint, unless it was advertised as biodegradable (IP70, female, aged 30).*
B1	*I think the paper packaging makes the product seem of a higher value than plastic (IP63, female, aged 22). Makes me think the quantity in the package might not be big enough (IP72, male, aged 29).*
B2	*Nice paper packaging and texture (IP78, male aged 36). Packaging seems a little bit too thick and heavy duty for a simple biscuit packaging (IP69, male, aged 18).*
Meat packages	
M0	*Film cover seems strong (IP21, female, aged 52). Looks like standard package, I just hate polystyrene (IP36, female, aged 46).*
M1	*Does look sufficiently sealed and would be prepared to buy if it was 'the norm' or environmentally friendly (IP38, male, aged 58). Looks cheap (IP22, female, aged 52).*
M2	*Package seems natural. No harmful toxic effects (IP23, female, aged 34). Not very eye catching (IP21, female, aged 52).*
M3	*Liked the natural feel of the paper tray (IP8, female, aged 21). Not a visible package (IP26, female, aged 24).*

3.2.2. Meat Packages

The mean liking scores of the meat packages are presented in Table 5. As can be observed, there were significant differences in all four liking dimensions. The appearance, design and overall liking of M0 were significantly higher than all the paper-based packages. No significant differences were observed between M2 and M3 for appearance, design or overall liking. In terms of the liking of the feel, the feel of M0 was significantly more liked than M1 and M3, but not M2.

Similar to the biscuits, AHC results are presented in Table 9 for the meat packages. Consumers in cluster 1 (27.7%) slightly liked the original package of the meat and disliked moderately to slightly the transparent film paper-based packages (M1 and M2), whereas they disliked very much the non-transparent paper-based package (M3). Cluster 2 (53.8%), the largest cluster, liked slightly M0 and M2, followed by M3 and M1. Finally, cluster 3 (18.5%) disliked very much the paper-based packages with transparent film (M1 and M2) and neither liked nor disliked the other two packages.

Table 9. Overall liking of the meat packages for the clusters of consumers obtained from agglomerative hierarchical clustering.

Cluster/Percentage of Consumers	Samples [1]				*p*-Value
	M0	M1	M2	M3	
1 (27.7%)	6.7a	3.8b	4.1b	2.1c	<0.0001
2 (53.8%)	6.3a	5.2c	6.0ab	5.6bc	0.0005
3 (18.5%)	4.8a	2.0b	2.8b	5.0a	<0.0001
Overall liking	6.1a	4.9b	4.5bc	4.2c	<0.0001

[1] Means not labelled with the same letters are significantly different ($p < 0.05$); means are from 36 consumers for cluster 1, 70 consumers for cluster 2 and 24 consumers for cluster 3, respectively. The mean for overall liking is from 130 consumers.

When consumers were asked to rank their preference in terms of overall liking, significant differences ($p < 0.0001$) were observed (Table 5). M0 significantly differed from all the other packages and was the most preferred. On the other hand, M1 and M3 did not differ significantly and were the least preferred of all. This result was again in agreement with the overall liking results discussed earlier.

Significant differences in Just-About-Right strength and naturalness attributes were observed for the four packages (Table 7). In terms of strength, M0 was perceived just above Just-About-Right (JAR = 3), whereas for the other three samples, the strength of the packages were considered 'not too strong'. For the naturalness attributes, the M2 sample was close to Just-About-Right, whereas the naturalness of M0 was considered 'not too natural'. The penalty analysis showed that for samples M1 to M3, there was a negative impact on the overall liking when the strength of the package was considered too low. Similarly, for naturalness, there was a significant drop in the liking of all the packages when the naturalness of the package was considered to be 'too little' by the consumers, with M0 considered to be the least natural of all the packages.

Finally, in terms of purchase intent, the mean scores for all the paper-based packages ranged between 2.4–2.8 (Table 5), which implied that consumers did not generally like the design of those packages. On the other hand, the purchase intent for samples M0 was at 3.3, between 'might or might not buy' and 'probably will buy'. Similar to the biscuit packages, participants' comments on the packages were both positive and negative, and examples of those comments are shown in Table 8.

4. Discussion

The present study aimed to (1) explore the sensory characteristics of the new paper-based packages developed during the study for two product categories (biscuits and meat) in comparison to the original packages, as assessed by a trained panel and (2) evaluate consumers' liking and perceptions of the said packages. The findings from this study build on and contribute to existing knowledge on consumer opinions and reactions to paper-based packaging material [27].

For the biscuit packages, no significant differences were observed for the liking of any of the four dimensions (appearance, design, feel or overall liking); however, consumer segmentation identified three relatively homogeneous groups of consumers exhibiting differences in hedonic reaction for the three packages. Even though no significant preference was observed ($p = 0.299$), consumers in each cluster varied in their responses. Consumers in cluster 2 (50%) "liked moderately" all three packages but seemed to "like significantly" more the new paper-based packages. Similarly, the paper-based packages were liked more by the consumers in cluster 3 (9.2%) who disliked the original package (B0). In a study conducted by Fernqvist et al. [11] exploring consumers' views on different aspects of fruit and vegetable packaging, the authors found that the design of the package was interpreted differently among participants. While some participants had a positive perception about the package, others had a negative opinion. Consumers were given the opportunity to add comments for the various packages, and it was clear that they appreciated the innovative packages of B1 and B2, and they loved the duo-pack design that meant a separation of the packages and that the consumption of a smaller portion was possible while keeping the other portion '*fresh, crisp and for longer*'. As expected, the paper-based packages had a more natural and sustainable feel when compared to the B0 package, and this was apparent from the Just-About-Right ratings and consumers' comments: '*it feels very natural*', '*it looks sustainable*', '*the packaging seems more natural and biodegradable*'. The results also demonstrated that there was a significant drop in the overall liking of the package when the naturalness was considered to be 'too little'. Prior research has shown that sustainability perceptions can be closely related to other benefits such as naturalness [13], which is a positive characteristic of sustainable packaging.

Focusing on the characteristics of the paper-based packages, it seemed that even though consumers liked the smoothness of the B1 bottom surface and its '*sustainable look and nice feel*', they thought the tray was not too rigid and was a bit fragile. This was confirmed from the sensory evaluation results, wherein trained panellists scored B1 significantly lower (43.7) for rigidity before opening the package compared to the original package (69.2), and also from the significantly lower score in terms of the JAR strength attribute. The perception of the rigidity of the package was further reduced to 30.8 after opening the package and removing the lid. On the other hand, the B2 tray had an embossed bottom surface, which consumers felt was 'easy to hold' and was seen as a positive characteristic. This was also confirmed by the trained panel wherein the level of perceived slipperiness was significantly lower (21.3) for B2 compared to the B0 and B1 samples. The perception of fragility may have had an effect on consumers' acceptability of the B1 package, as it may have been seen as a quality issue of the package that could affect its ability to protect its content.

There was also a cluster of consumers (cluster 1—40.8%) that significantly liked the original package compared to the new packages. These were consumers who preferred to go with what they were familiar with and were less keen to try new propositions. Some of the consumers in this group had comments such as '*love the compact design*', '*seems like the standard design so keen to buy*', '*I am familiar with this packaging*', '*it immediately reminds me of biscuits, which I like*'. Most consumers tend to be creatures of habit and unwilling to try new things, as found by Oloyede & Lignou [27]. In addition, consumers have an expectation of what the package design should be like and would generally be averse to trying designs that do not match the picture they have in their minds. Zhang et al. [19] reported that the design style or colour of the package of UHT milk was shown to have an influence on consumer attraction. The authors suggested that if consumers are more attracted to the design style or colour, their willingness to purchase will be higher. Ares and Deliza [17] showed that package shape and colour could have an impact on consumers' expected liking scores and their sensory expectations in a product category such as desserts, and similar results were demonstrated with this study. The relevance of package characteristics, in this case the shape of a standard biscuit package, had an effect on consumers' perception and acceptance and also on purchase intent. Consumers were more likely to buy the original package as earlier discussed.

Regarding the meat packages, significant differences were observed for appearance, design, feel and overall liking with subsequent significant preference of certain packages over others ($p < 0.0001$). In general, consumers liked the original package (M0) more than the paper-based packages (M1–M3); however, similar to the biscuits, consumer segmentation identified three clusters of consumers with varying overall liking for the four packages, which was clear from the comments they added. Consumers in the largest cluster (cluster 2—53.8%) equally liked M0 and M2 when compared to M1 and M3. Consumers felt that the polystyrene of M0 '*evokes hygiene—associated with meat*'. They liked the feel of the packaging, how sturdy and deep it was and the fact that the lid on top was not in direct contact with the meat. This result agrees with the findings of Oloyede & Lignou [27], wherein focus group participants were worried about contamination due to the top lid touching the meat. This was also confirmed by the trained panel, who scored significantly higher the depth of this package (72.6) and the rigidity before and after opening the package (94.6 and 93.2, respectively) compared to the other three packages. The overall liking in the other two clusters was mainly driven by whether the top lid was transparent or not. For example, consumers in cluster 1 (27.7%) disliked very much M3, equally disliked M2 and M3 and liked slightly M0, whereas consumers in cluster 3 (18.5%) equally disliked very much M1 and M2 and neither liked nor disliked M0 and M3.

Interestingly, no matter the cluster, the M1 and M2 packages had very similar characteristics in general, which was confirmed from the sensory evaluation. Both samples had a smooth bottom surface that resulted in significantly higher perceived ability to hold, level of slipperiness and very low rigidity before and after opening the packages compared to M0 and M4. Some consumers liked this feel and stated that it '*looked very neat*'. The only differences observed between the two packages was the difficulty of opening the package and the difficulty in separating the inner barrier, with both receiving a higher rating for the M1 package. Observing the results for the M3 package, it seemed that on one hand, consumers preferred the embossed packaging tray over the non-embossed due to the touch and feel of the paper, the sturdiness and the fact that it made the packaging look more attractive (5.6 hedonic liking for cluster 2 and 5.0 for cluster 3); however, it was clear that for certain consumers, the lidding material and its transparency was crucial (2.1 hedonic liking for cluster 1), as consumers in general prefer to see the content of the packaging [28], and especially when the product is meat. Transparent packaging has been shown to increase willingness to purchase, expected freshness and expected quality in different food categories (cereal, boxed chocolates, dried pasta and fresh fish) [29]. Consumers mentioned that there was a minimalistic feel associated with M3, and they liked the fact that it was all paper and no plastic; however, they worried that the paper package might absorb moisture or meat blood/liquid with time. These findings agree with the study by Magnier and Crie [2], who found that eco-friendly packages, because of their simplicity, minimalism and lack of colours, are often perceived as less appealing.

The results show that the positive and negative perceptions regarding the paper-based packages had an effect on the overall liking of the products, which in turn affected the purchase intent. The mean scores of the purchase intent for all three paper-based packages ranged between 2.4–2.8, which is between 'probably will not buy' and 'might or might not buy', implying that consumers did not generally like the design of these packages.

There are a couple of limitations to this study. Given the limited duration of the project, there was insufficient time to completely develop the packages and include all the relevant information regarding the labelling of the products. The biscuit packages, other than the red cover which had the same graphics as the original package, had no further information on the nutritional profile of the content or any information regarding the recyclability of the actual package. For the meat packages, the situation was even more complicated because there was no information at all about the product. Previous research has shown that consumers' responses to either visual or verbal responses can vary depending on cognitive resources [30]; however, in our case, no cues were provided to the consumers. Future research with packages having all the relevant information needed by the consumers printed on the package would allow for better comparisons, not only of the design and feel of the package/material but also the appearance and the messages to be delivered to the consumers.

5. Conclusions

The results from the sensory and consumer evaluation of the new paper-based packages clearly demonstrated that these packages were a good example of how paper can be used as an alternative to plastic or foil for the development of packages in product categories such as confectionery or chilled products. In summary, consumers liked the sustainable nature of the paper-based packages; however, they found the trays (particularly for the meat packages) to be flimsy and not strong enough. For the biscuits, they liked the innovative design of the double pack but also loved the compact design of the original package, as this was more familiar to them and looked like a standard pack of biscuits. The results showed that while consumers were open to sustainable propositions, other quality characteristics were key aspects that must be addressed if sustainable packaging is to become a viable option. From an industry point of view, considerations have to be based not only on the sustainable nature of the packaging material but also on the design and size of the packaging. This is because design and size of package are more important factors influencing consumer choice than the sustainable character of the packaging material. Thus, further work needs to be done to improve several quality characteristics (e.g., design and size of package), which would lead to better consumer acceptability.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/foods10050990/s1, Table S1: Summary table of assessor performance for biscuit and meat packages.

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Consumer Awareness, Attitudes and Preferences towards Heritage Cereals

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Abstract: Interest in heritage cereals is increasing among consumers, bakeries and farmers, and the trends point towards the local production of crops and connect to sustainability. The most known variety is spelt, which has opened up for old landraces such as Oland wheat. Heritage cereals have shown a higher resilience than modern varieties and have the potential to supply the market with alternative products that have an attractive cultural background. Delicious and nutritious products based on heritages cereals have a growing market potential. Consumers' attitudes and preferences to different products are affected by factors such as age, gender and education. The aim of this study was to investigate and analyse different consumer groups' awareness, attitudes and preferences toward heritage cereals. The number of respondents who participated in this study and answered the web-based questionnaire was 434. It can be concluded that most consumers are aware of heritage cereals. Geographic background had an influence, while academic background did not. Bread and pasta are the most consumed products and are regarded as the most popular future products to be based on heritage cereals. The most essential factors in bread are taste and flavour, followed by freshness and texture. The origin of the cereal and its health aspects are important; women are more concerned about the origin than men, while older consumers are more concerned about health. Older consumers are also more willing to pay extra for heritage cereal than younger consumers.

Keywords: heritage cereals; consumer attitudes; preferences and awareness

1. Introduction

Today's consumer trends are moving more towards the local and regional production of crops (e.g., ancient or heritage crops), mainly due to a rising interest in sustainability [1]. It has been shown that the taste experience of a product is of the greatest importance to the consumers. Furthermore, product claims, such as ancient, natural, organic, or local, are the most likely to have a positive impact on the consumer's preference and/or choice [2–5]. High acceptability has, for example, been shown for breads containing Kamut or spelt [6].

Despite the numerous genetic and historical data on the origins of agricultural products, there is no universal definition for modern and older cereals [7]. Ancient cereals, according to Giambanelli et al. (2013) [8], are represented by populations of primitive cereals, which were not subjected to any modern breeding or selection processes (e.g., emmer, einkorn and spelt). What are today named as landraces were originated by farmers using natural selection, consequently saving various seed types year after year [9–11]. For convenience, in this paper the term "heritage cereals" is meant to include ancient cereals, landraces and older varieties.

The pursuit of higher yields and the industrialisation of agriculture over the past 150 years, meant that heritage cereals were lost from many parts of the world [11–13]. For future sustainability, there is a need to build up resilient agricultural systems [13,14]. Heritage cereals have shown more resilience to drought or other extreme weather circumstances than the modern varieties, which in turn might contribute to a robust agricultural system [15,16].

There is currently a trend of revived interest in heritage cereals from consumers, artisan bakeries and farmers [6]. Farmers of organic crops are interested in certain agronomic traits in heritage cereals, which makes them suitable for organic production [17–19]. Additionally, the fact that they are often sold at a premium price makes the old varieties highly attractive for farmers [1,20]. Heritage cereals might as well supply the market with new types of products that have an attractive cultural background and connection to authentic stories. Storytelling is highly important for heritage cereals and their growers and is an influential "trademark" [21]. Moreover, the demand for locally produced food is increasing [22,23], and alternative types of distributional and sale systems have gained ground, i.e., "short food supply chains", in which the heritage cereals fit well. These short supply chains aim to redefine the producer–consumer relationship in terms of providing knowledge of the origin of the food [24]. In the case of Sweden, several initiatives promoting a direct contact between producer and consumer have emerged, with examples such as "Farmer's market", "Local Food Nodes" and "REKO-rings".

Encouraging the production and consumption of heritage cereals is in line with the Swedish food strategy and the current government goal to increase organic food production [25]. Cereal-based food products constitute a large and central part of the human diet and ancient cereals are suggested to possess health-promoting effects due to their unique nutritional content. Thus, the development of delicious products based on these ancient cereals may enhance the large market potential as well as boost the consumption of whole grain [1,26,27].

Consumers' attitudes and preferences for different kinds of products may differ according to factors such age, gender, education level and geographic background. For example, in the case of fruits and berries, it has been shown that sustainability aspects are of higher importance to women—mainly to younger women—than to men. In the case of bread consumption, Sandvik et al. [2] pointed towards a more traditional consumption structure among Swedish consumers, however, a lower consumption of rye and whole-grain bread could be observed among younger consumers. This is in accordance with other studies showing that older consumer groups are more concerned with health aspects in comparison to younger consumer groups [28]. Consumers with a higher educational level are more aware of the health aspects and are more receptive to trends [29,30], however, knowledge about the level of impact from education is low. Geographical and cultural backgrounds are further factors that might have an impact on the consumers. Thus, it is of interest to study awareness, knowledge and attitudes towards heritage cereals among different groups of consumers in higher education arenas.

2. Aim

The aim of this study was to investigate and analyse consumers' awareness, attitudes and preferences towards heritage cereals. A further aim was to study whether consumers differing in academic and geographic backgrounds varied in the mentioned aspects while taking age and gender into account.

3. Materials and Methods

3.1. Consumers

Swedish consumers from two different academic institutes in Sweden were invited to answer a questionnaire concerning awareness, attitudes and preferences towards heritage cereals. The academic locations were the Swedish University of Agricultural Sciences (SLU), which is a university with disciplines focusing on primary agricultural production, and Kristianstad University (HKR), which is a university with a multidisciplinary focus. The participants had to be affiliated with one of the universities, either as a student or as an employee. Participation was anonymous and voluntarily. To gain enough data for reliable statistical calculations, a minimum number of 100 adult consumers from each academic location aged 18 years or older was aimed for during the recruitment process [31].

3.2. Questionnaire

The web-based questionnaire was launched during the month of April 2019. The software, Eye Question (version 3.9.7, Logic 8, Elst, The Netherlands) was used for the data collection. The survey contained the following areas of investigation: (a) consumers' awareness and consumption of heritage cereals; (b) consumers' attitudes towards heritage cereals; (c) consumers' preferences of future products with heritage cereals. The different areas of investigation are given in Table 1. The full questionnaire is provided in Supplementary File S1.

Table 1. Areas and questions covered in the web-based questionnaire.

Investigation Area	Indicators Used
A. Consumers' awareness and consumption of heritage cereals	• Approaches and habits of consuming bread and cereal based products. • Awareness about different varieties of heritage cereals. • Types and popularity of bread consumed. • Accessibility, baking at home vs. purchasing site preference.
B. Consumers' attitudes towards heritage cereals	• Bread attributes that manipulate the choice of the bread. • Receptiveness for new sorts of bread and cereal products that are based on heritage cereals. • Willingness to pay more for bread and cereal products that are based on heritage cereals. • Main attributes that would influence the choice of bread and products that are based on heritage cereals.
C. Consumers' preferences of future products with heritage cereals	• Kind of heritage cereals that are most likely to be consumed. • Preference to accessibility: baking at home vs. purchasing sites.

3.3. Statistical Evaluation

The collected questionnaire data were processed using descriptive and analytical statistics. Mean values and standard deviations were calculated. A multiple comparison test was performed by one-way ANOVAs in conjunction with Tukey's Post-Hoc Tests to compare groups of consumers. For observed frequency data, a chi-squared test was performed to determine the level of significant differences between the expected frequencies and the observed frequencies. For all statistical calculations, the significance level was set to $p < 0.05$. SPSS (Version 23, IBM, New York, NY, USA) was used throughout the calculations. The free software, Wordle (wordle.net, IBM Corporation, New York, NY, USA) was used to generate a word cloud out of the words used to illustrate which type of bread the study group consumed.

4. Results

4.1. Consumers

The total number of participating consumers in the questionnaire was 434, of which 311 were women, 117 men and 6 X (unidentified). Details about the participants are shown in Table 2. From the total study population, 323 participants were affiliated with SLU and 111 participants were affiliated with HKR. The SLU participants consisted of 227 women, 92 men and 4 X. Age group 1 consisted of 120 participants, age group 2 consisted of 108 while age group 3 consisted of 95. The HKR participants consisted of 84 women, 25 men and 2 X. Age group 1 consisted of 37 participants, age group 2 consisted of 42 and age group 3 consisted of 32. Since there was a low number of participants in gender group X, the resulting data from this group have not been taken into consideration.

Table 2. Demographical distribution of the study population. Age in years.

Population Sector	Mean	Standard Deviation	Range
All	40.3	±15.0	19–91
Women	39.1	±15.0	19–91
Men	43.1	±14.8	21–74
SLU participants	40.1	±14.8	20–74
HKR participants	40.8	±15.7	19–91
Age Group 1	24.5	±2.6	19–30
Age Group 2	40.4	±5.6	31–50
Age Group 3	59.5	±6.8	51–91

4.2. Consumers' Awareness and Consumption of Heritage Cereals

To get insight about consumers' awareness concerning heritage cereal varieties, they were presented with different varieties of heritage cereals and asked to identify those that they were familiar with. Figure 1 presents the different varieties of heritage cereals and the frequencies of awareness within the different population sectors. Spelt was the most known variety among the different population sectors, while Halland wheat was the least known. No significant difference between the groups was shown in the awareness of spelt, while chi-squared tests showed that Halland wheat was significantly more (χ^2 = 5.98; $p < 0.05$) known to HKR than to SLU participants. Additionally, Oland wheat was significantly more (χ^2 = 9.47; $p < 0.05$) identified by the HKR participants, yet, it was the least known within age group 3. Furthermore, einkorn was significantly more (χ^2 = 5.97; $p < 0.05$) known to age group 1. Regarding the identification of varieties Kamut (χ^2 = 9.23; $p < 0.05$) and Halland wheat (χ^2 = 8.18; $p < 0.05$) there was significant difference in their recognition among the age groups, where they were the least known for age group 3.

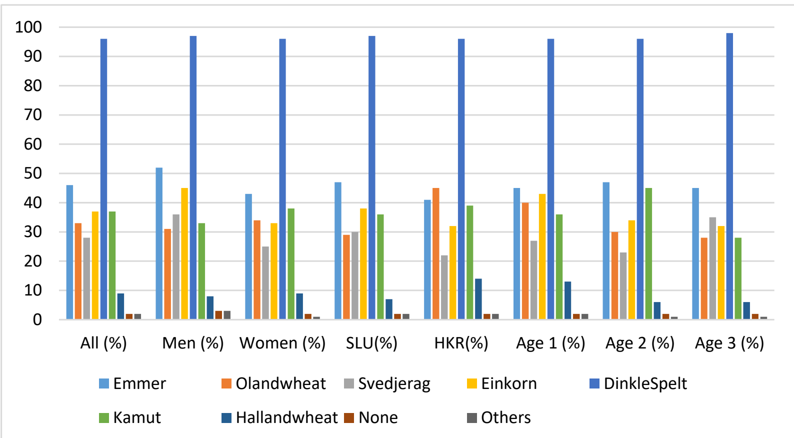

Figure 1. Frequency data given in percentages for each group showing the awareness of the different varieties of heritage cereals. The category "others" included black oat, quinoa, buck wheat, dala wheat, spring wheat, millet, naked oat, and teff. Swedish University of Agricultural Sciences (SLU), Kristianstad University, Sweden (HKR).

The popularity of the consumption of cereal-based products was investigated by the rate of consumption of the products on weekly bases, as shown in Figure 2.

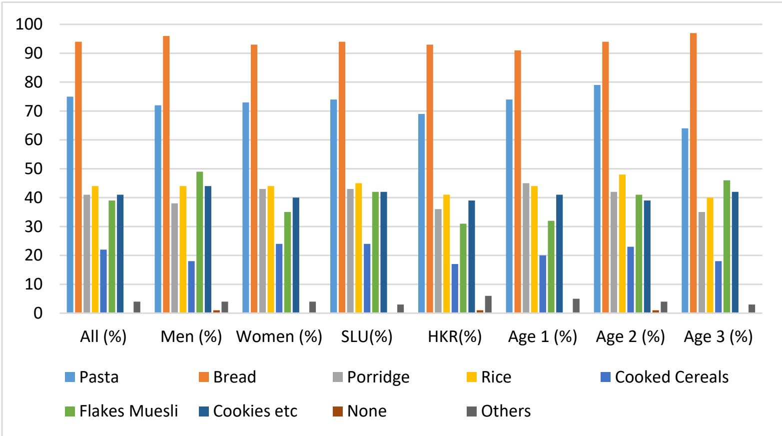

Figure 2. The frequency of consumption given in percentages for each group of cereal based products per week. The category "others" included couscous, rice cookies, crispbread, beer, pancakes, quinoa, millet, seeds, gluten free, buck wheat, and bulgur.

The responses to the question about the cereal products consumed at least once per week revealed that bread, followed by pasta, was the most consumed product among all categories of cereal-based products. Chi-squared tests revealed that the consumption of pasta was significantly lower in age group 3 compared to the younger age groups ($\chi^2 = 8.30$; $p < 0.05$). Flakes and Muesli were significantly more consumed by men ($\chi^2 = 6.66$; $p < 0.05$) among SLU participants ($\chi^2 = 4.56$; $p < 0.05$) and within age group 3 ($\chi^2 = 6.30$; $p < 0.05$). Figure 2 shows that more than 90% of the study population consumed bread. Figure 3 gives an indication of the most common types of bread consumed among the study population. Among the most widely consumed were crispbread, sourdough bread, sourdough dark bread, rye bread, whole grain and home-baked bread.

Figure 3. Illustration giving an indication of the popularity of bread types consumed. The figure is based on the qualitative data given in the questionnaire.

4.3. Consumers' Attitudes towards Heritage Cereals

Responses about the consumers' habits and attitudes when it comes to home baking compared to purchasing sites are illustrated in Figure 4, showing that purchasing at grocery stores was, according to one-way ANOVA, a significantly more common habit among the study population than home-baking or purchasing bread in a baker's store. There was no significance difference when comparing home-baking or purchasing at a bakery shop, nor was there significant different due to gender or academic institution. However, it was significantly more common to purchase bread at bakery shops in age groups 2 and 3 compared to age group 1 (*f* = 11.30; $p < 0.05$).

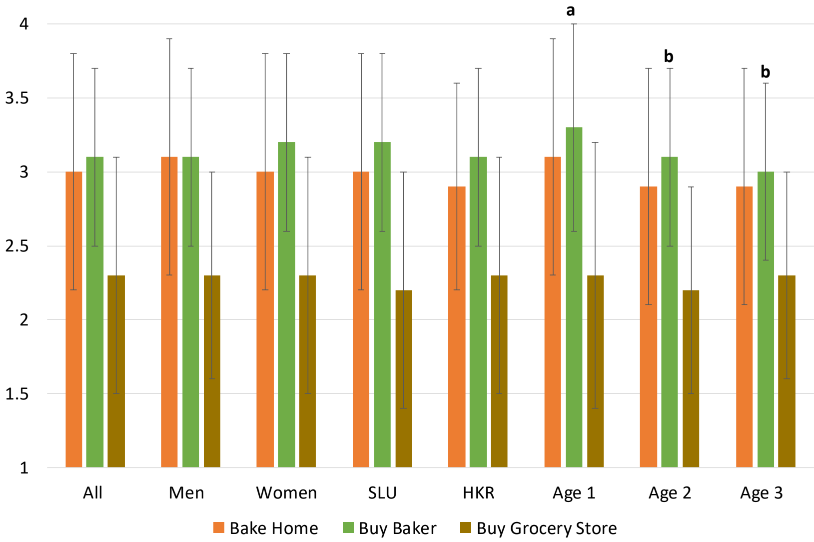

Figure 4. Mean and standard deviations showing trends of purchasing at different sites. Significant differences are indicated with different letters. The scale was 1–4, where 1 = always, and 4 = never.

Factors that govern consumers' preferences for products based on heritage cereals are presented in Table 3.

From Table 3 it can be inferred that Taste/Flavour and Freshness were the most important quality aspects of the bread. When comparing women to men, it was found out by one-way ANOVA that that texture (*f* = 8.82; $p < 0.05$), having the bread made with wholemeal flour (*f* = 14.54; $p < 0.05$) as well as the origin (*f* = 19.64; $p < 0.05$) of the cereal, were significantly more important factors to women than to men. On the other hand, the brand of the bread seemed to be the factor that was least thought about; however, age group 3 seemed to more concerned with this than the younger consumer groups.

When comparing the two institutions, it was found that bread features such as. its appearance (*f* = 4.32; $p < 0.05$), made by sourdough (*f* = 7.61; $p < 0.05$) and its freshness (*f* = 7.83; $p < 0.05$) were significantly more important to the participants from HKR compared to those from SLU.

When investigating bread attributes in relation to age, it was revealed that Odour/Aroma is significantly less important for age group 1 than for older age groups (*f* = 18.65; $p < 0.05$). Sourdough is significantly less important for age group 1 than for age group 3 (*f* = 5.58; $p < 0.05$). Wholemeal is significantly less importance for age group 2 than for age group 1 and age group 3 (*f* = 4.39; $p < 0.05$). The importance of the health aspects of the bread was significantly different among the groups, where it was the most important factor for age group 3 (*f* = 9.41; $p < 0.05$). Being an organic cereal was of significantly less importance for age group 1 than for age groups 2 and 3 (*f* = 12.94; $p < 0.05$). The importance of the price of the bread differed among the groups. Nevertheless, it was significantly of the most important to age group 1 and of the least importance to age group 3 (*f* = 17.27; $p < 0.05$). Freshness of the bread was significantly less important for age group 1 than for age group 2 and age group 3 (*f* = 12.13; $p < 0.05$).

In Table 3, the mean values and standard deviations are given as well as indications of significant differences.

Table 3. Mean and standard deviations showing the importance of essential characteristics of the bread. Significant differences are indicated with different letters. A 5-pointed scale was used where five was regarded as a very important factor, while one represented the least important factor.

Character	All M ± std	Men M ± std	Women M ± std	X M ± std	Age 1 M ± std	Age 2 M ± std	Age 3 M ± std	HKR M ± std	SLU M ± std
Taste/Flavour	4.7 ± 0.6	4.7 ± 0.5	4.7 ± 0.1	4.6 ± 0.9	4.7 ± 0.6	4.8 ± 0.6	4.8 ± 0.5	4.7 ± 0.6	4.7 ± 0.5
Freshness	4.3 ± 0.8	4.2 ± 0.8	4.4 ± 0.9	4.8 ± 0.4	4.1 ± 0.9 [a]	4.5 ± 0.7 [b]	4.5 ± 0.7 [b]	4.5 ± 0.8 [a]	4.3 ± 0.9 [b]
Texture	4.2 ± 0.8	4.0 ± 0.9 [a]	4.3 ± 0.8 [b]	4.2 ± 0.8 [ab]	4.1 ± 0.9	4.3 ± 0.7	4.2 ± 0.9	4.3 ± 0.8	4.2 ± 0.8
Origin	3.8 ± 1.2	3.4 ± 1.3 [a]	4.0 ± 1.1 [b]	3.4 ± 1.8 [ab]	3.8 ± 1.2	3.8 ± 1.2	3.9 ± 1.2	3.7 ± 1.3	3.9 ± 1.1
Odour/Aroma	3.7 ± 1.1	3.6 ± 1.0	3.7 ± 1.1	3.8 ± 1.3	3.3 ± 1.1 [a]	3.9 ± 0.9 [b]	3.9 ± 0.9 [b]	3.7 ± 1.0	3.7 ± 1.1
Health	3.6 ± 1.1	3.4 ± 1.1	3.7 ± 1.0	3.4 ± 1.9	3.3 ± 1.1 [a]	3.6 ± 1.8 [b]	3.9 ± 1.0 [c]	3.7 ± 1.1	3.6 ± 1.1
Wholemeal	3.5 ± 1.1	3.2 ± 1.2 [a]	3.7 ± 1.0 [b]	3.6 ± 1.7 [ab]	3.7 ± 1.2 [a]	3.6 ± 1.0 [b]	3.7 ± 1.0 [a]	3.7 ± 1.1	3.5 ± 1.1
Shelf life	3.3 ± 1.1	3.2 ± 0.9	3.3 ± 1.2	3.6 ± 1.7	3.3 ± 1.1	3.4 ± 1.1	3.3 ± 1.1	3.4 ± 1.1	3.3 ± 1.1
Sourdough	3.1 ± 1.2	3.1 ± 1.2	3.1 ± 1.2	3.0 ± 1.4	2.9 ± 1.3 [a]	3.1 ± 1.2 [ab]	3.4 ± 1.1 [b]	3.4 ± 1.3 [a]	3.0 ± 1.1 [b]
Appearance	3.1 ± 1.1	3.0 ± 1.1	3.2 ± 1.1	3.0 ± 1.0	3.0 ± 1.1	3.2 ± 0.9	3.2 ± 1.1	3.3 ± 1.0 [a]	3.1 ± 1.1 [b]
Price	3.1 ± 1.0	3.0 ± 0.9	3.1 ± 1.0	2.8 ± 2.8	3.4 ± 1.0 [a]	3.0 ± 1.0 [b]	2.7 ± 0.9 [c]	3.1 ± 1.1	3.0 ± 1.0
Organic	2.8 ± 1.3	2.6 ± 1.4	2.9 ± 1.3	3.8 ± 0.8	2.4 ± 1.2 [a]	3.1 ± 1.3 [b]	3.0 ± 1.3 [b]	2.9 ± 1.3	2.8 ± 1.3
Brand	2.1 ± 1.1	2.0 ± 1.1	2.1 ± 1.1	1.2 ± 0.4	2.2 ± 1.1	3.0 ± 1.1	3.0 ± 1.1	2.1 ± 1.1	2.1 ± 1.1

Significant differences are indicated with different letters. SLU: Swedish University of Agricultural Sciences; HKR: Kristianstad University, Sweden; M: mean; std: standard deviation.

On the question: "May you consider purchasing bread or other products that are based on heritage cereals?", as many as 98.4% of the study population responded to consider purchasing bread products based on heritage cereals.

4.4. Consumers' Preferences of Future Products with Heritage Cereals

To explore the future willingness of the study population to purchase cereal products based on heritage cereals, they were presented with set of product categories and were asked which product or products they would consider purchasing. The categories are presented in Figure 5. When comparing gender, the chi-squared test showed that the willingness to purchase porridge was significantly higher among women than men (χ^2 = 7.45; $p < 0.05$). When comparing age groups, it was revealed that age group 3 was more likely to purchase bread and significantly less probable to purchase pasta when compared to younger age groups (χ^2 = 21.16; $p < 0.05$). A similar pattern was seen for the purchase of porridge (χ^2 = 10.47; $p < 0.05$), cooking cereals (χ^2 = 14.86; $p < 0.05$) and cookies (χ^2 = 9.57; $p < 0.05$). On the other hand, participants in age group 2 were significantly more likely to purchase flakes (breakfast cereals) (χ^2 = 7.73; $p < 0.05$) and flour (χ^2 = 9.56; $p < 0.05$). Bread was the most popular product to be considered purchasing. No differences were observed between SLU and HKR participants.

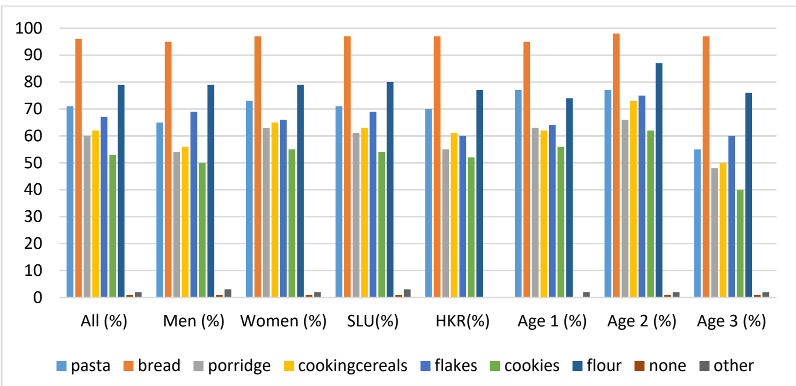

Figure 5. Future willingness to purchase heritage cereal products. The category "others" includes drinks, smoothies, beer brewing, alcoholic beverages and everything today that is done by modern cereals.

To be able to get a deeper understanding of the population preferences regarding the accessibility of heritage cereal products, the participants were asked about the location where they would prefer to purchase products. The set of locations are presented in Figure 6. Grocery stores were the most popular site for purchasing, followed by the bakery. However, according to chi-squared analysis, there was no significant difference among group categories. Only some respondents chose the category "others".

Figure 6. Preference of purchasing sites for heritage cereal products in the future. The category "Others" included the following options: Delivery to home/to work, REKO-ring, on-line/online store, directly from producer/grower, café, farm shop, bake yourself and market.

The willingness to pay more for products based on heritage cereals was a common attitude in the different groups of the study population, being more pronounced in age group 3. The chi-squared test showed that age group 1 was significantly the least willing to pay more for products based on heritage cereals in comparison to the other groups ($\chi^2 = 9.89$; $p < 0.05$), as shown in Figure 7.

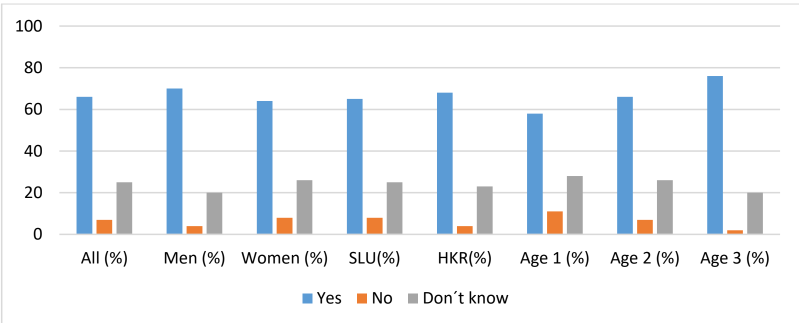

Figure 7. Frequency in percentages showing willingness to pay more for heritage cereal products.

5. Discussion

This study shows a great consumer interest in heritage cereals, where almost all consumers would consider purchasing bread or other products based on heritage cereals. This may be explained by the health trends and their relation to heritage cereals [32]. Furthermore, this great interest is well supported by respondents' abilities to identify different varieties of heritage cereals (e.g., more than 95% were aware of the variety spelt). This predominance could, to some extent, be explained by the fact that spelt has a very long history and was used as staple cereal thousands of years ago [33–35], and it has been shown that the acceptance of spelt is high among consumers [6]. Over the last few decades, spelt has become more commonly used in baking, and the addition of spelt flour during bread-making gives unique sensory characteristics to the bread (e.g., makes the bread stiffer as well as giving it a prolonged shelf life) [36]. About 40%–50% of the respondents were familiar with other varieties (e.g., emmer, Kamut and Oland wheat). The high percentage of awareness amongst the respondents could probably be explained by their academic background and that many of them belonged to agricultural and food studies departments. Robinson [32] explained European that consumer interest and awareness is influenced by mainstream media, which consequently has become the driving demand for flours from heritage cereals. Swedish consumers, however, are more likely to be influenced by social media and influencers such as Adam Arnesson (@ekobonden), Sebastien Boduet

(@sebastienboduet) and many more. It is inferred that respondents from the academic institute HKR had a higher awareness of Oland wheat and Halland wheat compared to SLU, which could be related to the geographic location of the academic institute, where HKR is situated closer to areas where these varieties are cultivated.

It is noteworthy that bread and pasta are the most consumed cereal products. These are also the products that the respondents indicated as most suitable for future heritage cereal products and which they were most willing to purchase. The phenomenal product recognition, in this case bread and pasta, is well known, and for food innovations a combination of recognition, quality, tradition and social approval are very important factors for consumer acceptance [37]. This could also explain the oldest group's lower interest in pasta.

This study showed that the most important factors for bread are taste and flavour. This is supported by rising consumer interest for better and more authentic flavours [32,38]. Freshness and texture are other important factors and, according to the respondents, they are more important than other factors, such as health factors, being organic and origin. This is in line with other studies that have reported the importance of flavour and other sensory attributes [28,39]. It was also established that health factors are more important to older consumers than to younger ones [29], an observation that is supported by the results from this study where the oldest consumer group regard health aspects as significantly more important than the younger group.

It is reported that Sweden has a fairly high consumption of organic products [40,41], thus it was surprising that the current study has signalled that the younger respondents regarded a cereal being labelled "organic" less important than the older consumer groups. "Locally produced" has recently been shown as more important to the consumers than "organic farming" [22], suggesting that organic farming would require more land than conventional farming and, in that respect, contribute more to climate change [42].

The word cloud illustration in Figure 3 points out wholegrain as a popular type of bread, which is in line with Kyrø, et al. (2012) [26] who reported on the consumption of bread in the Scandinavian countries during the 1990s, showing that rye contributed the most to the whole-grain intake: in Denmark about 70%; in Sweden about 50%; in Norway only about 20%. Furthermore, the total whole-grain consumption among different Swedish consumer groups were as follows: white-bread consumers had a mean total intake of 38 g/day; whole-grain bread consumers reported 45 g/day [2]. This supports the current study findings that the participants reported crispbread as the most consumed type of bread. Likewise, sourdough bread was reported to be commonly consumed; more common than white-bread and toast-bread. It should be highlighted that the consumers in the current study were affiliated with universities and, therefore, might have had a higher awareness about the role of whole-grain and sourdough for human health. The potential of sourdough to obtain healthier cereal products is becoming increasingly known [43].

In the current study, and based on the above discussion, it is evident that age is a critical factor. For instance, younger consumers are more aware of heritage cereals and different varieties than older consumers. This high-level of awareness is reflected by younger consumers showing a greater interest in natural agricultural products [44]. The younger group was also more sensitive to price and significantly fewer young respondents were willing to pay more for heritage cereals compared to respondents in the older consumer groups, which could be explained by differences in economical levels. Similarly, Hwang [45] showed that older consumers are more willing to pay a higher price for food when they are motivated to do so. This is in line with the results in this study where the older consumers were willing to pay a higher price for products based on heritage cereals than younger consumers. The same pattern could be seen in the habit of purchasing bread at the bakery, which was more frequent among the older consumers.

Another important factor for the older consumer group was the health aspects. Kraus et al. [30] found that food health aspects are of greatest importance for women and older consumer groups in studies on functional food. Gender difference was more obvious when studying the importance of consuming wholegrain products and knowledge about the origin of the cereal. In these assessments it was found out that women considered those as more important factors compared to men. This is also in line with Kraus et al., whose studies show that women are more concerned about nutritional aspects and consuming natural products than men. Moreover, women consumed less muesli and breakfast cereals than men, yet ate more porridge compared to men.

Regarding the groups differing in academic background, it could be seen that the sites' geographies seemed to influence the awareness of varieties of heritage cereals. The site of the academic institute seemed to have an impact, mainly on the awareness of different types of heritage cereals, which correlates with a study showing a high awareness of the importance of regional products among consumers [46]. Further, the results indicate that respondents affiliated with SLU consumed more muesli and flakes compared to HKR affiliates, while for respondents from HKR the factors appearance, sourdough and freshness were of higher importance than for those from SLU. These differences and the differences in awareness between academic sites could be due to the fact that HKR has a multidisciplinary focus with research and teaching within many subjects. Therefore, it is possibly more open to influences from a broader number of different disciplines compared to the agricultural focus at SLU.

Limitations: It should be noted that a limitation of this study was the unbalanced sample sizes of the consumer groups. The gender group X (unidentified sex) consisted of only six consumers, thus this group was too small to imply any relevant results and was, therefore, kept out of analysis. It should as well be noted there was an uneven sample sizes regarding men and women, as well as consumers belonging to the different academic institutes. To compare the frequencies of groups, the percentages of frequencies were calculated. It should be noted that a larger sample size of women is common in consumer studies [39,47,48]. Further, it should be noted that the two participating universities differ in size, where SLU is substantially larger than HKR.

6. Conclusions

It could be concluded that most consumers are aware of heritage cereals, where dinkle/spelt is the most well-known variety. Other varieties such as emmer, Kamut and Oland wheat were known by approximately 50% of the consumers. The geographic location of the academic institutions seemed to influence the awareness of heritage cereal varieties. The focus on academic background seemed to have only minor influence on attitudes towards heritage cereals. Bread and pasta are the most consumed products and are also regarded as the most potential future products that could be based on heritage cereals. With regards to bread, the most important factor is taste and flavour, followed by freshness and texture. Cereal origin and health aspects are of importance, however, women are significantly more concerned about the origin of the cereal than men, while older consumers are more concerned about health aspects of cereals and cereal-based products. Older consumers are also significantly more willing to pay more for products based on heritage cereal than younger consumer groups.

Supplementary Materials: The following are available online at http://www.mdpi.com/2304-8158/9/6/742/s1, File S1: Consumer Questionnaire.

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Article

Millennials' Consumption of and Attitudes toward Meat and Plant-Based Meat Alternatives by Consumer Segment in Finland

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Abstract: Millennials are considered the key generation with regard to the consumption of plant-based meat alternatives via flexitarianism. This study sought to characterize millennials' consumer segments based on their consumption of and attitudes toward meat and meat alternatives. We conducted an online survey on the hedonic tones of the associations evoked by meat and meat alternatives, consumption of such foods, and diet-related attitudes among a representative sample of Finnish millennials (N = 546, 59% women, age 20–39 years). Some 41% of respondents regularly ate plant-based meat alternatives, while 43% had tried such foods. We divided the respondents into six segments based on the hedonic tones of their meat vs. meat alternatives associations. The segments differed in terms of their consumption of meat alternatives and the underlying reasons why, importance of meat in meals, and Meat Commitment Scale scores. The segment that reported much more positive associations with meat than meat alternatives (~14% of the respondents) may prove resistant to interventions intended to reduce meat intake, whereas the segment that displayed the most positive attitudes toward meat alternatives (~18%) did not eat much meat. Thus, the four middle segments (totaling ~68%), whose associations' hedonic tones were close to each other, may be the best targets for future interventions designed to reduce meat consumption through the use of meat alternatives. To conclude, introducing a simple segmentation allowed us to identify consumer segments with large potential to reduce meat consumption.

Keywords: acceptance; consumer segmentation; flexitarian; meat analogue; meat substitute; online survey; plant-based protein; sustainability; vegan; vegetarian

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1. Introduction

The need for more environmentally sustainable alternatives to meat (and especially to red and processed meat) is increasing due to planetary boundaries (i.e., global biophysical limits for safe operating space in, e.g., climate change, biosphere integrity, land-system change, and freshwater use [1]) limiting the capacity to produce more meat for the increasing global population [2]. In addition, while meat is an important source of nutrients, especially protein, heavy meat consumption may have adverse effects on human health (for a review, see [3]). The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems stated that the "transformation to healthy diets by 2050 will require substantial dietary shifts, including a greater than 50% reduction in global consumption of unhealthy foods, such as red meat and sugar" [2]. This goal will likely prove difficult to achieve, as global meat consumption (both the average per capita and total consumption) continues to rise [3].

Food products that are made of protein-rich nonanimal sources intended to resemble meat and that are used instead of meat are often referred to as meat analog(ue)s, meat substitutes, or meat alternatives. In the literature, these terms are generally used synonymously [4], although their definitions do sometimes differ among authors. The term meat analogue has been commonly used in recent reports on the production of such products using extrusion technology [5–11]. For instance, Kumar et al. [12] defined a meat analogue as "a food product that approximates the aesthetic qualities and/or chemical characteristics of certain types of meat. These are made from non-animal protein and their appearance and smell are very much similar to meat". Dekkers et al. [13] considered functionality alongside sensory properties and defined meat analogues as "products that can replace meat in its functionality, being similar in product properties/sensory attributes, and that can also be prepared by consumers as if they were meat". Moreover, the terms meat analogues and meat substitutes are often used to refer to products that more closely resemble meat in terms of their sensory properties than meat alternatives, a term that is used in a broader sense to refer to alternatives to meat. For example, Elzerman et al. [14] defined meat substitutes as "products that were developed to be eaten instead of meat" (e.g., vegetarian sausages and steaks) and meat alternatives as "other products that are often eaten as protein source in vegetarian meals, such as pulses and nuts". However, Choudhury et al. [15] regarded plant-based meat alternatives as a "sustainable source of proteins that can match the taste and texture, color, and nutritional profile of specific types of meat". Based on the previously mentioned studies, it appears that a consensus has not yet been reached concerning the terminology for these products.

Meat intake can be reduced in many ways and with proteins derived from many sources: using conventional vegetarian foods (e.g., pulses), hybrid meat products (containing both meat and plant-based ingredients) [16], and meat alternatives. The most commonly used alternative protein ingredients originate from plants (especially soy, pea and other legumes, oilseeds, and wheat), fungi (mycoprotein), insects, and algae (macroalgae and microalgae) [4,17,18]. In addition, cultured meat (in vitro meat) is regarded as an alternative to meat from livestock [4,17]. To distinguish among the different protein sources and so render the utilized term more precise, the source of the protein is sometimes included, for example, in plant-based meat alternatives. This term has been used to refer to commercial products in several recent reports, including some consumer studies [4,15,19–23]. Likewise, we used the term plant-based meat alternatives in the present study because it focused on respondents' orientations specifically toward plant-based alternatives to meat.

Plant-based proteins appear to be the most widely accepted meat alternatives/alternative proteins from the perspective of consumers [23,24]. Gómez-Luciano et al. [25] investigated the willingness to purchase three types of meat alternatives (plant-based proteins, cultured meat, and insects) on the part of consumers from four countries with dissimilar economic developmental statuses (the United Kingdom, Spain, Brazil, and the Dominican Republic) and found plant-based proteins to be the most preferred option. Similarly, Lundén et al. [26] reported Finnish consumers to prefer plant-based ingredients when compared with ingredients of insect or microbial origin.

Importantly, modern meat alternatives are targeted not only toward vegans and vegetarians but also toward flexitarians [15]. According to Dagevos [27], "a flexitarian abstains from eating meat occasionally without abandoning meat totally". He concluded that flexitarians are not a homogeneous group that follow a strict diet; rather, they represent a middle category between consumers who regularly eat meat and those who fully abstain from it [27]. In the absence of a strict definition of what flexitarian exactly means, it is understandable that Dagevos's review found the proportion of flexitarians to vary widely across studies, ranging from 11% to 66% [27]. Regardless of this variation, the number of flexitarians is likely to be substantially higher than the number of those who totally abstain from eating meat. Indeed, vegetarians and vegans represent only a low percentage of consumers in most countries [28], accounting for ~5% of consumers in the United States (2018) [29], 2.5% in France (2018) [30], and ~2% in Finland (2017) [31]. Therefore, flexitarianism is likely to make a substantial contribution to reducing meat consumption at the population level. However, flexitarians are a heterogeneous and rarely studied group [27]. Thus, further research on both flexitarians and prospective flexitarians is required to successfully implement strategies for reducing meat consumption [32].

The millennial generation (or millennials, who are also referred to as Generation Y) are young(ish) adults who are considered to be more knowledgeable and concerned about environmental issues than older generations [33,34]. Therefore, millennials have been the target group in recent studies concerning food sustainability [35,36]. While there is no widely accepted definition of millennials, they are often considered to be people who reached adulthood during the early 21st century, that is, the people who were born during the 1980s and 1990s [37]. Millennials also represent an important consumer group because many are presently the parents of young children, and the parents' role is essential in terms of mediating the food consumption habits of their children [38].

Meat alternatives have the potential to grow from being niche products into mainstream ones [39]. According to the Food Sector Report by Smart Protein project [40], in Europe, the sales value of plant-based food increased by ~50% from 2018 to 2020. Yet, while the sales of plant-based meat alternatives are growing rapidly, in the United States, for example, they accounted for only around 1% of the value of all retail meat sales in 2019 [15]. In 2017, based on a review of 38 articles (published in 2004–2016) concerning consumers' sustainable protein consumption, Hartmann and Siegrist [41] concluded that consumer awareness of the environmental impacts of meat production and consumers' willingness to reduce meat consumption were, on average, low. Nevertheless, the market for plant-based meat alternatives is evolving rapidly, and many new companies producing meat alternatives have been founded in recent years. In fact, according to Choudhury et al. [15], more than half of all companies producing meat alternatives were founded in the last 10 years [15].

Onwezen et al. [23] recently conducted a systematic review of studies on consumer acceptance of alternative proteins. They found that the main product-related motives/barriers with regard to the use of plant-based meat alternatives stemmed from ethical, environmental, health, nutritional, and sensory aspects, in addition to familiarity/previous experiences of the products. Furthermore, the main psychological factors of relevance to the acceptability of meat alternatives were consumers' attitudes and beliefs regarding the products as well as food neophobia [23].

It is important to note, however, that the drivers and barriers concerning the use of plant-based meat alternatives are not the same for everyone, which means that an intervention that works for one consumer segment may not be effective for a different segment [42]. Therefore, it should prove useful to achieve the meaningful segmentation of consumers and then to investigate the differences among the segments.

Consumers can be classified simply based on whether or not they eat meat alternatives. Hoek et al. [43] reported that the key barriers for nonusers of meat alternatives were unfamiliarity with the products and their lower sensory attractiveness when compared with meat. To make meat alternatives more attractive to nonusers, the authors recommended improving the sensory quality and resemblance to meat, rather than highlighting ethical arguments, because such arguments only motivated heavy users of meat alternatives. The resemblance to meat was also identified as a desirable feature for meat alternatives by Michel et al. [20]. This feature appears to be especially important for light users of meat alternatives, as the desire for similarity decreased with increasing consumption frequency in the study by Hoek et al. [43].

Consumers can also be segmented by means of a multivariate data analysis of their responses to a set of questions. For instance, Lacroix and Gifford [44] identified three consumer groups using a latent profile analysis: "meat-reducers", "moderate-hindrance meat eaters", and "strong-hindrance meat eaters". Furthermore, Lemken et al. [42] searched for clusters within consumer data from Germany and New Zealand using a latent class analysis and identified five clusters in each country (three clusters were common to both countries, while two were unique for each country). Recently, Götze and Brunner [45] segmented a sample of Swiss consumers into six segments via a hierarchical cluster analysis.

While the consumer groups included exclusive meat-eaters and meat-avoiders, the majority were found to lie between those extreme segments. In Finland, Niva and Vainio [46] recently studied consumers' past, current, and intended future consumption of beef, plant-based protein products, and insect-based products. Using latent class analysis they identified five clusters of consumers, two of which (totaling ~46%) were characterized by consuming both beef and plant-based protein products. The findings of these studies are in accordance with the results of Dagevos [27] and confirm the existence of a remarkable proportion of flexitarians.

The present study sought to characterize the consumption of meat and plant-based meat alternatives as well as to provide in-depth insights into the underlying motives in this regard among various consumer segments of millennials. Based on this knowledge, we further aimed to draw conclusions regarding the potential of the segments to replace meat with meat alternatives in their diet. To achieve these aims, we conducted an online survey among a representative sample of Finnish millennials. In Finland, plant-based meat alternatives are widely available in grocery stores (brands including PulledOats, Härkis, and Beanit), making it reasonable to run this survey in the country. The criteria for the different consumer segments were defined in such a way as to allow other researchers to replicate the segmentation in future studies.

2. Materials and Methods

2.1. Overview

We conducted an online survey that was jointly designed by all the authors, initially in English. The text of the survey was then translated into other languages as required to be used in Germany, Finland, France, and the United Kingdom. The first results of the survey conducted in Germany, France, and the United Kingdom have been reported by Michel et al. [47]. Here, we report results based on data collected in Finland. These data are being reported separately because in Finland we studied the millennials whereas in the other countries respondents' age range was wider (20–69 years, [47]) and because the questionnaire used in Finland differed somewhat from the questionaries used in the other countries. More specifically, the Finnish version included most but not all the parts of the original survey (e.g., the questions featuring pictures were excluded). The English version was translated into Finnish by four of the authors, who were all native Finnish speakers (A.K., K.J, T.S-S., and V.P.), and a research assistant from the University of Helsinki.

2.2. Data Collection

The required data were collected from millennials who lived in Finland. For this study, we decided to define millennials as people who were aged from 20 to 39 years at the time of the data collection (i.e., born in 1980–1999). Thus, we used age as the inclusion criterion for the study.

The nationality and ethnicity of the respondents were not probed in the survey. However, we assumed that virtually all the respondents were Finnish, as the invitations to the survey were only sent to people living in Finland and the text of the survey was solely in Finnish.

We employed a market research company (Taloustutkimus Ltd., Helsinki, Finland) to conduct the data collection in order to achieve a representative sample of millennials from among the general population of Finland. The company had its own online panel of preregistered volunteers, who were regularly invited to respond to surveys. Taloustutkimus was aware of the demographics of the registered panelists and, therefore, could invite defined samples from the panel to participate in survey studies. We provided the questions and response options for our survey to the company, which then collected responses from its online panel over the course of a week (20–26 November 2019) and provided us with data from 550 individuals.

The key concept featured in the survey was "meat alternative". However, at the time of the study, there was no established translation of this term in Finnish. We decided to translate "meat alternative" into Finnish as "kasviproteiinituote", although the Finnish term refers to meat alternatives made solely of plant-based proteins (the Finnish words "kasvi", "proteiini", and "tuote" denote "plant", "protein", and "product", respectively) and so excludes other kinds of meat alternatives (such as those made of microbial proteins, whey, insects, or cultured meat).

The survey included both validated scales described in the prior scientific literature and additional questions designed specifically for this study. Lists of the questions/scales from the survey and their response options are presented in Tables 1 and 2, wherein they are grouped thematically. Table 1 includes questions related to diet and hedonic tone concerning meat and meat alternatives and their consumption, as well as drivers and barriers associated with their consumption. Table 2 contains questions derived from published scales measuring attitudes and food-related behavior. The text of the survey in Finnish is available in the (Supplementary Materials Table S1). The survey also included a few questions that were beyond the scope of the present study and, thus, are not reported here. The age and gender of the respondents were provided by Taloustutkimus from its registry.

Table 1. Survey questions 1–9: specific questions on diet, education, hedonic tone, consumption of meat and meat alternatives, reasons for use/nonuse, and importance of meat in meals and for guests.

No.	Question [1]	Response Options
Q1	Diet	Omnivore; Flexitarian; Pescetarian; Vegetarian; Vegan
Q2	Education in years [2]	(Number of years)
Q3 [3]	Hedonic tone (valence) of the first association with meat	11-point scale from "Extremely negative" (−5) to "Extremely positive" (+5)
Q4 [3]	Hedonic tone (valence) of the first association with meat alternatives	11-point scale from "Extremely negative" (−5) to "Extremely positive" (+5)
Q5	"How frequently do you eat (1) meat (pork, poultry, beef, ham, sausages, etc.) and (2) meat alternatives?"	Never or rarely; 1–3 times per month; 1–3 times per week; 4–6 times per week; Daily; More than once per day
Q6	"Do you eat plant-based meat alternatives?"	"Yes, on a regular basis"; "I have sampled meat alternatives, but do not eat them on a regular basis"; "No"
Q7a	"Why do you eat plant-based meat alternatives regularly?" (only if the response to Q6 was "Yes, on a regular basis")	Check all that apply from among 8 options (including an "Other reason" option)
Q7b	"Why do you not eat plant-based meat alternatives regularly?" (only if the response to Q6 was other than "Yes, on a regular basis")	Check all that apply from among 12 options
Q8	"How important do you consider meat to be for your main meal in the following situations?" (1) Typical weekday; (2) Weekend; (3) Restaurant	7-point scale from "Not important at all" (1) to "Very important" (7)
Q9	"How difficult is it for you to think of a vegetarian main course for invited guests?"	11-point scale from "Very easy" (0) to "Very difficult" (10)

[1] The Finnish translation of these questions is available in the (Supplementary Materials Table S1). [2] Education was the only demographical factor probed in the survey. The age and gender of the respondents were available from the register of the utilized market research company. [3] The order of presentation of Q3 and Q4 was randomized.

The questions related to the first associations with meat (Q3) and meat alternatives (Q4) were presented in a randomized order for each respondent. We placed these questions at the beginning of the survey in an effort to minimize the influence of the other items on the answers. After Q3 and Q4, we provided a definition of meat alternatives to be considered throughout the rest of the survey. It read as follows: "For the following questions, we refer to meat alternatives as commercially available plant-based convenience foods that can be used instead of meat. Examples are vegetarian sausages, veggie patties, or plant-based minced 'meat'". The remaining questions (Q5–Q14) were then presented.

Table 2. Survey questions 10–14: multi-item scales.

No.	Scale [1]	No. of Items	Example of the Items	Response Options	Reference
Q10	Diet-Related Health Consciousness Scale	4	"I think it is important to eat healthily."	7-point Likert scale from "Do not agree at all" (1) to "Totally agree" (7) [2]	Dohle et al., 2014 [48] [3]
Q11	Ecological Welfare Scale	5	"It is important that the food I eat on a typical day . . . ", e.g., " . . . has been produced in a way that animals have not experienced pain."	Not at all important (1); A little important (2); Moderately important (3); Very important (4)	Lindeman and Väänänen, 1999 [49] [4]
Q12	Natural Content Scale	4	"It is important that the food I eat on a typical day . . . ", e.g., " . . . contains no additives."	Not at all important (1); A little important (2); Moderately important (3); Very important (4)	Steptoe et al., 1995 [50] [5]
Q13	Meat Commitment Scale	7	"I don't want to eat meals without meat."	7-point Likert scale from "Strongly disagree" (1) to "Strongly agree" (7)	Piazza et al., 2015 [51]
Q14	Food Neophobia Scale	10	"I don't trust new foods."	7-point Likert scale from "Strongly disagree" (1) to "Strongly agree" (7)	Pliner and Hobden, 1992 [52]

[1] The Finnish translation of these questions is available in the (Supplementary Materials Table S1). [2] A seven-point scale was used instead of the original six-point scale (from "Don't agree at all" [1] to "Fully agree" [6]) used by Dohle et al. [48]. [3] The Diet-Related Health Consciousness Scale by Dohle et al. [48] was partly based on the items from the Health Consciousness Scale by Schifferstein and Oude Ouphuis [53]. [4] One of the three scales developed by Lindeman and Väänänen [49], namely the Ecological Welfare Scale (including the subscales for Animal Welfare and Environment Protection), was used in this study. [5] The original three-item Natural Content Scale (part of the Food Choice Questionnaire) was complemented with a fourth item, " . . . is as little processed as possible".

2.3. Data Analysis

First, we cleaned the data of obvious errors. During the data cleaning, 4 out of 550 individuals (0.7%) were removed from the dataset due to providing inconsistent or otherwise doubtful responses. Therefore, we included answers from 546 respondents in our further analyses.

Second, the composite scores for the published multi-item scales (Table 2) were calculated according to the instructions in the original sources [48–52,54]. Thanks to the use of an electronic questionnaire, the data included no missing values (i.e., no missed responses). Cleaned data (N = 546) with the calculated scores are available in the (Supplementary Materials Table S2).

The data were analyzed statistically using the IBM SPSS Statistics version 27 software package (IBM, Armonk, NY, USA). We applied descriptive and analytical statistics to the data, and we used $\alpha = 0.05$ as the criterion for statistical significance. The independent samples t-test, one-way and two-way analysis of variance (ANOVA), and Pearson's chi-squared tests were also used as appropriate. The answer categories "Daily" and "More than once per day" for the questions concerning the eating frequency of both meat and meat alternatives (Q5) were combined into one category named "Daily" to increase the clarity of the results. This category implies eating a food item at least once per day.

Essentially, we classified the respondents into six groups based on the hedonic tone (valence: negative–positive) of their first associations with meat (Q3) and meat alternatives (Q4), as described below (in Section 3.2). In this paper, we refer to these groups of respondents as (consumer) segments.

We employed a two-way ANOVA using the respondents' gender and consumer segment as fixed factors (independent variables) in order to study the quantitative variables as appropriate. A full factorial model was run first and the significance of the gender×segment interaction was observed. If the interaction was nonsignificant, the interaction term was left out of the model and the results were reported based on the model including only the main effects. Furthermore, if the main effect of the segment was significant, Tukey's post hoc test was applied to reveal which of the segments differed from the others.

3. Results

3.1. Demographics and Diet

The data (total $N = 546$) included more responses from women (322; 59.0%) than men (224; 41.0%). In comparison, according to official statistics concerning Finland [55], the gender distribution among 20–39-year-old Finns (at the end of 2019) was 48.4% women and 51.5% men [56].

The mean age of the respondents was 31.2 years and the age distribution was rather evenly distributed across 20–39 years (with the range defined by the inclusion criterion). The women respondents were, on average, a little younger than the men (30.6 vs. 32.0 years, respectively; $t(504) = 3.04$, $p = 0.002$). By contrast, the respondents' education, as measured by the number of years (including both school and professional education), did not differ between the genders (16.3 vs. 15.9 years, respectively; $p > 0.05$).

Among all the respondents, about two-thirds (67.2%) identified themselves as omnivores (agreeing with the statement "I eat all animal products"), while about one-third (32.8%) followed a diet that limited the consumption of animal products in one way or other. Following a limited diet in terms of the consumption of meat/animal-based products was more prevalent among the women than the men. Indeed, nearly half of the women (42.5%) but only about a fifth of the men (18.8%) followed a non-omnivorous diet, that is, identified themselves as either flexitarian, pescetarian, vegetarian, or vegan (Pearson's chi-square = 33.9, $p < 0.001$) (Table 3).

Table 3. Respondents' diet by gender.

Diet	All		Women		Men	
	n	%	*n*	%	*n*	%
Omnivore	367	67.2	185	57.5	182	81.3
Flexitarian	67	12.3	52	16.1	15	6.7
Pescetarian	52	9.5	41	12.7	11	4.9
Vegetarian	25	4.6	19	5.9	6	2.7
Vegan	35	6.4	25	7.8	10	4.5
Total	546	100.0	322	100.0	224	100.0

Furthermore, approximately two-thirds of the non-omnivores (66.5%, corresponding to 21.8% of all the respondents) were either flexitarians or pescetarians, while the remaining third of the non-omnivores (33.5%, corresponding to 11.0% of all the respondents) were either vegetarians or vegans.

3.2. Hedonic Tones of the First Associations with Meat and Meat Alternatives

The hedonic tone (valence on a scale ranging from −5, "extremely negative", to 5, "extremely positive") of the first associations (words, images, or thoughts) spontaneously evoked when thinking about meat was, on average, close to neutral (1.1). Likewise, the average hedonic tone of the first associations with meat alternatives was close to neutral (1.0). No statistically significant difference was observed between the values ($t(1090) = 0.61$; $p = 0.542$). However, the individual differences in the ratings of the hedonic tones were large (SD 3.4 and 3.1 for meat and meat alternatives, respectively), implying that not all the respondents rated their associations as neutral.

3.2.1. Hedonic Tone by Diet and Gender

The two-way ANOVA involving diet and gender as fixed factors showed no significant diet×gender interaction in terms of the hedonic tone of the first associations with either meat ($F(4,536) = 1.52$; $p = 0.195$) or meat alternatives ($F(4,536) = 0.75$; $p = 0.560$). This implied that within a given diet group, both genders provided similar ratings.

Diet had a significant main effect on the hedonic tones of the first associations evoked by both meat ($F(4,540) = 191.1$; $p < 0.001$) and meat alternatives ($F(4,540) = 44.1$; $p < 0.001$). Similarly, gender had a significant main effect in the case of both meat ($F(1,540) = 7.6$; $p = 0.006$) and meat alternatives ($F(1,540) = 5.9$; $p = 0.015$). The omnivores and men rated their first associations with meat as more positive (and those with meat alternatives as more negative) than the non-omnivores (i.e., flexitarians, pescetarians, vegetarians, and vegans) and women, respectively (Table 4).

Table 4. Hedonic tones of first associations with meat and plant-based meat alternatives (rated on a scale from −5 to 5) by diet and gender.

Group		Meat		Meat Alternatives	
	N	**Mean**	**SD**	**Mean**	**SD**
Diet [1]					
Omnivore	367	2.9 d	2.1	−0.1 a	2.9
Flexitarian	67	−1.0 c	2.7	2.8 b	2.3
Pescetarian	52	−2.8 b	2.0	3.4 b	1.9
Vegetarian	25	−3.8 ab	1.6	3.5 b	2.1
Vegan	35	−4.2 a	1.9	3.9 b	1.5
Gender					
Women	322	0.4	3.5	1.5	3.0
Men	224	2.1	3.0	0.2	3.0
All	546	1.1	3.4	1.0	3.1

[1] The means among the diet groups (within a column) not sharing a common letter are significantly different (Tukey's test, $p < 0.05$).

Diet appeared to more clearly influence the respondents' hedonic responses to their first associations with meat than their first associations with meat alternatives. Although the overall means of the hedonic tones concerning meat and meat alternatives were similar, the difference between the means in the most extreme diet groups in terms of the hedonic tone associated with meat was 7.1 points (from −4.2 in vegans to 2.9 in omnivores), while it was only 4.0 points in the case of meat alternatives (from −0.1 in omnivores to 3.9 in vegans). Among the non-omnivorous diet groups, significant differences were observed in the average hedonic tone associated with meat but not that associated with meat alternatives (Table 4).

We observed a clear negative correlation between the hedonic tones associated with meat and meat alternatives, although the correlation was not strong (Pearson's $r = -0.55$, $p < 0.01$). Among the omnivores (the largest diet group) in particular, there was wide variation in the hedonic tone associated with meat alternatives (SD 2.9), although the mean was close to zero (neutral). Some omnivores may have had positive associations with both meat and meat alternatives, or alternatively, they may have regarded both neutrally. This led us to assume that it could prove useful to classify the respondents into segments based on the hedonic tones associated with both meat and meat alternatives (instead of using the hedonic tone associated with either meat or meat alternatives).

3.2.2. Segmentation of the Respondents

We cross-tabulated the ratings of the hedonic tones of the first associations with meat and meat alternatives to identify potential clusters of respondents that could be used as consumer segments in further analyses. Indeed, a visual inspection of the crosstab suggested that the hedonic responses were clustered, not evenly distributed.

We identified six clusters, which we defined and labeled as follows: The most obvious clusters existed in the upper left corner of the crosstab (those respondents who had very positive associations with meat alternatives (Ma) but negative associations with meat, labeled "MaPos" and marked with dark green in Figure 1) and the lower right corner (those who had very positive associations with meat but negative associations with meat alternatives, labeled "MeatPos" and marked with red in Figure 1). Furthermore, between these two extreme clusters in the corners, there were groups of respondents who slightly or moderately preferred their associations with meat (labeled "MeatPref" and marked with orange in Figure 1) or meat alternatives (labeled "MaPref" and marked with light green in Figure 1). However, there was also a cluster of respondents who reported positive associations with both meat and meat alternatives (labeled "BothPos" and marked with yellow in Figure 1). Finally, there was a cluster of respondents who did not report positive associations with either meat or meat alternatives, instead rating the associations with both as neutral or even slightly negative (labeled "NoPos" and marked with light grey in Figure 1).

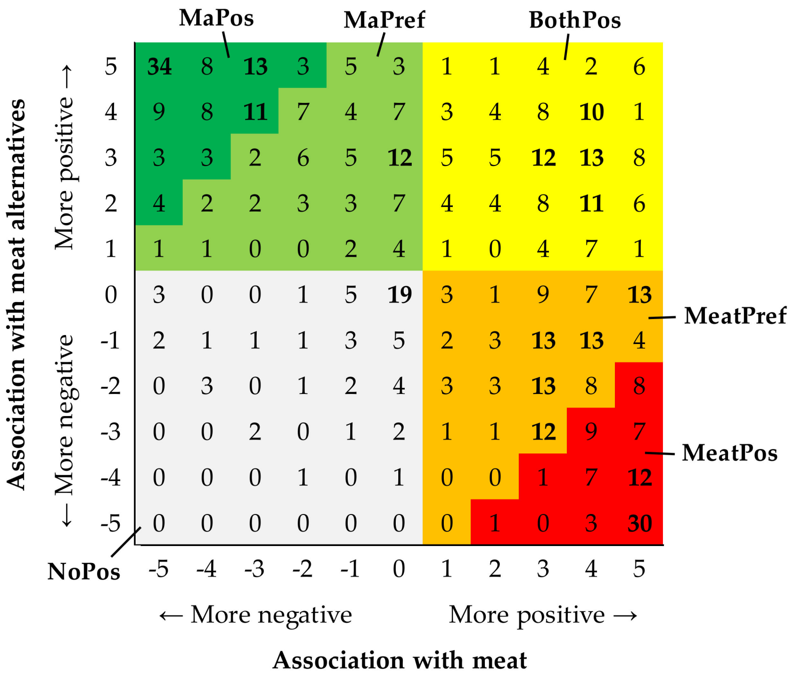

Figure 1. Cross-tabulation of the hedonic tones (valence, on a scale from −5 to 5) of the first associations evoked by meat and plant-based meat alternatives and classifying the respondents into six consumer segments (marked with different colors). The numbers in the cells denote the counts of individual respondents who gave the respective combination of responses. Counts ≥10 are marked in bold to highlight the clustering (total N = 546 individuals).

The definition, size, and gender distribution of the formed consumer segments are summarized in Table 5. The size of the segments ranged from 58 (10.6%) to 129 (23.6%) individuals. The percentage of women in a segment increased with an increasing preference for meat alternatives (Table 5). By contrast, no difference in age ($F(5,540) = 1.6$; $p = 0.158$) or number of years in education ($F(5,540) = 1.2$; $p = 0.314$) was observed between the segments.

The omnivores represented the largest fraction in all the segments, except for the segment most positive with regard to meat alternatives (MaPos). Unsurprisingly, the segments that reported the associations with meat to have relatively more positive hedonic tones (MeatPos and MeatPref) consisted almost exclusively of omnivores. Yet, more than half of the respondents in the segments that did not exhibit a clear difference in terms of the hedonic tones (BothPos and NoPos) were also omnivores. Moreover, the omnivores even represented the largest diet group in the segment that reported a higher hedonic tone with regard to meat alternatives (MaPref), although this segment also consisted of a remarkable fraction of flexitarians and pescetarians (Table 6). The dominance of the omnivores in almost all the segments can be explained by the fact that the omnivores were also the overall largest diet group (67.2% of all respondents).

Table 5. Consumer segments based on the hedonic tones of the first associations with meat and plant-based meat alternatives.

Segment	Definition	Women [1]	Men [1]	Total	Of All [2]
MeatPos	Hedonic tone with meat was ≥7 points higher than with meat alternatives.	33 42.3%	45 57.7%	78 100.0%	14.3%
MeatPref	Hedonic tone with meat was positive (and 3–6 points higher than with meat alternatives), while it was negative with meat alternatives.	53 48.6%	56 51.4%	109 100.0%	20.0%
BothPos	Hedonic tone was positive with both meat and meat alternatives.	74 57.4%	55 42.6%	129 100.0%	23.6%
NoPos	Hedonic tone was neutral or negative with both meat and meat alternatives.	37 63.8%	21 36.2%	58 100.0%	10.6%
MaPref	Hedonic tone with meat alternatives was positive (and 3–6 points higher than with meat), while it was negative with meat.	50 65.8%	26 34.2%	76 100.0%	13.9%
MaPos	Hedonic tone with meat alternatives was ≥7 points higher than with meat.	75 78.1%	21 21.9%	96 100.0%	17.6%

[1] Values of the prevailing gender in a segment are highlighted in bold. [2] Relative size of a segment out of all 546 respondents.

Table 6. Diet by consumer segment.

Segment [1]	Including [2]				
	Omnivore	Flexitarian	Pescetarian	Vegetarian	Vegan
MeatPos	77 98.7%	1 1.3%	0 0.0%	0 0.0%	0 0.0%
MeatPref	106 97.2%	2 1.8%	1 0.9%	0 0.0%	0 0.0%
BothPos	110 85.3%	15 11.6%	2 1.6%	0 0.0%	2 1.6%
NoPos	38 65.5%	9 15.5%	7 12.1%	3 5.2%	1 1.7%
MaPref	32 42.1%	24 31.6%	12 15.8%	6 7.9%	2 2.6%
MaPos	4 4.2%	16 16.7%	30 31.3%	16 16.7%	30 31.3%

[1] Consumer segments formed based on the hedonic tones of the first associations with meat and plant-based meat alternatives (see Figure 1 and Table 5). [2] Values of the largest diet group in a segment are highlighted in bold. Note that the majority of all respondents (67.2%) were omnivores.

3.3. Consumption Frequency of Meat and Meat Alternatives and the Underlying Reasons Why

3.3.1. Consumption

Meat, including various meat products (but not fish), was consumed on a daily basis by a third of the respondents (33.5%). By contrast, a fifth (20.5%) of the respondents reported eating meat never or only rarely. Notably, the remainder, that is, almost half of the studied millennials (46.0%), reported sometimes eating meat but abstaining from it at least one day per week. As expected, the segments that reported their associations with meat to have a more positive hedonic tone (Table 5) also consumed meat more frequently (Figure 2a).

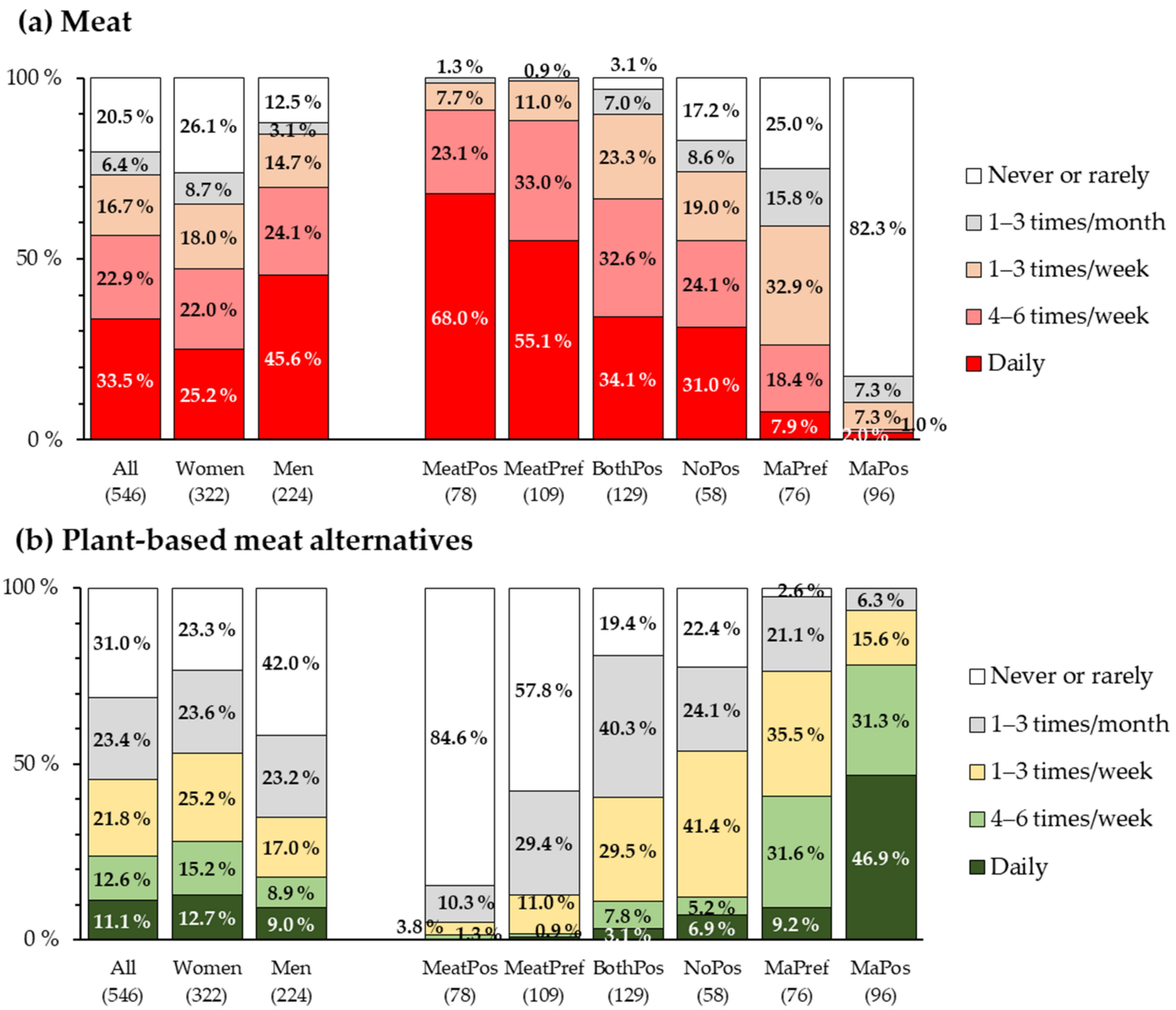

Figure 2. Use frequencies of (**a**) meat (pork, poultry, beef, ham, sausages, etc.) and (**b**) plant-based meat alternatives (including vegetarian patties, soy, tofu, etc.) by gender and consumer segment. The number of individuals in a group is given in parentheses. For details concerning how the respondents were classified into segments, see Figure 1 and Table 5.

Plant-based meat alternatives were eaten daily by only about 11% of the respondents, although almost half of the respondents (45.5%) consumed them at least once a week. About two-thirds of the millennials (68.9%) ate meat alternatives at least once a month, whereas about one-third (31.0%) ate them rarely or never. As in the case of meat, the hedonic tone of the first associations with meat alternatives was reflected in how often such products were consumed (Figure 2b). These findings suggest that the hedonic tones of the first associations with meat and meat alternatives could be used to predict people's consumption of these food categories.

Next, we asked how many respondents consumed both meat and meat alternatives. Some overlap in terms of the consumption of these foods was expected because, in the case of both meat and meat alternatives, the majority of respondents reported eating them at least occasionally. In addition, we expected that some respondents consumed meat alternatives in an attempt to reduce their meat consumption (while not totally abstaining from eating meat), as 12.3% identified themselves as flexitarians (Table 3) and almost a quarter (23.6%) reported positive hedonic tones with regard to the associations with both meat and meat alternatives (Table 5).

To investigate this issue, we cross-tabulated the consumption frequencies of meat and meat alternatives. This confirmed that almost half of the respondents (48.6%) ate both meat and meat alternatives at least once a month. Only meat (no meat alternatives) was eaten by 31.0%, while only meat alternatives (no meat) were eaten by 20.4% of the respondents. Notably, about a fifth of the respondents (20.4%) regularly ate (at least once a week) both meat and meat alternatives (Figure 3). The consumer segment that reported positive associations with both meat and meat alternatives (BothPos) represented the largest group among those who consumed both meat and meat alternatives at least once a month (37.7%) and those who consumed them on a weekly basis (36.0%).

Meat alternatives \ Meat	Never or rarely	1–3 times/mo	1–3 times/wk	4–6 times/wk	Daily
Daily	9.3 %	1.1 %	0.4 %	0.2 %	0.2 %
4–6 times/wk	6.6 %	1.1 %	4.0 %	0.9 %	0.0 %
1–3 times/wk	3.8 %	3.3 %	5.3 %	5.7 %	3.7 %
1–3 times/mo	0.7 %	0.7 %	4.4 %	8.6 %	9.0 %
Never or rarely	0.0 %	0.2 %	2.6 %	7.5 %	20.7 %

Figure 3. Cross-tabulation of the consumption frequencies of meat (pork, poultry, beef, ham, sausages, etc.) in columns and plant-based meat alternatives (including vegetarian patties, soy, tofu, etc.) in rows. The percentages in the cells denote the proportion of respondents who responded with the combination represented by that cell (out of the total $N = 546$ respondents). Among all the respondents, 31.0% (red cells) consumed only meat, 20.4% (green cells) consumed only meat alternatives, and 48.6% (blue cells) consumed both meat and meat alternatives.

3.3.2. Reasons for Eating and Not Eating Meat Alternatives

The question about why a respondent ate or did not eat plant-based meat alternatives was connected to a separate simple question concerning the consumption of meat alternatives. We first asked, "Do you eat plant-based meat alternatives?" (Q6), which had three response options. If the answer to Q6 was "Yes, on a regular basis", we then asked, "Why do you eat plant-based meat alternatives regularly?" (Q7a). If the answer to Q6 was "No" or "I have sampled meat alternatives but do not eat them on a regular basis", the next question was "Why do you not eat plant-based meat alternatives regularly?" (Q7b). Both questions concerning the reasons for eating/not eating meat alternatives were check-all-that-apply (CATA)-type questions with 7 (Q7a) and 12 (Q7b) predefined response options.

Approximately 4 out of 10 respondents (40.8%) reported eating plant-based meat alternatives on a regular basis. The regular consumption of meat alternatives was more common among the women (47.8%) than the men (30.8%) ($X^2_{(2)} = 17.6$; $p < 0.001$). The proportion of regular users of meat alternatives varied widely across the consumer segments (from 2.6% for MeatPos to 92.7% for MaPos) (Table 7).

Table 7. Overall consumption of plant-based meat alternatives by gender and consumer segment.

"Do You Eat Plant-Based Meat Alternatives?" [1]	All (546) [2]	Women (322)	Men (224)	Consumer Segment					
				Meat-Pos (78)	Meat-Pref (109)	Both-Pos (129)	NoPos (58)	MaPref (76)	MaPos (96)
Yes, on a regular basis	40.8%	47.8%	30.8%	2.6%	10.1%	37.2%	27.6%	75.0%	92.7%
I have sampled meat alternatives but do not eat them on a regular basis	43.2%	39.8%	48.2%	42.3%	67.9%	53.5%	60.3%	23.7%	7.3%
No	15.9%	12.4%	21.0%	55.1%	22.0%	9.3%	12.1%	1.3%	0.0%

[1] The percentages (%) within a column indicate the proportion of a group who responded with a given answer. The most common response within each group is highlighted in bold. [2] The total number of individuals in a group is given in parentheses.

Environmental reasons were the most frequently cited motive for the regular consumption of meat alternatives among all the respondents (80.7%), followed by animal welfare reasons (64.6%) and health reasons (53.8%) (Table 8). There were some differences in motives between the genders. Notably, a larger proportion of women (59.7%) than men (33.3%) selected "I like the taste" as a reason for regularly eating meat alternatives.

Table 8. Reasons for eating plant-based meat alternatives regularly: percentage of regular eaters (40.8% of all respondents) offering a specific reason by gender and consumer segment.

"Why Do You Eat Plant-Based Meat Alternatives Regularly?" [1]	All (223) [2]	Women (154)	Men (69)	Consumer Segment					
				MeatPos (2)	Meat-Pref (11)	BothPos (48)	NoPos (16)	MaPref (57)	MaPos (89)
Because ...									
of environmental reasons	80.7%	84.4%	72.5%	n/a [3]	54.5%	66.7%	81.3%	80.7%	91.0%
of animal welfare reasons	64.6%	69.5%	53.6%	n/a	27.3%	37.5%	50.0%	64.9%	86.5%
of health reasons	53.8%	52.6%	56.5%	n/a	36.4%	47.9%	43.8%	54.4%	59.6%
I like the taste	51.6%	59.7%	33.3%	n/a	0.0%	41.7%	37.5%	61.4%	59.6%
I like trying new foods	50.2%	51.3%	47.8%	n/a	72.7%	75.0%	43.8%	54.4%	31.5%
my social environment expects me to eat meat alternatives	11.2%	11.7%	10.1%	n/a	27.3%	18.8%	12.5%	8.8%	5.6%
of financial reasons	7.2%	7.1%	7.2%	n/a	9.1%	6.3%	12.5%	1.8%	9.0%
other	4.9%	3.9%	7.2%	n/a	9.1%	4.2%	12.5%	5.3%	3.4%

[1] The percentages within a column indicate the proportion of a group who responded with a given answer (multiple answers possible). The response options were sorted from the most to the least frequent response among all the respondents. The two most frequent responses within each group are highlighted in bold. [2] The total number of regular eaters in a group is given in parentheses. [3] n/a, not applicable. Because only 2 out of 78 (2.6%) respondents in the MeatPos segment ate meat alternatives regularly, their responses are not shown.

The consumer segments differed in terms of their motives for eating meat alternatives. Environmental reasons were among the two most commonly mentioned reasons in all the segments, while they were the top motive for the MaPos, MaPref, and NoPos segments. Interestingly, the most frequently reported motive for the MeatPref and BothPos segments was "I like trying new foods".

Among those respondents who did not consume meat alternatives regularly, the most commonly cited reason for this behavior was "I do not like the taste of meat alternatives" (56.7%), followed by "Meat alternatives are too expensive" (51.4%) (Table 9). These two reasons were the top two reasons given by both the women and the men. However, in terms of the women, the third most commonly mentioned reason for not eating meat alternatives regularly was "I do not know how to cook meat alternatives", whereas for men it was "Meat alternatives are not a good replacement for meat".

Table 9. Reasons for not eating plant-based meat alternatives regularly: percentage of those who did not eat meat alternatives regularly (59.2% of all respondents) offering a specific reason by gender and consumer segment.

"Why Do You Not Eat Plant-Based Meat Alternatives Regularly?" [1]	All (323) [2]	Women (168)	Men (155)	Consumer Segment					
				MeatPos (76)	Meat-Pref (98)	BothPos (81)	NoPos (42)	MaPref (19)	MaPos (7)
I do not like the taste of meat alternatives	56.7%	47.6%	66.5%	75.0%	70.4%	38.3%	50.0%	15.8%	n/a [3]
Meat alternatives are too expensive	51.4%	48.2%	54.8%	42.1%	56.1%	53.1%	52.4%	47.4%	n/a
Meat alternatives are too processed	37.8%	41.7%	33.5%	56.6%	37.8%	21.0%	40.5%	31.6%	n/a
I do not know how to cook meat alternatives	34.1%	44.6%	22.6%	10.5%	33.7%	49.4%	33.3%	57.9%	n/a
Meat alternatives are not a good replacement for meat	31.6%	22.0%	41.9%	61.8%	37.8%	12.3%	19.0%	0.0%	n/a
My family won't eat it	22.3%	29.8%	14.2%	21.1%	23.5%	27.2%	19.0%	10.5%	n/a
Meat alternatives are unhealthy	11.8%	9.5%	14.2%	30.3%	10.2%	1.2%	9.5%	0.0%	n/a
Meat alternatives are something for vegans and vegetarians only	10.2%	6.0%	14.8%	22.4%	11.2%	2.5%	7.1%	0.0%	n/a
Meat alternatives are too much packaged	9.9%	11.9%	7.7%	17.1%	4.1%	11.1%	7.1%	10.5%	n/a
Meat alternatives are not available where I go shopping	6.5%	6.5%	6.5%	3.9%	8.2%	4.9%	7.1%	10.5%	n/a
I do not know what meat alternatives are	5.6%	5.4%	5.8%	2.6%	9.2%	4.9%	4.8%	5.3%	n/a
Meat alternatives are too much like meat	3.4%	2.4%	4.5%	2.6%	3.1%	1.2%	7.1%	10.5%	n/a

[1] The percentages within a column indicate the proportion of a group who responded with a given answer (multiple answers possible). The response options were sorted from the most to the least frequent response among all the respondents. The two most frequent responses within each group are highlighted in bold. [2] The total number of regular eaters in a group is given in parentheses. [3] n/a, not applicable. Because only 7 out of 96 (7.3%) respondents in the VegePos segment did not eat meat alternatives regularly, their responses are not shown.

The main reasons for not eating meat alternatives regularly also differed among the consumer segments. For the segments that reported a less positive hedonic tone with regard to meat alternatives (Meat Pos and Meat Pref), the top reason was clearly "I do not like the taste of meat alternatives". For the segments that reported a positive attitude toward meat alternatives (BothPos and MaPref) but who still do not eat such products regularly, the two most frequently mentioned reasons were "Meat alternatives are too expensive" and "I do not know how to cook meat alternatives". While the frequency of citing various reasons varied considerably among the segments in general, the reason "Meat alternatives are too expensive" was mentioned by a somewhat similar proportion of individuals in all the segments (42.1–56.1%).

3.4. Status of Meat in Meals

3.4.1. Importance of Meat in Main Meals

We asked the respondents "How important do you consider meat to be for your main meal in the following situations?", that is, for a "typical weekday", "weekend", and "at a restaurant" (Q8, 7-point scale ranging from 1, "Not important at all", to 7, "Very important"). The mean rating for the importance of meat in a main meal was close to the midpoint of the scale and similar for the typical weekday (3.6), weekend (3.9), and at a restaurant (4.0) options.

The women considered meat in all of the given situations to be less important than the men did (indicating the significant main effect of gender). The mean importance ratings given by the women and men were 3.1 vs. 4.4 for meat in a main meal on a typical weekday ($F(1,539) = 29.7$; $p < 0.001$), 3.4 vs. 4.6 on the weekend $F(1,539) = 25.9$; $p < 0.001$), and 3.4 vs. 4.8 at a restaurant $F(1,539) = 17.6$; $p < 0.001$), respectively.

The consumer segments varied greatly in terms of their responses here. The main effect of the segment was significant for meat on a typical weekday ($F(5,539) = 121.9$; $p < 0.001$), on the weekend ($F(5,539) = 127.2$; $p < 0.001$), and at a restaurant ($F(5,539) = 118.9$; $p < 0.001$). As expected, the MeatPos segment rated the importance of meat in all the studied situations the highest, while the MaPos segment rated it the lowest.

3.4.2. Difficulty of Thinking of a Vegetarian Main Course for Invited Guests

The responses to the question "How difficult is it for you to think of a vegetarian main course for invited guests?" (Q9, rated on an 11-point scale from 0, "Very easy", to 10, "Very difficult") varied widely among the respondents. The women regarded it as easier to think of a vegetarian main course for guests than the men (2.8 vs. 5.0, indicating a significant main effect for gender ($F(1,539) = 18.5$; $p < 0.001$). Similarly, the consumer segment had a significant main effect on the responses to this question ($F(5,539) = 58.2$; $p < 0.001$). As expected, among the various segments, the MaPos segment rated it the easiest to think of a vegetarian main course for guests (0.3), followed by the MaPref (1.9), BothPos (3.5), NoPos (3.7), MeatPref (5.6), and MeatPos (7.5) segments (the means of all the segments, except those of the BothPos and NoPos segments, differed from each other according to Tukey's test, $p < 0.05$).

3.5. Diet-Related Attitudes

Finally, we analyzed whether the genders and consumer segments differed in terms of their responses to the selected multi-item scales. All the scales showed good internal consistency as measured using Cronbach's alpha: diet-related health consciousness (0.77), ecological welfare concerns (0.90), importance of the natural content of foods (0.90), meat commitment (0.97), and food neophobia (0.89).

The women scored higher than the men in relation to the Ecological Welfare Scale (3.2 vs. 2.8, $F(1,539) = 16.2$; $p < 0.001$) and Natural Content Scale (2.8 vs. 2.6, $F(1,539) = 22.1$; $p < 0.001$). By contrast, the women scored lower than the men in terms of the Meat Commitment Scale (2.8 vs. 4.2, $F(1,539) = 37.3$; $p < 0.001$). No significant main effect of gender was observed with regard to scores for Health Consciousness Scale or Food Neophobia Scale (Table 10).

Table 10. Scores for the diet-related attitude scales by gender and consumer segment (means (M) and standard deviations (SD)).

Scale (Potential Range) [Reference]		All (546) [1]	Women (322)	Men (224)	Consumer Segment [3]					
					MeatPos (78)	Meat-Pref (109)	BothPos (129)	NoPos (58)	MaPref (76)	MaPos (96)
Health Consciousness (1–7) [48]	M	5.2	5.2	5.2	5.1 ab	4.9 a	5.2 ab	5.1 ab	5.4 bc	5.7 c
	SD	1.1	1.0	1.1	1.3	1.0	1.0	1.1	1.0	1.0
Ecological Welfare (1–4) [49]	M	3.0	3.2 [2]	2.8 [2]	2.7 a	2.7 ab	3.0 abc	3.0 bc	3.2 c	3.6 d
	SD	0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.6	0.4
Natural Content (1–4) [50]	M	2.7	2.8 [2]	2.6 [2]	2.9 b	2.7 ab	2.7 ab	2.8 ab	2.7 ab	2.5 a
	SD	0.8	0.8	0.8	0.9	0.8	0.8	0.8	0.8	0.8
Meat Commitment (1–7) [51]	M	3.4	2.8 [2]	4.2 [2]	6.2 f	4.7 e	3.4 d	2.9 c	1.8 b	1.1 a
	SD	2.1	1.9	2.0	1.0	1.5	1.4	1.7	1.0	0.4
Food Neophobia (10–70) [52]	M	28.8	28.7	28.9	31.7 a	30.5 a	26.8 a	31.2 a	27.6 a	26.9 a
	SD	11.5	11.8	11.0	12.6	11.8	11.2	12.9	10.1	9.8

[1] The total number of individuals in a group is given in parentheses. [2] The main effect of gender was significant for these variables (ANOVA, $p < 0.05$). [3] The main effect of segment was significant for all the variables (ANOVA, $p < 0.05$). The letters denote results of the Tukey's test, that is, which of the mean values (segments) are statistically different and which not (in a given variable, i.e., within a line). Lowest mean value has been marked with "a", next lowest with "b" and so on. The means between the segments (within the same row) not sharing a common lowercase letter differed (Tukey's test, $p < 0.05$).

According to the two-way ANOVA, the consumer segment had a significant main effect on the scores for all the attitude scales: Health Consciousness ($F(5,539) = 6.6$; $p < 0.001$), Ecological Welfare ($F(5,539) = 19.3$; $p < 0.001$), Natural Content ($F(5,539) = 4.0$; $p = 0.001$), Meat Commitment ($F(5,539) = 179.3$; $p < 0.001$), and Food Neophobia ($F(5,539) = 3.5$; $p = 0.004$). Tukey's test confirmed these results and classified the segments into different homogeneous subsets for all the variables except food neophobia. In the case of food neophobia, Tukey's test classified all the segments into the same homogeneous subset ($p = 0.058$) (Table 10).

The differences between the segments were the most obvious when it came to meat commitment and ecological welfare: the MaPos and MaPref segments were less committed to meat and more concerned about ecological welfare than the MeatPos and MeatPref segments. The scores from the scales measuring health consciousness, naturalness, and food neophobia did not reveal any systematic differences across the segments.

4. Discussion

4.1. Hedonic Tones of the Associations with Meat and Meat Alternatives

The millennials' mean hedonic tones evoked by the first associations with meat and meat alternatives were similar and slightly positive (1.1 vs. 1.0, respectively, on a scale ranging from −5 to 5). This finding conflicts somewhat with the findings of the studies reviewed by Onwezen et al. [23], who concluded that acceptance of alternative proteins was relatively low when compared with acceptance of meat. Our finding that the millennials' associations with meat alternatives were, on average, as positive as their associations with meat may reflect millennials' greater concern and knowledge regarding environmental issues when compared with older generations [33,34]. The millennials' orientation toward plant-based diets was also supported by the higher proportion of vegans and vegetarians in the present study (total 11.0%) when compared with the general population of 25–74-year-old Finns in 2017 (1.8%) [31] and 18–79-year old Finns in 2018 (6.7%) [46].

As expected, the women reported, on average, more positive associations with plant-based meat alternatives (and less positive associations with meat) than the men. However, the women rated their associations with meat alternatives as more positive than those with meat (1.5 vs. 0.4), which suggests that millennial women are, at least in countries such as Finland, a potential target group for plant-based meat alternative products.

It was also expected that the followers of diets that limited the consumption of meat (i.e., flexitarians, pescetarians, vegetarians, and vegans) would report negative associations with meat and positive associations with meat alternatives. Our findings confirmed that the vegetarians and vegans reported positive associations with meat alternatives more frequently, as did the flexitarians, although some plant-based meat alternatives on the market may resemble meat closely (to appeal to flexitarians). Interestingly, only 3.4% of those who did not regularly eat meat alternatives mentioned "Meat alternatives are too much like meat" as a reason why. This suggests that the plant-based meat alternative products sold in Finland do not resemble meat to such an extent that vegetarians are put off.

The individual variation in the hedonic tones of the associations with meat and meat alternatives was wide, which formed the basis for our segmentation procedure. As meat alternatives are by definition designed to replace meat in a person's diet, we assumed that it would be useful to study attitudes toward both meat and meat alternatives (not only toward one of them). Indeed, when cross-tabulating the ratings for the hedonic value of the associations with meat vs. meat alternatives, we observed that the ratings for meat and meat alternatives were not always simply opposite values (positive association with meat combined with negative association with meat alternatives, or vice versa), as some respondents reported positive (or neutral) associations with both meat and meat alternatives.

4.2. Consumption of Meat and Meat Alternatives and the Underlying Reasons Why

Both gender and consumer segment were associated with the consumption of meat and meat alternatives. The women and the consumer segments that reported more positive associations with meat alternatives (MaPref and MaPos) ate meat alternatives more frequently than the men and the consumer segments that reported more positive associations with meat (MeatPref and MeatPos). The men's greater preference for meat was in line with the findings of prior research [46,57,58]. In Finland, according to the National FinDiet 2017 Survey [59], even 79% of men but only 26% of women ate more red and processed meat than the national guidelines recommend (500 g/week [60]).

The consumption of meat did not exclude the consumption of meat alternatives. This observation is consistent with the finding by Götze and Brunner [45] that meat alternatives can serve as a complementary component in one's diet. In a survey by Smart Protein project conducted in 2021 in adult consumers of 10 European countries (Austria, Denmark, France, Germany, Italy, Netherlands, Poland, Romania, Spain, UK), on average, 30% of the respondents identified themselves as flexitarians [24]. In the present study, around half of the respondents (48.6%) ate both meat and meat alternatives at least once per month. Thus, they can be referred to as flexitarians in a broad sense. However, a much lower proportion of respondents (12.3%) actually identified themselves as flexitarians. This could be because the description of a flexitarian in our questionnaire was strict ("I only rarely eat meat") and because the concept of flexitarian may still be largely unfamiliar to the general public. Nevertheless, the fraction of regular users of meat alternatives and those who had at least tried them totaled 84.0% in the present study (mean age 31.2 years). A slightly lower percentage (76%) of somewhat older respondents (mean age 57.4 years) had tried meat alternatives in the study by Götze and Brunner [45].

Environmental reasons represented the top motive for eating meat alternatives regularly. Among the women (and the respondents overall), the second most commonly cited motive was animal welfare, whereas among the men it was health reasons. A similar set of reasons, that is, "ecological welfare" and "health" (together with "sensory appeal"), were found to be the top food choice motives for using meat substitutes in the study by Hoek et al. [43]. These results suggest that many consumers regard meat alternatives as healthy. However, the nutritional value of novel plant-based meat alternatives may not always be as high as thought, because some products can, for example, contain high amounts of saturated fat and sodium. For further discussion on nutritional aspects of meat alternatives, see the review by Tso et al. [61] and commentary by Tso and Forde [62]. Of course, the quality of the diet as a whole is more important than its single items, also when considering replacement of animal-based foods in a diet [63]. For example, results from a clinical intervention study by Päivärinta et al. [64] indicated that replacing part of the animal-based proteins with plant-based proteins in a Nordic diet increased fiber intake, improved fat quality, and benefited blood lipoprotein profile.

In the present study, the drivers of consumption differed between the consumer segments, similar to the situation in previous studies [43,65]. Interestingly, for the MeatPref and BothPos segments, the most frequently given reason for regularly eating meat alternatives was "I like trying new foods". Although food neophobia (i.e., reluctance to try new foods) has been frequently identified as one of the barriers to the consumption of alternative proteins [23,46,66], it may be more important in relation to certain other kinds of meat alternatives, such as insects and cultured meat, than plant-based meat alternatives [23]. Moreover, in the present study, the consumer segments did not differ significantly (according to Tukey's test) in terms of their Food Neophobia Scale scores.

With regard to the barriers to consumption, the most commonly cited reasons for not eating meat alternatives regularly were "I do not like the taste of meat alternatives" and "Meat alternatives are too expensive". Taste being given as a reason for not eating meat alternatives is consistent with previous findings by, for example, Hoek et al. [43] (for a review, see [67]). Similarly, price was identified as a top barrier toward eating plant-based products in flexitarians in the survey by Smart Protein project [24]. Likewise, price being given as a barrier is in line with the conclusion by Michel et al. [20] that meat alternatives must be offered at competitive prices if they are to have a good chance of replacing meat. However, the frequencies of citing reasons differed considerably between the consumer segments. For example, among those who did not use meat alternatives regularly despite reporting relatively positive associations with them (from the MaPref and

BothPos segments), one of the most frequently mentioned reasons for nonuse was "I do not know how to cook meat alternatives".

4.3. Consumer Segments

In contrast to the present study, Lemken et al. [42] and Niva and Vainio [46] used latent class analysis and Götze and Brunner [45] hierarchical cluster analysis and multiple variables to segment consumers from different countries (Germany/New Zealand, Finland, and Switzerland, respectively) and studied adults of all ages. Despite the clear differences between these studies and the present investigation, they all ended up with a similar number of segments (5–6/population) with comparable features. All four studies identified a consumer cluster firmly oriented toward eating meat. Lemken et al. [42] termed the consumer group resembling our "MeatPos" segment the "meat only" cluster; Niva and Vainio [46], "established beef lovers"; and Götze and Brunner [45], the "uncompromising meat-eaters". Similarly, all the authors identified a segment strongly devoted to meat alternatives/legumes. The majority of individuals in the former type of segment were men, while the majority in the latter were women [42,45,46].

Most respondents in the present study (68.1%), similar to the situation in the studies by Lemken et al. (55.7% in Germany and 57.3% in New Zealand) [42], Niva and Vainio (53.8%) [46], and Götze and Brunner (67.6%) [45], were classified into the middle groups/segments, whose attitudes toward meat/meat alternatives and/or their consumption were not as extreme as those in the two segments described above. The middle segments arguably exhibit the highest potential to reduce their meat consumption by replacing it with meat alternatives. The segments with the strongest orientation toward meat may prove resistant to interventions intended to reduce meat consumption, while the segments that report the strongest avoidance of meat may not need to reduce their consumption. Therefore, the middle segments could be the best targets for interventions aiming to reduce meat consumption with the help of plant-based meat alternatives.

4.4. Limitations

The present study focused on millennials (20–39-year-old individuals). No respondents from other age groups were studied. Thus, we cannot directly compare millennials to consumers from other generations in the same population. Likewise, we only included respondents from one country/culture (Finland) in our study. However, we compared our results with those of relevant prior studies conducted in other countries and with wider age ranges of respondents [42,45]. Furthermore, we have allowed access not only to our results but also to our questionnaire (Table S1) and data (Table S2) to enable other researchers to utilize them in future studies.

Most of the questions in our survey were derived from published and validated multi-item scales (Table 2). However, among the scales, a validated translation was only available in Finnish for the Food Neophobia Scale [68]. Nevertheless, four of the present authors, who were all native Finnish speakers and experts in the field of food sciences, proofread the translations of the other scales. Yet, we acknowledge the need for further validation of these scales in the Finnish language and culture.

5. Conclusions

Our survey data, which were obtained from a representative sample of Finnish millennials, suggest that the hedonic tones of the first associations with meat vs. plant-based meat alternatives (positive-negative) are not unidimensional; rather, they are two-dimensional phenomena that can be used for easy consumer segmentation. The hedonic tone associated with meat alternatives was opposite to that associated with meat for some respondents, albeit not for all of them. In fact, some people think positively about both meat and meat alternatives, while other consumers are neutral concerning both food categories. Our classification of consumers was performed based on their responses to two simple questions, and it led to six segments. This allowed us to distinguish not only people who exclusively promote meat or vegetarian diets but also those who have positive attitudes toward both meat and meat alternatives. These respondents were mostly flexitarians or omnivores who consumed meat alternatives because they liked to try new foods, in addition to environmental reasons. Thus, this consumer segment was considered the best target group for behavioral interventions designed to replace meat consumption with the consumption of meat alternatives.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/foods11030456/s1, Table S1: Survey questions (in English and Finnish), Table S2: Data (responses to the online survey).

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and followed the ethical principles concerning sensory and consumer research at University of Helsinki, approved by the University of Helsinki Ethical Review Board in the Humanities and Social and Behavioural Sciences (Statement 46/2016).

Informed Consent Statement: Informed consent was obtained digitally from all respondents involved in the study.

Data Availability Statement: The data that have been analyzed for this article (anonymized responses to the online survey) are available as (Supplementary Materials Table S2).

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Drivers and Inhibitors in the Acceptance of Meat Alternatives: The Case of Plant and Insect-Based Proteins

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Abstract: Insects as an alternative protein source has gained traction for its advantageous environmental impact. Despite being part of many traditional food cultures, insects remain a novelty in Western cultures and a challenging concept for many. Even though plant-based protein alternatives are not facing the same barriers, product unfamiliarity and limited exposure hinder adoption, which could be detrimental to growth within the food sector. This study is aimed at evaluating plant- and insect-based proteins as alternative dietary proteins. A model indicating the drivers of consumer attitudes towards meat-alternative proteins and consumer willingness to try, buy, and pay a premium was tested. Further, 3091 responses were collected using surveys in nine countries: China, USA, France, UK, New Zealand, Netherlands, Brazil, Spain, and the Dominican Republic. Structural Equation Modelling was used to analyze the data. We found that consumer's behavioral intentions towards both plant-based and insect-based alternatives are inhibited by food neophobia but to an extent, are amplified by the perceived suitability and benefits of the protein, which in turn are driven by nutritional importance, environmental impact, healthiness, and sensory attributes for both alternatives. The expectation of the nutritional value of meat is the strongest (negative) influence on perceived suitability/benefits of plant-based protein and willingness to try, buy, and pay more for plant-based proteins, but it only has a relatively small impact on the suitability/benefits of insect-based protein and no impact on willingness to try, buy, and pay more for insect-based proteins. Overall, we conclude that consumer adoption towards meat alternatives is complex and is strengthened by the perceived suitability/benefits of the protein and general importance of perceived food healthiness and sustainability. Conversely, adoption is hindered by dietary factors and the experiential importance of meat and food neophobia.

Keywords: willingness to try; neophobia; structural equation model

1. Introduction

Much has been publicized about how the unsustainable ways of traditional meat production and consumption [1–3] is detrimental to both the environment and human health [4–6]. As a result, meat, particularly red meat, has attracted much criticism in recent years [7,8]. This, compounded with demographic pressures and socio-economic growth trends, has encouraged new product development and the introduction of a variety of alternatives to traditional animal proteins, thus extending the availability of meat substitutes in many markets. In order for the necessary changes to become a reality in our current food systems, we need to have a better understanding of how consumers view meat alternatives and gauge their willingness to change their purchasing and consumption habits.

Meat alternatives are not new, particularly plant-based and mycoproteins such as Quorn. Nevertheless, Quorn's global market share has not spread much outside the UK and the product has remained niche in most countries outside the UK. Conversely, pulses, which are a great source of plant proteins, have been a traditional part of staple diets in many cultures for millennia [9]. More recently, plant-based protein sources have been part of extensive new product development by the food industry bringing meat alternatives to the market that are promoted under higher sustainability credentials [10,11], thus catering to the burgeoning vegetarian and vegan segments.

The potential of insects as an alternative protein source has also gained traction because of advantages in resource usage, such as land, feed, water, and energy, and the role they can play in circular production systems [12,13]. Insects are and have been part of food cultures of large swathes of the world population. Yet, it is felt that in the more economically developed western countries, insect eating, entomophagy, and the consumption of products made with insect protein are still a novelty and a challenging concept for many consumers. Consumers' unfamiliarity and limited exposure to different food products hinders the adoption of new foods, which holds true for most foods made with alternative proteins [14,15].

1.1. Theoretical Underpinning

Western consumers tend to possess an ingrained barrier to eating insects and insect-based products, which is expressed through fear and disgust [16]. Such a behavior is typical of a food neophobic trait. Kush et al. [13] posited that consumers tended not to change their purchasing behaviors easily. The consumers' reluctance to change could be attributed to an inbuilt evolutionary-derived encoded instinct to protect humans against potential poisonous foods over familiar ones that are more beneficial to health and growth [17,18]. Thus, a predisposition to avoid unusual foods is based on instinctual neophobia [19], which has been socially constructed and filtered through the consumers' system of values [20]. This could play a major role with regards to protein consumption, where an aversion to alternative proteins could constitute a major impediment for replacing meat for another substitute because of the consumer's values, dietary habits, and preferences [21]. This is not unlike when plant-based proteins were first introduced into people's diets more widely [22].

Some of this behavior can be described as food neophobia, which is considered an expression of an aversion trait in consumers' choice behavior with regards to new foods [23]. However, the more frequent and intense the exposure to a new food product through information, education, and experimentation, the lesser the rejection by consumers. Therefore, it can be argued that food neophobia boundaries can be shifted over time. Clark and Bogdan [24] demonstrated that considerable barriers continue to confront the expansion of the market for plant-based proteins. However, their research suggested that once consumers have adopted plant-based meat alternatives, they were more likely to try new plant-based protein versions within the same product category in the future.

Schouteten et al. [25] compared meat, plant, and insect protein in the format of burgers. The overall liking of the plant and insect burger was similar, however the majority of consumers expressed disappointment for both alternatives compared to the traditional meat burger. However, when informed of the ingredients prior to tasting, the approval of the insect burger was significantly higher compared to when the information was not disclosed [25]. Gómez-Luciano et al. [26] found a greater willingness to purchase plant-based protein compared to insect-based proteins, however the responses varied between countries analyzed. Despite a reluctance to immediately adopt new foods, consumers indicated to being open to future changes, supporting a growing dietary shift to alternative dietary proteins [27]. These findings are in agreement with van der Weele et al. [28] who concluded that organizational and institutional coordination were required to enable the acceptance of meat alternatives (insect, pulses, and cultured meat), with recommendations to drive nutritional, sustainability, technological, and societal changes.

It is well understood that one of the major constraints concerning consumers' willingness to engage with sustainable food innovations is the consumers themselves [25–27]. Pliner and Hobden [29] developed a Food Neophobia Scale (FNS), which has since served to measure the consumers' willingness to consume foods that they might not be familiar with or have held a life-long aversion to. Cox and Evans [30] investigated food-related neophobia one step further and considered the possible aversion to new foods produced by novel technologies, which has been coined as Food Technology Neophobia [30]. Both the Food Neophobia scale and the Food Technology Neophobia scale have been widely validated in many different contexts [23,31,32]. However, Bäckström et al. [32] mentioned that familiarity played an important role in people's willingness to try a product that they do not recognize or have not encountered before. Consequently, unfamiliar products would face barriers to consumption as they clash with habit-bound consumer behavior [32]. Capitanio et al. [33] concluded that the aversion to consume novel foods was driven by a fear of what a food product could contain regarding ingredients and the processes used in its production. Chang et al. [34] argued that for organic foods, when too much processing had taken place, a product's perceived authenticity would be diminished, resulting in a lower purchase intention, which agrees with Eyhorn et al. [35]. Furthermore, despite a greater willingness to try a novel food product, consumers' intentions to pay more for meat alternatives is often low [36,37]. Therefore, despite the growing literature around the topic, there is still the need to investigate the drivers that influence consumers' attitudes towards meat alternatives. This study's contribution is to bring to light what consumers' attitudes would be toward willingness to buy, willingness to try, and willingness to pay a premium for meat alternatives such as plant- and insect-based products.

1.2. Model Development

The overarching aim of this study was to evaluate whether plant- and insect-based proteins could be realistic meat alternatives from the consumers' point of view. In order to test a theoretical model, attitudes towards the two types of meat substitutes were analyzed and the extent to which there were differences in consumers' attitudes and preferences between the alternatives was tested. Meat functioned as the default to which consumers could compare a widely accepted meat alternative (plant-based) and a meat alternative that could be integrated into a circular production system (insect-based) [38,39]. It also aimed at establishing a model indicating the drivers of consumers' attitudes towards meat-alternative proteins and consumers' willingness to try, buy, and pay a premium for them.

The model (Figure 1) was designed based on the literature that supported the notion that new and unfamiliar foods affected consumer behavior [20,31]. It was expected that Food Neophobia and Food Technology Neophobia would inhibit consumers' willingness to try, to buy, and pay more for meat-alternative proteins. Nine hypotheses were tested (Figure 1). The consumers' attitudes towards the importance of meat taste, texture, smell, and the nutritional importance of meat were expected to be negatively influenced by their perception of meat-alternative suitability and benefits [19,21].

Suitability and benefits were defined as a combination of sensory benefits, nutritional importance, environmental impact, and health influence that was unique to the meat substitute in question. The importance consumers placed on healthiness and the environmental impact of their food choices, in general, was likely to enhance their assessment of meat substitutes [40]. Consumers' attitudes towards the suitability of and benefits derived from a particular meat-alternative protein should also augment their willingness to adopt it [26,27]. Therefore, the proposed model should establish a better understanding of how consumers viewed meat alternatives and their willingness to change their purchasing and consumption habits.

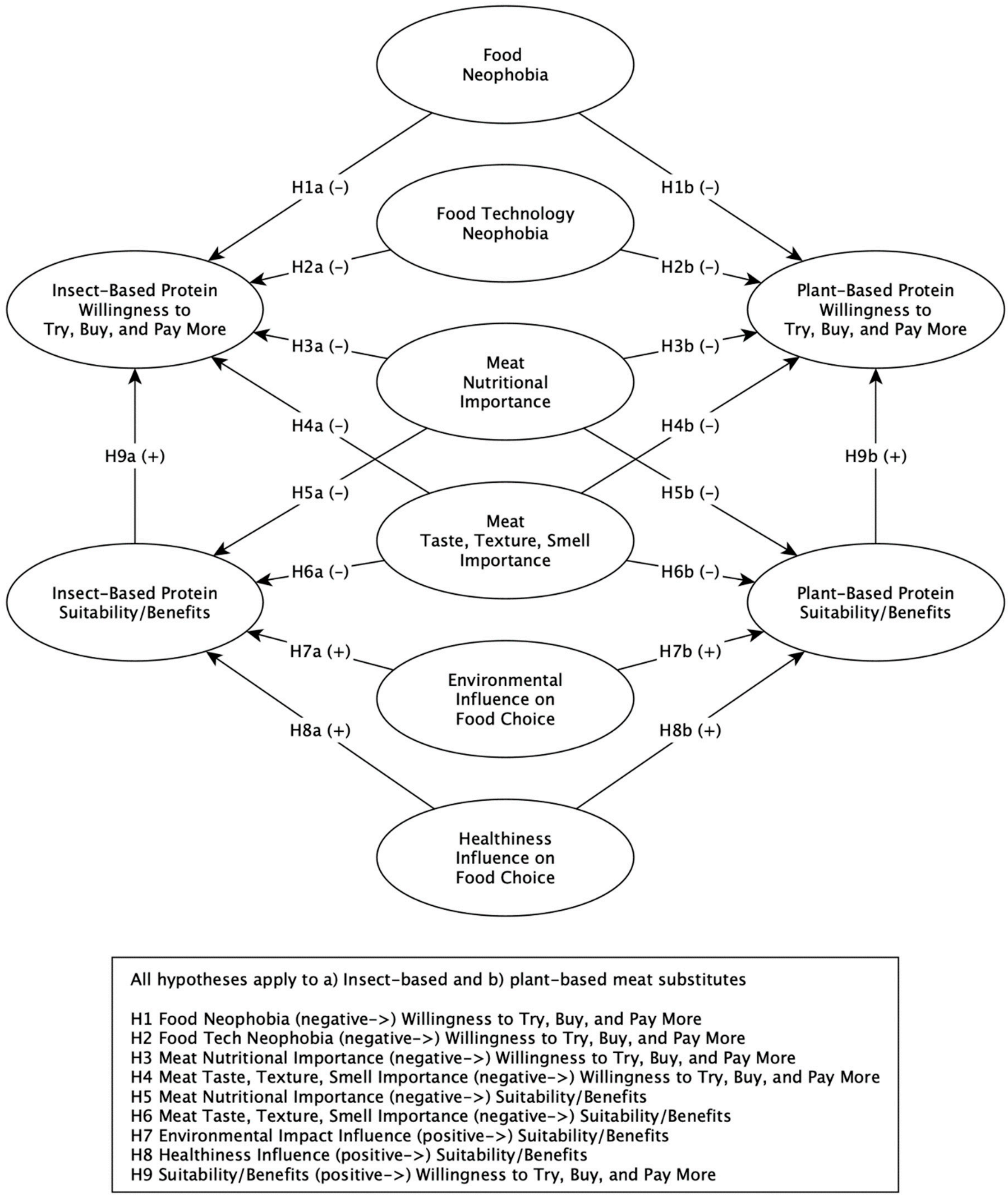

Figure 1. Conceptual Model and Hypotheses.

2. Method

A sample of 3091 responses in total was obtained from surveys carried out in nine countries. The sample was composed of 571 respondents from China (CN), 539 from the USA (US), 484 from France (FR), 366 from the UK, 268 from New Zealand (NZ), 231 from the Netherlands (NL), 216 from Brazil (BR), 210 from Spain (ES), and 206 from the Dominican Republic (DR). Data collection started in February 2017 and finished in April 2018 in CN, the US, FR, the UK, BR, ES, and the DR. From February 2018 until May 2019, data were collected in NZ and the NL. The gender distribution was 59.2% females, 38.9% males, and 1.9% who preferred not to answer. The mean age of the sample was 34, with quartile ranges of 16–21, 22–28, 29–44, and 45–86. Table 1 provides a country-by-country insight into the demographics of the survey respondents.

Table 1. Demographics (gender and age) of the survey respondents per country.

Country	*n*	Gender			Age	
		Male%	Female%	Prefer not to Say	Mean ± SD	Range
China	571	38.0%	60.8%	1.2%	31.2 ± 11.6	19–72
USA	539	24.6%	75.4%	NA *	44.1 ± 21.7	18–71
France	484	59.9%	31.8%	8.3%	29.0 ± 17.3	18–68
UK	366	23.8%	76.2%	NA	32.0 ± 16.8	19–67
New Zealand	268	46.8%	53.2%	NA	37.9 ± 12.9	18–70
Netherlands	231	37.7%	62.3%	NA	29.6 ± 15.4	17–70
Brazil	216	43.1%	56.9%	NA	38.3 ± 22.1	17–77
Spain	210	49.5%	48.1%	2.4%	35.1 ± 19.5	19–83
Dominican Republic	206	32.5%	66.0%	1.5%	26.2 ± 9.5	16–69
Total	**3091**	**38.9%**	**59.3%**	**1.8%**	**34.1 ± 15.4**	**16–83**

* NA = not applicable.

The questionnaire was initially written in English and then translated into the various respective languages by native speakers who were fluent in both English and their mother tongue to improve the accuracy of meaning and avoid misunderstandings by the various linguistic cohorts. The languages were also adjusted for variations in grammar/spelling, i.e., UK-English, US-English, and NZ-English; ES-Spanish and DR-Spanish; as well as Brazilian Portuguese. The translated versions were back-translated into English to ensure that the meaning had not deviated from the initial word concept or idea. The various collaborators and co-authors were responsible for distributing the survey at a country level (mainly through social media and existing e-mail contact lists). All data gathered were centrally collected and collated at Harper Adams University (HAU) in the UK. In most instances, the questionnaire was distributed in a digital format, however when requested, a hardcopy version was also made available. In the DR, the responses were predominantly collected using a hardcopy, catering for the relatively scant access to the Internet in that country. The research and questionnaire were approved by the Harper Adams University (HAU/UK) Research Ethics Committee (HAU-0006-201701). Furthermore, as part of the ethics declaration, each questionnaire also included a contact e-mail at HAU, so that questions arising from answering the questionnaire could be addressed.

Questionnaire and Scaling

The questionnaire included various distinct sets of questions and statements consistent with a previous study [26]. The participants gave their informed consent to partake in the survey. The first group of statements probed the respondents' attitudes towards new foods, new food technologies, health, convenience, and the environmental impact of their food choices (Table 2). More specifically, the following scales were used in the questionnaire to measure the various constructs: Food Neophobia Scale, with 10 items, adapted from Pliner and Hobden [29] (Table 2, 08.1 through to 08.10); Food Technology Neophobia Scale, with five items, which was inspired by Cox and Evans [30] (Table 2, 09.1 through to 09.8); Healthiness of Food Choices, with three items, adapted from the "impact of the healthiness of food choices" scale [40] (Table 2, 10.1 through to 10.3); and Environmental Impact of Food Choices, with three items, adapted from the "environmental impact of food choices" scales in Roberts [41] and Verbeke [37] (Table 2, 12.3 through to 12.3). Many of the above-mentioned scales were adapted from previously described tools [26,29,30,37,40,41] in relation to assessing people's willingness to engage with new foods. In these adaptations, we made careful choices with regards to which survey items to include in our study to avoid unnecessary duplication, utilize the most appropriate items, and avoid potential survey fatigue. For instance, the original food technology neophobia scale [30] contains items covering health and environmental factors, however we found that these topics were better addressed using the survey items used elsewhere [37,40,41]. As such, we also detached those sub-topics from the original scale and addressed them separately. The second group of statements probed the respondents' perceived importance of meat in terms of its nutritional benefits and sensory experience (Table 2). More specifically, a 3-item scale measured Meat Nutritional Importance (Table 2, 13.1 through to 13.3) and a 3-item scale measured Meat Taste, Texture, and Smell Importance (Table 2, 14.1 through to 14.3). All the questions were presented in the form of statements to which the respondents expressed their opinion using a five-point Likert scale ranging from "strongly disagree" to "strongly agree" (Table 2).

Table 2. Scale Loadings, Reliabilities, and Convergent Validity.

Scales and Items	Factor Loadings	Cronbach's Alpha	Composite Reliability	AVE
Food Neophobia		0.795	0.844	0.355
08.1R. I am constantly sampling new and different foods	0.576			
08.2. I do not trust new foods	0.662			
08.3R. I like foods from different countries	0.615			
08.4. If I do not know what is in a food, I will not eat it	0.523			
08.5R. At dinner parties I will try a new food	0.565			
08.6. Some foods look too weird to eat	0.485			
08.7. I am afraid to eat things I have never had before	0.673			
08.8. I am very particular about the foods I eat	0.506			
08.9R. I will eat almost anything	0.588			
08.10R. I like to try new foods from all over the world	0.717			
Food Tech Neophobia		0.746	0.829	0.495
09.1. The benefits of new food technologies are often grossly overstated	0.585			
09.3. There are plenty of tasty foods around so that we do not need to use new food technologies to produce more	0.745			
09.5. New food technologies decrease the natural quality of foods	0.792			
09.7R. New products using new food technologies can help people have a balanced diet	0.673			
09.8R. Innovations in food technology can help us produce foods in a sustainable manner	0.707			
Healthiness Influence		0.716	0.838	0.633
10.1R. The healthiness of food has little impact on my food choices	0.718			
10.2. I am very particular about the healthiness of the food I eat	0.842			
10.3R. I eat what I like and I do not worry much about the healthiness of food	0.822			
Environmental Impact Influence		0.647	0.810	0.588
12.1. When I buy foods I try to consider how my use of them will affect the environment	0.699			
12.2. I am worried about humankind's ability to provide the nutritional needs for all people living on earth now	0.830			
12.3. Something drastic has to change in order to feed all the people on earth by 2050	0.766			

Table 2. *Cont.*

Scales and Items	Factor Loadings	Cronbach's Alpha	Composite Reliability	AVE
Meat Nutritional Importance		0.779	0.873	0.698
13.1. Eating meat is necessary for obtaining beneficial nutrients	0.871			
13.2. The nutritional benefits of meat can easily be matched by alternative protein sources	0.732			
13.3. Meat is an important part of a healthy and balanced diet	0.894			
Meat Taste, Texture, Smell Importance		0.941	0.962	0.895
14.1. The taste of meat is important to me	0.952			
14.2. The texture of meat is important to me	0.955			
14.3. The smell of meat is important to me	0.931			
Plant-Based Protein Suitability/Benefits		0.786	0.854	0.546
19.1. Plant-based protein is healthy	0.836			
19.2. Plant-based protein is safe to eat	0.697			
19.3. Plant-based protein is nutritious	0.840			
19.4. Plant-based protein is more sustainable	0.765			
19.6. Plant-based protein is cheaper	0.506			
Plant-Based Protein Willingness to Try, Buy, and Pay More		0.726	0.845	0.646
20.1. Willing to try plant-based protein	0.752			
20.2. Willing to purchase plant-based protein	0.891			
20.3. Willing to pay more for plant-based protein	0.760			
Insect-Based Protein Suitability/Benefits		0.890	0.920	0.699
35.1. Insect-based protein is healthy	0.907			
35.2. Insect-based protein is safe to eat	0.880			
35.3. Insect-based protein is nutritious	0.886			
35.4. Insect-based protein is more sustainable	0.830			
35.6. Insect-based protein is cheaper	0.653			
Insect-Based Protein Willingness to Try, Buy, and Pay More		0.823	0.893	0.740
36.1. Willing to try insect-based protein	0.915			
36.2. Willing to purchase insect-based protein	0.946			
36.3. Willing to pay more for insect-based protein	0.697			

The questionnaire then included descriptions of plant-based and insect-based alternatives to meat proteins. Consumers were asked about their perceptions of the suitability of or the benefits derived from plant-based and insect-based proteins. These questions consisted of six items measuring healthiness, safety, nutrition, sustainability, taste, and affordability relative to meat protein (Table 2). Finally, a consumer behavioral intention scale was used to measure aspects such as willingness to try, willingness to buy, and willingness to pay more for plant-based and insect-based proteins. The questionnaire also collected some demographic characteristics of the respondents.

3. Analysis

A two-step Structural Equation Modelling was used. The first step was related to the evaluation of the measurement model using confirmatory factor analysis. This step evaluated the measurement scales and their items, examining construct convergent and discriminant validity and reliability. The second step tested the model, assessing the significance of the hypothesized relationships between the variables and confirming that goodness-of-fit criteria were satisfied. This two-step analysis was selected due to its appropriateness in the measurement and examination of structural models and testing coefficient paths. For an excellent discussion on the ongoing development and generally accepted process for employing the type of Structural Equation Modelling used in this research, see [42].

3.1. Construct Validity and Reliability

Construct validity was evaluated using factor loadings and average variance extracted (AVE). As shown in Table 2, the result of convergent validity assessment indicated that except for the Food Neophobia scale item, "Some foods look too weird to eat," all of the standardized loadings were above the cut-off level of 0.5, as set by Anderson and Gerbing [43]. Except for the Food Neophobia and Food Tech Neophobia scales, Table 2 also shows that the AVE of all the scales was higher than the 0.5 cut-off level as suggested by Hair et al. [44]. Unfortunately, the removal of any items to those scales resulted in the lowering of Cronbach's Alpha and Composite Reliability values, so it was decided not to take remedial action.

Table 2 also shows that the scales demonstrated adequate reliability. All but one (Environmental Impact Influence) of the scales had Cronbach's Alpha values above the cut-off level of 0.7 and all the scales had composite reliability values above the suggested cut-off level of 0.7 [44].

The discriminant validity of the construct scales was acceptable using both the Fornell-Larker criterion and the Heterotrait-Monotrait (HTMT) ratio methods. Table 3 shows that the Fornell-Larcker criterion was satisfied as the shared variance between the constructs was lower than the variance captured by the construct (along the diagonal). The HTMT ratio was also satisfied as the HTMT correlation estimates between the scales were below the recommended threshold of 0.85 [45], confirming adequate discriminant validity.

Table 3. Scale Discriminant Validity.

Fornell-Larcker Criterion	Environmental Impact Influence	Food Neophobia	Food Tech Neophobia	Healthiness Influence	Insect-Based Protein Suitability/Benefits	Insect-Based Protein Willingness to Try, Buy, and Pay More	Meat Nutritional Importance	Meat Taste, Texture, Smell Importance	Plant-Based Protein Suitability/Benefits	Plant-Based Protein Willingness to Try, Buy, and Pay More
Environmental Impact Influence	0.767									
Food Neophobia	−0.102	0.595								
Food Tech Neophobia	−0.066	0.214	0.704							
Healthiness Influence	0.217	−0.012	0.061	0.796						
Insect-Based Protein Suitability/Benefits	0.180	−0.255	−0.178	0.014	0.836					
Insect-Based Protein Willingness to Try, Buy, and Pay More	0.105	−0.284	−0.118	0.004	0.525	0.860				
Meat Nutritional Importance	−0.325	0.112	0.030	−0.189	−0.130	−0.024	0.835			
Meat Taste, Texture, Smell Importance	−0.241	−0.004	−0.004	−0.143	−0.049	0.055	0.632	0.946		
Plant-Based Protein Suitability/Benefits	0.316	−0.128	−0.098	0.174	0.201	0.047	−0.456	−0.304	0.739	
Plant-Based Protein Willingness to Try, Buy, and Pay More	0.279	−0.168	−0.120	0.205	0.184	0.181	−0.494	−0.391	0.451	0.804

Table 3. *Cont.*

Fornell-Larcker Criterion	Environmental Impact Influence	Food Neophobia	Food Tech Neophobia	Healthiness Influence	Insect-Based Protein Suitability/Benefits	Insect-Based Protein Willingness to Try, Buy, and Pay More	Meat Nutritional Importance	Meat Taste, Texture, Smell Importance	Plant-Based Protein Suitability/Benefits	Plant-Based Protein Willingness to Try, Buy, and Pay More
Heterotrait-Monotrait Ratio										
Environmental Impact Influence										
Food Neophobia	0.194									
Food Tech Neophobia	0.180	0.266								
Healthiness Influence	0.317	0.171	0.124							
Insect-Based Protein Suitability/Benefits	0.241	0.296	0.219	0.078						
Insect-Based Protein Willingness to Try, Buy, and Pay More	0.154	0.334	0.145	0.064	0.586					
Meat Nutritional Importance	0.458	0.219	0.070	0.266	0.160	0.065				
Meat Taste, Texture, Smell Importance	0.313	0.180	0.048	0.180	0.060	0.079	0.729			
Plant-Based Protein Suitability/Benefits	0.434	0.217	0.166	0.217	0.240	0.083	0.559	0.328		
Plant-Based Protein Willingness to Try, Buy, and Pay More	0.398	0.281	0.180	0.288	0.239	0.280	0.644	0.457	0.563	

3.2. Structural Model

Following Hair et al. [44], a bootstrapping method with 500 repetitions was applied to assess the significance of the indicator weights and the path coefficients. In addition, the corrected R^2 of all constructs was estimated as a diagnostic tool to evaluate the model fit. The Goodness of Fit (GoF) measure applies the geometric mean of the communality and the average R^2 for endogenous dependent constructs. The standard for evaluating the outcomes of the GoF analysis is small (0.02), medium (0.25), and large (0.36) [44]. In this research, a GoF value of 0.390 (see Table 4) shows that the proposed model of the relationship between consumer food attitudes and their assessment of and willingness to try and purchase plant-based and insect-based proteins is large, signifying that the model performs well.

Table 4. Model Goodness of Fit (GoF) Index.

Scale	AVE	R^2	Q^2(CVC)	Q^2(CVR)
Insect-Based Protein Suitability/Benefits	0.699	0.042	0.532	0.027
Insect-Based Protein Willingness to Try, Buy, and Pay More	0.740	0.310	0.466	0.213
Plant-Based Protein Suitability/Benefits	0.546	0.243	0.342	0.119
Plant-Based Protein Willingness to Try, Buy, and Pay More	0.647	0.331	0.308	0.200
Average Score	0.658	0.232		4.20%
AVE × R^2		0.152		
GoF = $\sqrt{(\text{AVE} \times R^2)}$		0.390		

Chin et al. [46] argued that an investigator should be able to employ the magnitude of R^2 and Stone-Geisser's Q^2 value as a criterion for the predictive relevance of a model for a particular construct. The results of Q^2 calculations for all the endogenous constructs were greater than zero, indicating that they have satisfactory predictive relevance [44].

Further, Table 4 depicts some results from testing the structural model, indicating that the model does a good job of explaining the variance of willingness to try, buy, and pay more for both meat substitutes. The model explains 33.1% (R^2 = 0.331) of the variance of Plant-base willingness and 31.0% (R^2 = 0.310) of the variance of Insect-based willingness. However, the model was able to explain 24.3% (R^2 = 0.243) of the variance of consumer perceptions of plant-based suitability/benefits compared with only 4.2% (R^2 = 0.042) of the insect-based protein suitability/benefits.

4. Results and Discussion

4.1. Food Neophobia

Food neophobia inhibits willingness to adopt both meat substitutes (Table 5), fully supporting hypotheses H1a/b, but food tech neophobia only inhibits willingness to adopt for plant-based substitutes, supporting H2b.

Faccio and Fovino [19] made it very clear in their review that the relationship between neophobia and technological innovation in the agrifood industry was complex and required nuance when the concept of neophobia was used outside its original context. Their contention was that a consumer's willingness to try new or unusual food was filtered through their system of norms and values and until new foods or processes become more mainstream, some resistance or avoidance is expected. Our results show that Food Neophobia and Food Technology Neophobia would inhibit consumer willingness to try, buy, and pay more for meat-alternative proteins, however the notion of neophobia by itself might not have been a sufficient indicator to gauge consumers' drivers. The possibility that for some foods, disgust could be a greater influencer than neophobia [16,18,19] should not be overlooked, however the notion of disgust itself was outside the scope of this study.

Table 5. Direct Path Coefficients.

Hypothesized Path Relationship	Coefficient	*t*-Stat	*p*-Value
Food Neophobia → Insect-Based Protein Willingness to Try, Buy, and Pay More	−0.172	10.713	<0.001
Food Neophobia → Plant-Based Protein Willingness to Try, Buy, and Pay More	−0.089	5.195	<0.001
Food Tech Neophobia → Insect-Based Protein Willingness to Try, Buy, and Pay More	0.005	0.320	0.749
Food Tech Neophobia → Plant-Based Protein Willingness to Try, Buy, and Pay More	−0.070	4.549	<0.001
Meat Nutritional Importance → Insect-Based Protein Willingness to Try, Buy, and Pay More	0.015	0.751	0.452
Meat Nutritional Importance → Plant-Based Protein Willingness to Try, Buy, and Pay More	−0.273	12.672	<0.001
Meat Taste, Texture, Smell Importance → Insect-Based Protein Willingness to Try, Buy, and Pay More	0.067	3.272	0.001
Meat Taste, Texture, Smell Importance → Plant-Based Protein Willingness to Try, Buy, and Pay More	−0.137	6.983	<0.001
Meat Nutritional Importance → Insect-Based Protein Suitability/Benefits	−0.123	4..91	<0.001
Meat Nutritional Importance → Plant-Based Protein Suitability/Benefits	−0.379	16.505	<0.001
Meat Taste, Texture, Smell Importance → Insect-Based Protein Suitability/Benefits	0.063	2.583	0.010
Meat Taste, Texture, Smell Importance → Plant-Based Protein Suitability/Benefits	−0.007	0.309	0.757
Environmental Impact Influence → Insect-Based Protein Suitability/Benefits	0.162	7.642	<0.001
Environmental Impact Influence → Plant-Based Protein Suitability/Benefits	0.176	9.725	<0.001
Healthiness Influence → Insect-Based Protein Suitability/Benefits	−0.035	1.504	0.133
Healthiness Influence → Plant-Based Protein Suitability/Benefits	0.061	3.636	<0.001
Insect-Based Protein Suitability/Benefits → Insect-Based Protein Willingness to Try, Buy, and Pay More	0.487	38.956	<0.001
Plant-Based Protein Suitability/Benefits → Plant-Based Protein Willingness to Try, Buy, and Pay More	0.265	14.276	<0.001

4.2. *Perceived Importance of Meat*

The results also show that meat nutritional importance only inhibited willingness to adopt plant-based substitutes (support for H3b), however meat nutritional importance negatively influenced the perceived suitability/benefits of both meat substitutes (supporting H5a/b). Meat taste/texture/smell importance inhibited willingness to adopt both meat substitutes (supporting H4a/b) and negatively influenced the perceived suitability/benefits of only insect-based substitutes (supporting H6a).

The outcome of hypotheses 3 to 6, examining attitudes towards the importance of meat taste, texture, smell, and the nutritional importance of meat, was consistent with the findings of Schouteten et al. [25] and Mishyna et al. [47].

4.3. *Food Choice Values*

The importance of the environmental impact of food choices positively influenced the perceived suitability of both meat substitutes (supporting H7a/b) and the importance of the healthiness of food choices positively influenced the perceived plant-based meat substitutes (supporting H8b).

The importance of healthiness, environmental impact, and suitability of consumers' food choices was examined in hypotheses 7 to 9 and the results support that the food choices were clearly linked with personal values and that these determine the feasibility of a sustainable diet. This is consistent with the information about food choices influencing overall liking [24], that the role meat plays in the diet for many people is beyond its nutritional needs [48], and people rationalize meat consumption [49]. The proposed model included attitudes that were rich in moral implications linked to neophobia values, which offered a multifaceted view of how consumers viewed meat alternatives and their willingness to change their purchasing and consumption habits.

4.4. Behavioral Intension

Food preference research has found links between food ingredients and consumers' willingness to try them. As such, barriers to trying unfamiliar products is linked to the absence of familiar ingredients and the requirement of a relationship between product and territorial context will determine the adoption of innovation [33]. Similarly, customers are more willing to try novel foods when they contain familiar ingredients, although they are unlikely to pay more for novel products—for example, organic meat, moderation of meat consumption, and sustainable fish are accepted, although willingness to pay more is lower than willingness to consume [36]. Furthermore, the readiness by consumers to adopt insects as an alternative meat ingredient where traditional meat consumption showed that only consumers with a weak attachment to meat would consider trying the insect alternative [37]. In this research, consumer perceptions of the suitability and benefits of insect-based meat substitutes augmented their willingness to try, buy, and pay more for them (supporting H9a). The model was able to account for 31% of the variance of behavioral intention and perceived suitability/benefits of insect-based protein was the dominant predictor of behavioral intention, with a notable non-significant influence of food tech neophobia, meat nutritional importance, and healthiness of food.

For plant-based substitutes, the model performed largely as proposed, explaining 33% of the variance of behavioral intention. The paths suggested that meat nutritional importance and plant-based suitability/benefits are the most important predictors of willingness to try, buy, and pay more for plant-based substitutes (supporting H9b).

4.5. Plant-Based vs. Insect-Based Comparisons

The literature [25–28] suggests that for many components of the model, plant-based meat substitutes are likely to be considered more suitable and consumers are more willing to adopt them compared to insect-based substitutes. While no specific predictions were made, Table 6 shows the Paired Sample T tests for comparisons between plant-based and insects-based examples for specific items from the suitability/benefits scales and the willingness to try, buy, and pay more scales. For every pair, the plant-based responses were significantly higher than the insect-based responses, which is most likely due to the notion that plant-based meat substitutes are well established in most cultures, while insect-based meat substitutes are still a novelty with a strong stigma attached [26,27].

Table 6. Plant-Based vs. Insect-Based Comparisons.

Scale Items (1 = Strongly Disagree to 5 = Strongly Agree)	Mean	*t*-Stat
19.1. Plant-based protein is healthy	4.192	35.759 *
35.1. Insect-based protein is healthy	3.432	
19.2. Plant-based protein is safe to eat	4.076	38.583 *
35.2. Insect-based protein is safe to eat	3.221	
19.3. Plant-based protein is nutritious	4.142	27.410 *
35.3. Insect-based protein is nutritious	3.555	
19.4. Plant-based protein is more sustainable	3.641	15.151 *
35.4. Insect-based protein is more sustainable	3.272	
19.5. Plant-based protein is tastier	2.645	14.236 *
35.5. Insect-based protein is tastier	2.327	
19.6. Plant-based protein is cheaper	3.253	6.795 *
35.6. Insect-based protein is cheaper	3.086	

Table 6. *Cont.*

Scale Items (1 = Strongly Disagree to 5 = Strongly Agree)	Mean	*t*-Stat
20.1. Willing to try plant-based protein	2.633	43.130 *
36.1. Willing to try insect-based protein	1.928	
20.2. Willing to purchase plant-based protein	2.392	43.136 *
36.2. Willing to purchase insect-based protein	1.677	
20.3. Willing to pay more for plant-based protein	1.699	30.968 *
36.3. Willing to pay more for insect-based protein	1.278	

* = $p < 0.001$.

Overall, we analyzed consumer perceptions with regards to meat and two alternative dietary protein sources in nine very diverse countries: China, USA, France, UK, New Zealand, Netherlands, Brazil, Spain, and the Dominican Republic. We analyzed our data (3091 respondents) as a single global cohort, rather than providing country-by-country analyses. A country-by-country analysis would have provided more granularity in interpretation; however, it would also have created a very complex and potentially confusing discussion. Our global approach to data interpretation does provide a clear insight into consumers' perceptions regarding alternative protein sources.

5. Conclusions

The findings in this study clearly show that there are differences in consumer attitudes and these influence behavioral intentions towards plant-based and insect-based protein as meat alternatives. To gain more insight into behavioral intentions (willingness to try, buy, and pay a premium), a model was proposed and tested to evaluate the consumers' attitude drivers and determine if plant- and insect-based proteins were realistic meat alternatives. This confirms that consumer adaptation towards sustainable meat alternatives can be complex and is influenced by a diverse set of attitudinal and cognitive-based perceptions.

Our results show that consumer's behavioral intentions towards meat alternatives are inhibited by food neophobia but to a larger extent, are augmented by the perceived suitability and benefits of the protein. The perceived suitability and benefits of the protein alternatives are driven by environmental impact, healthiness, nutritional importance, and sensory attributes for both plant and insect alternatives. Food neophobia and food tech neophobia do not influence the consumer's attitude towards suitability and benefits but have a very clear influence on the behavioral intentions and tend to decrease the willingness to try, buy, and pay more for meat-alternative proteins. The model also shows that consumer attitudes about the environmental impact and to a lesser extent, the healthiness of food, lead to stronger perceived suitability and benefits of plant-based protein. Stronger importance of meat nutrition and to a lesser extent, meat taste, texture, and smell, lead to lower levels of plant-based protein suitability and perceived benefits and lower willingness to try, buy, and pay more for plant-based proteins. For insect-based protein, consumer attitudes towards the suitability and benefits are a strong predictor of willingness to try, buy, and pay more, but those attitudes do not seem to be clearly derived from importance of healthiness, environmental impact of food in general, or their attitudes towards meat. The importance of meat nutritional value is the strongest (negative) influence on perceived suitability/benefits of plant-based protein and willingness to try, buy, and pay more for plant-based proteins, but it only has a small impact on the suitability/benefits of insect-based protein and no impact on willingness to try, buy, and pay more for insect-based proteins.

This study indicates that consumer preferences are influenced by behavioral intentions but does not consider all possible underlying individual attributes such as educational status, knowledge of food and its origins, nutritional values of meat and its alternatives, or the ability to cook a meal. Neither does it consider the potential change in those behaviors with consideration to the importance of, for example, further processing of food ingredients. The contribution of this study is evident by the model created, which is a valuable tool to evaluate what needs to change in consumer attitudes to alter their behavioral intentions. The consumer's understanding of the nutritional role of meat in their diets and the sensory aspects of meat seem to be pivotal as they influence both attitudes and behavioral intentions.

This study is based on 3091 respondents from nine countries and did not answer the cultural role of meat consumption. Further studies should focus on whether food tech neophobia is a larger driver in more technologically advanced meat alternatives such as fungal-based protein and cultured meat. Further, it is unclear what role culture plays as a driver of consumer attitudes towards meat alternatives, such as whether meat substitutes are more accepted in low meat-eating cultures compared to high meat-eating cultures.

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Sensory and Conceptual Aspects of Ingredients of Sustainable Sources—Finnish Consumers' Opinion

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Abstract: Sustainable strategies that enable development of alternative sustainable novel ingredients for food are needed to ensure adequate resources for food in the future. Determining consumer attitudes and acceptance of novel ingredients is essential for wider usage of products including these ingredients. The purpose of the study was to reveal consumers' perspectives on novel, and partly traditional but marginally utilized, ingredients to be used in regular cooking and their sensory characteristics and nutritional and environmental aspects. Consumer attitudes were obtained with two online consumer surveys. Consumer surveys revealed the most interesting ingredients. Plant-based ingredients are preferred over raw materials of animal or insect origin and these are also perceived as more pleasant. Plants were also regarded as credible, ecological, natural, healthy and nutrient-rich. Finnish consumers are not ready to adopt insects into their diet. Neither synthetic meat nor three-dimensional printed food have potential without further knowledge or experience of consumers. Findings of this research give baseline information on consumer attitudes towards novel ingredients. Further research is needed to investigate the perceived pleasantness when the potential ingredients are tasted.

Keywords: consumer attitudes; ingredients; pleasantness; sensory; sustainability

1. Introduction

A crisis of resource sustainability is facing us as a population. A key driver for this is the socio-culturally defined selectivity in consumption habits within developed countries [1]. Sustainable strategies that enable increasing agricultural production and the development of alternative sustainable novel ingredients for food are needed [2]. Determining consumer attitudes and acceptance of novel ingredients of sustainable sources is essential for the commercialization and wider usage of products including these ingredients.

Environmental preservation has become one of the main concerns of consumers [3]. Consumers' interest in environmentally friendly products has grown over recent decades [3–7]. However, regarding food choices, health-related issues and food origin are more preferred reasons than environmental awareness [8]. Other major dichotomies consumers use in categorizing food ingredients are natural vs. unnatural and positive vs. negative [9] which might hinder the acceptance of many underutilized ingredients. Furthermore, consumers perceive ingredients more risky when they are not familiar with them [9,10]. Thus, though consumers might pursue more sustainable food choices, many potential new ingredients suffer from unfamiliarity and various bad images, which makes their application in new products risky for the food producers. Therefore, it is essential to gather understanding about the preliminary images consumers have about new sustainable ingredients and the differences between these images, in order to opt for the most potentially acceptable ingredients for the development of new sustainable food products.

Insects have been allowed to be used as food in the European Union (EU) since the beginning of 2018 after the Novel Food Regulation (Regulation (EU) 2015/2283) came into force regarding edible insects [11]. Opinions and acceptance regarding insects as food in Western countries have recently gained a lot of academic interest (see e.g., [12–18]). Insects are eaten in numerous countries around the world and insect-based food was estimated to include 2000 species of edible insects [19]. However, Western consumers, such as the Europeans, are only beginning to familiarize themselves with insects as food [14,15]. Rejection of insects as food is mainly caused by disgust which is primarily not based on sensory properties of insects but on knowledge of the history and nature of a potential food [14]. This is supported by the results of Megido et al. [12] who reported high willingness to eat and cook insects as food in the near future after tasting insect preparations. Other predictors for the acceptance of edible insects are previous insect consumption, food neophobia, gender, sensation seeking and food technology neophobia [20]. Willingness to consume insects is found to be culturally relative and differing even in European subcultures [15,21]. Consumers in Northern Europe have a more positive attitude towards insect food compared to consumers in Central Europe [15].

Food wastes and by-products are another possible group of novel sustainable ingredients. A circular economy model can be implemented to the food sector by recycling its by-products and hence creating added value with fewer resources [22]. By-products have been considered as low value and discarded without further processing [23]. Recently, food by-products have been studied as a source of sustainable ingredients or bioactive compounds to be used in functional foods as they can have high nutritional value [23,24].

Three-dimensional food printing has suggested to have implications for future food development. Implications include reducing food waste using food that is usually discarded, such as fruits and vegetables having poor quality in appearance [25]. However, little research has been conducted on consumer perception of three-dimensional-printed (3D-printed) food. Manstan and McSweeney [25] reported a positive attitude towards 3D-printed food, even when compared to a conventional counterpart. Three-dimensional printed food products were believed to be healthier and less processed than conventional food products. Results by Brunner et al. [16] oppose this finding as they found Swiss participants to have a negative overall attitude towards 3D-printed food.

Wild food plants have traditionally been used around Europe, but there has been a dramatic loss of traditional knowledge and practices and the use of these plants in nutrition is very low [26]. However, usage is highly dependent on the region and culinary culture [27,28]. In Mediterranean culinary culture, wild plants are still often used as a part of diet [28]. Food made of cultivated plants and bought from the supermarket appears on the table with relatively little effort, while collecting wild species is more time consuming and season-dependent, thus making them less convenient to be used in everyday cooking [26]. There is a live tradition to use wild berries and mushrooms in Sweden and Finland as these are freely available resources for everyone thanks to legal right of access to private land [26,29]. Wild berries are also used in the food industry and restaurants. Wild plants have recently been promoted by avant-garde restaurants in Northern Europe [26].

When novel ingredients are introduced to consumers, they can potentially cause neophobia, that is fear and refusal of new food [30]. Neophobia limits individuals' readiness to try new foods and thus restricts the marketability of new ingredients [31]. It is possible that neophobia explains the common thread among all these novel foods or ingredients.

The purpose of the study was to reveal consumers' perspectives on novel food sources for discovering new potential raw materials for food products and cooking. Our hypothesis was that consumers differ in their opinions on plant-based and other ingredients. The key motivator for this research was to find out the potential barriers and drivers for these food ingredients. Our context of the research was in attitudes of consumers towards novel ingredients and willingness to try and adopt them in cooking and food products. The ingredients need to be either novel or traditional but marginally utilized. Another important aspect to consider in relation to acceptance of novel food ingredients is consumers' motivation to eat them; such aspects were measured by asking a number of questions related to sensory characteristics and to nutritional and environmental aspects. Furthermore, differences between consumer groups were investigated to achieve a more extensive understanding of the attitudes and to identify possible groups of early adopters of the ingredients.

2. Materials and Methods

2.1. Preliminary Stage

The basis of the study was the involvement of consumers in every stage of the process. In the preliminary stage the consumers were engaged in collecting ideas for novel ingredients. This was implemented in a local food fair in autumn 2017 (total number of visitors approximately 20,000). Visitors of the annual food fair were encouraged to write down their ideas on the topic "What are we going to eat from nature 2027?". The list of raw materials (around 100) collected from consumers was supplemented by authors with ideas based on literature and insights from media to increase variation and include some current raw materials. A total of 81 raw materials, presented in Figure 1, were included in the following consumer survey.

2.2. Consumer Survey 1

A consumer survey was applied to discover the interest of Finnish consumers towards novel raw materials as food ingredients. The consumer survey was distributed as an online survey with Compusense Cloud (Compusense Inc., Guelph, ON, Canada). Randomly, 30 of the 81 raw materials were presented for each consumer in randomized order. Consumers were asked to choose at least five of the presented raw materials that they would be interested in using in cooking or eat. There was no maximum limit for choices. Gender and age were collected as demographic information of the participants.

Adult volunteers participating in the survey were recruited from a consumer register administered by the University of Turku. There was no exclusion or inclusion criteria for participation. Participants replied to the survey anonymously and they were not rewarded with any incentive. The study was conducted following the ethical principles of the Declaration of Helsinki. Consumer survey 1 worked as a pretest for consumer survey 2.

2.3. Consumer Survey 2

Another consumer survey was implemented in December 2017 to further investigate the opinion of Finnish consumers on these novel ingredients. Based on the results of the first consumer survey the ingredients were chosen for the second survey. Ten raw materials were included in the survey. The list of the 81 raw materials in the first survey also included raw materials which are already regularly in use in Finnish diets. Therefore, seeds and pulse were excluded from the next survey even though they were the most interesting raw materials according to the results. The following five most interesting raw materials were included in the survey: nettle, berry bush leaves, spruce or pine shoots, leaves and stem of broccoli and cauliflower and clover. Root vegetable tops were combined with broccoli and cauliflower parts to broaden the selection of the raw materials. These represent the generally wasted parts of the vegetables commonly used in Finnish food culture. This combination excluded peels which were considered less interesting.

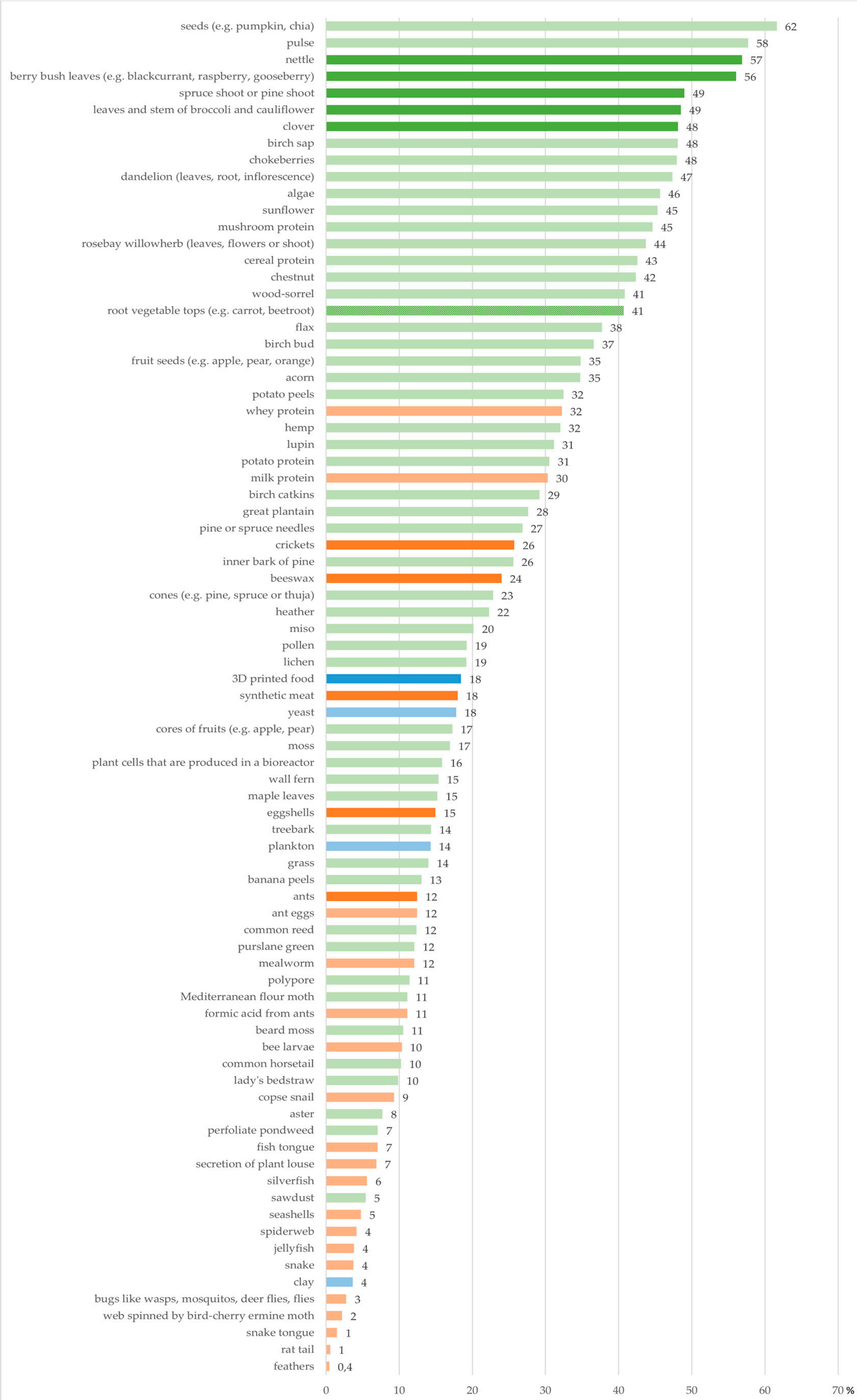


Figure 1. Raw materials listed in order of rated as most interesting by the participating consumers. Plant-based ingredients are marked with green, animal- and insect-based in orange and either or neither with blue. Darker shade indicates the raw materials chosen to consumer survey 2.

Plant-based raw materials were abundant on the original list of the 81 raw materials. These were also selected as the most interesting ones. Nevertheless, the most interesting raw materials of animal or insect origin were considered justified to be included to the survey to obtain a broader impression on consumers' opinions on the subject. The plant-based novel ingredients considered most interesting based on consumer survey 1 did not include significant protein sources. This was another argument to include raw materials of animal and insect origin. Whey protein and milk protein were found to be the most interesting raw materials of animal origin. These were excluded from the survey based on their prevalence in food manufacturing at present. Crickets, beeswax and ants were the most interesting insect-based raw materials, and they were included in consumer survey 2. Synthetic meat and eggshells were the most interesting raw materials of animal origin. Three-dimensional-printed food was included to the list of raw materials of the second consumer survey. This was argued for, though 3D-printed food is not a raw material, but is a novel method for utilizing both plant-based and animal-based raw materials, as well as for processing by-products into edible food in the future. However, 3D-printed food could be considered equal to the other ingredients because rarely is a whole meal is printed, it is usually parts of it. The 3D printing of food was not common by the time the consumer survey was executed as no 3D-printed food, dish or food ingredient were marketed for Finnish consumers.

Second consumer survey questionnaire was assembled of the questions regarding the raw materials and questions regarding the participants as background variables. A consumer survey was distributed as an online survey with Surveypal (Surveypal Inc., Tampere, Finland). Consumers were given instructions to think about the raw material as an ingredient of a food product or in cooking. Only the name of the raw material was given in the form with no further information. Consumers' willingness to try and opinion on usage and the conceptual properties of the raw materials was gauged with 7-point Likert scale. Prospects of the raw materials were investigated with statements such as "I could eat or cook made of this raw material" and "I would be interested in trying food made of this raw material". The scale was verbally anchored from both ends (1 totally disagree, 7 totally agree). The pleasantness of the sensory characteristics of the raw materials was evaluated with 7-point hedonic scale from 1 (extremely unpleasant) to 7 (extremely pleasant). Participants evaluated pleasantness of appearance, odor and flavor, and feel in fingers and mouth. Each participant evaluated three randomly presented raw materials.

Consumers' attitudes and values were collected as background variables. Attitudes towards new food was studied with the food neophobia scale (FNS) [30]. The FNS consists of 10 items with a seven-category response scale ranging from "disagree strongly" (1) to "agree strongly" (7). Half of the items are reversed, therefore scoring of these items was reversed before calculating the FNS score as a sum of all the item scores. The Finnish translation of the FNS was used with minor revisions in wording as published in a Finnish textbook [32,33]. Participants were divided into three groups based on their FNS score. The three groups were formed following the procedure by Knaapila et al. [34]. Participants with low FNS scores (10–24) were regarded as "food neophilics"—score 25–39 indicates "median group" and score 40–67 indicates "food neophobics". Gender, level of education, part of Finland where the participant lives, type of neighborhood, type of the household and diet were collected with category scales. Participants were asked to inform on whether they grow vegetables, berries or fruits themselves or pick berries, mushrooms or other ingredients from nature for food or cooking (Yes, I grow/Yes, I pick/No, I do not grow or pick). The questionnaire was completed anonymously.

Volunteer participants responding to the survey were recruited by a commercial supplier of consumer surveys. A total of 1014 participants were recruited to obtain adequate amount of replies for each raw material. To ensure variation of the background of the participants, quotas for demographic variables were generated. Usually women tend to participate in the surveys more eagerly than men. In our study, a minimum of 30% male participants was pre-established to secure adequate representation of both genders. In addition, participants from different parts of Finland were recruited from southern, western, eastern and northern parts of Finland at approximately 25% each. Highly educated participants are often overrepresented in the sample. Therefore, a quota for a minimum of 50% lower educated participants was created. Inclusion criteria were interest to participate and responsibility of groceries of the household alone or together with others. The group of participants was not representative of the Finnish population. The commercial supplier rewarded the participants according to their normal procedure.

2.4. Statistical Analysis

Results of consumer survey 2 were statistically analyzed using SPSS (IBM SPSS Statistics, 26, IBM Corporation, Armonk, NY, USA). Comparisons between the distribution of the results were performed to analyze differences between samples and respondent groups. Independent samples t-test or one-way analysis of variance (ANOVA) with Tukey's or Tamhane's post hoc test were used for variables and groups with normal distribution of categories. Most of the distributions were not normal. Therefore, a Mann–Whitney U-test and Kruskal–Wallis 1-way ANOVA methods with pairwise comparison were applied. The pairwise comparison was performed and significance values were adjusted by the Bonferroni correction for multiple tests. The criterion for statistical significance in all tests was $p < 0.05$.

3. Results

Participants of both consumer surveys were volunteer Finnish consumers. Demographic information of the participants is presented in Table 1. A more detailed description of the participants is presented in Section 3.1. and Section 3.2.1.

3.1. Consumer Survey 1

Participants in consumer survey 1 were not predetermined with quotas. A total of 380 replies of volunteer participants was received. In total, 82.8% of the participants were women, 15.4% men and 1.8% other or did not want to specify gender. Consumers who participated were 18 to 81 years old and mean age was 42.9 years. Detailed information of the participants is presented in Table 1.

Plant-based ingredients were the most interesting according to consumers similarly to the type of suggestions. Only 24 of the 81 raw materials were of animal or insect origin and only the 24th of the raw materials in order of the most interesting ones was of animal origin.

Although nettle is well known in Finland [35], it is not commonly used in current cuisine. There is potential for future usage, since 57% of the respondents were interested in using nettle. It was the most interesting of the wild vegetables. Berry bush leaves were almost as preferred as nettle (56%). Black currant leaves are to some extent used in seasoning in certain traditional food and drinks, but the amounts consumed are very small. Pine and spruce shoots are traditionally used as medicine and are, for example, eaten to avoid C-vitamin deficiency. In recent years, small food companies have started to produce food products from spruce shoots, but these are not widely used. Usage of pine or spruce shoots in cooking at homes is very rare. The fourth interesting wild vegetable was clover, which is used in salads, soups or herbal drinks, but the usage is marginal [36].

The following group after wild vegetables was the wasted parts of vegetables. The most preferred raw material representing this group was leaves and stem of broccoli and cauliflower (49%). These are used to some extent together with the other parts of broccoli or cauliflower, but they compose a great amount of wasted food material especially during the domestic season when the prices are lower. Root vegetable tops (41%), fruit seeds (35%) and potato peels (32%) represent the same group of raw materials and were also quite popular.

The most preferred raw materials of animal origin were whey protein (32%) and milk protein (30%). These are already commonly used in food products by manufacturers but not generally used by individuals at home. Synthetic meat (18%) was the first raw material of animal origin after proteins mentioned earlier. In this context it was considered to be synthesized animal cells. Eggshells were the following animal-based raw material and 15% of the respondents regarded them interesting.

Table 1. Participants of consumer survey 1 and 2.

Consumer Survey 1 *n* = 380		**Consumer Survey 2 *n* = 1014**	
	% of the Participants		**% of the Participants**
Gender		Gender	
Female	83.4	Female	58.3
Male	15.5	Male	41.5
Did not want to specify gender	1.1	Did not want to specify gender	0.2
Age		Age	
Mean	42.9	Mean	50.2
18–34	35.5	18–34	21.9
35–49	29.7	35–49	24.9
50–64	25.5	50–64	30.7
65–80	9.2	65–80	22.6
		Education	
		Basic	12.7
		Intermediate	42.6
		higher level	44.7
		Part of Finland where lives	
		South	23.3
		West	24.2
		East	24.2
		North	28.4
		Neighborhood	
		center of a large city (over 100,000 inhabitants)	21.1
		center of a smaller city or municipality	26.9
		housing estate	33.1
		rural area	18.8
		Type of household	
		Single	32.1
		adult household	45.4
		family with children	22.6
		Diet	
		mixed diet	80.5
		plant-oriented mixed diet	11.1
		lacto-ovo-vegetarian	3.7
		Vegan	1.3
		Other	3.4
		Food neophobia group (Food Neophobia score)	
		food neophilics (10–24)	20.0
		median group (25–39)	51.3
		food neophobics (40–70)	28.7

Insects were not preferred by the participants. At the time of the survey, insects were not allowed to be sold as food in Finland, but it was decided that legislation would change from the beginning of 2018. Therefore, a lot of news and discussion about insects in the food sector has been underway. Thus, the interest towards insects might have been higher. Crickets were the most interesting insects in the survey and 26% of the respondents were interested in using them in food products and cooking. Beeswax was interesting to 24% of the respondents. Beeswax is used as a food additive—e.g., in coating certain fruits. Ants were the third interesting of the insect-based raw materials but only 12% of the respondents choose it as an interesting one. Ant eggs and mealworms were similarly interesting (12%). Since the beginning of 2018, mealworms have been allowed to be sold as food in Finland but are not widely used.

3D-printed food was equated with raw materials since with this method parts of dishes can be produced. In the printing process either plant- or animal-based ingredients can be utilized. Otherwise wasted materials could, for example, be printed to accepted food products. However, 3D-printed food was not considered interesting by the respondents of the study. It was considered equally interesting as a synthetic meat. This result, together with the top of the list including many wild vegetables and herbs, indicates naturalness as an important factor for consumers when considering the new interesting raw materials. The same findings indicate familiarity or tradition to be another significant element when choosing new ingredients as food which is also shown in previous research [37]. The top raw materials are traditionally used as medicine or in cooking. They are also commonly found plants on Finns' own yards. Preferring plants over animal-based raw materials might signify either the importance of ecological aspects or unfamiliarity regarding edible insects. Insects were under discussion at the time of the survey and therefore were hypothesized to be trendy. Healthiness together with tastiness are considered when choosing raw materials for food [38]. These above-mentioned factors were included in consumer survey 2 to further investigate consumers' opinion on the subject.

Results of consumer survey 1 were used as screener of the raw materials for the consumer survey 2 as described in Section 2.2.

3.2. Consumer Survey 2

3.2.1. Participants of Consumer Survey 2

Detailed information of the participants in consumer survey 2 is presented in Table 1. In total, 58.3% of the participants were women, 41.5% men and 0.2% other or did not want to specify gender. Consumers who participated were 18 to 80 years old and mean age was 50.2 years. The majority (87.3%) of the participants had higher than basic education. There was an even distribution of respondents from different parts of Finland. Representatives of city life and countryside were featured. People from households of only adults formed the majority of the respondents; 22.6% of the participants had children in their household. Most (80.5%) of the respondents had a mixed diet. Special diets for different allergies, intolerances or disease or weight control were mentioned as "other". Participants were divided into three groups based on their FNS score as explained in methods (see Section 2.2): 51.3% formed the median group, 28.7% were defined as food neophobics and 20.0% as food neophilics. Picking ingredients from nature or participants growing them themselves was assumed to affect opinions regarding parts of the raw materials in question. Nettle, berry bush leaves, pine or spruce shoots and clover can be picked from nature in Finland and they are available around the country. They also grow in gardens. Furthermore, apples, berries and root vegetables among other food ingredients are grown in gardens. Growing raw materials themselves was assumed to make them more interesting and otherwise affect opinions regarding the conceptual characteristics and pleasantness. Picking berries, mushrooms or other ingredients from nature is quite common among participants; 63.7% reported picking ingredients from nature. Frequency of picking was not predefined. Growing vegetables, berries or fruits was not as common as picking ingredients. Only 28.6% reported growing food raw materials themselves. Amounts grown or area used for growing was not predefined.

3.2.2. Consumers' Opinion on Willingness to Try and Conceptual Characteristics

As the 1014 participants answered the questions regarding three randomly selected raw materials, there were 226–415 responses for each. Distribution of the responses of each statement regarding the possibility to use, willingness to try and the conceptual characteristics are presented in Figure 2A–H. Raw materials are presented in order of the interest according to consumer survey 1 so that the first five are plant-based and next five animal- or insect-based to get a view of the raw material groups based on their origin. According to consumer survey 1, the origin of the raw material (animal/insect or plant) was a significant factor for the respondents, thus it is relevant to examine these groups. Significant differences in the distribution of the responses between raw materials are presented with lower-case letters. Differences are reported with significance level $p < 0.05$.

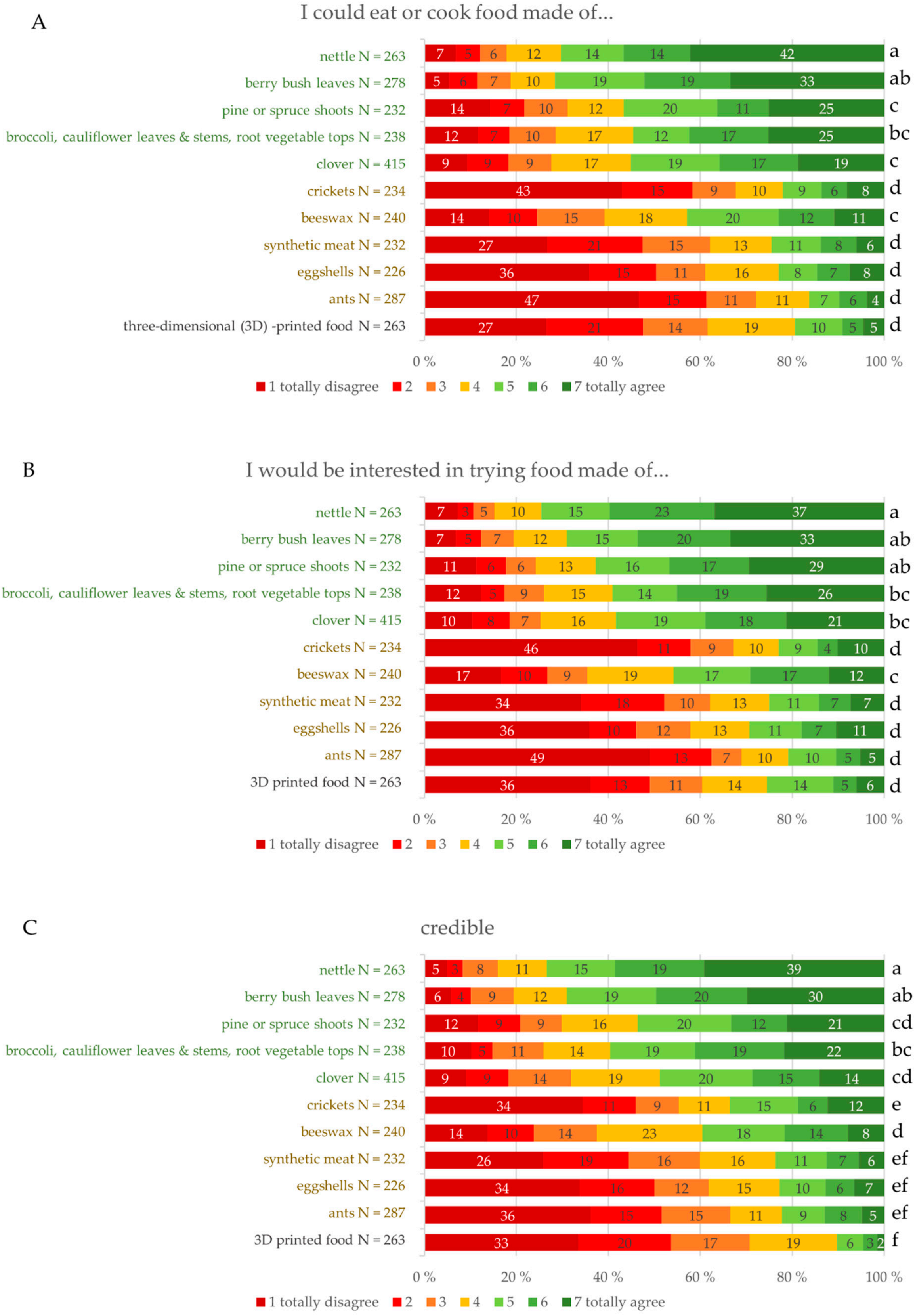
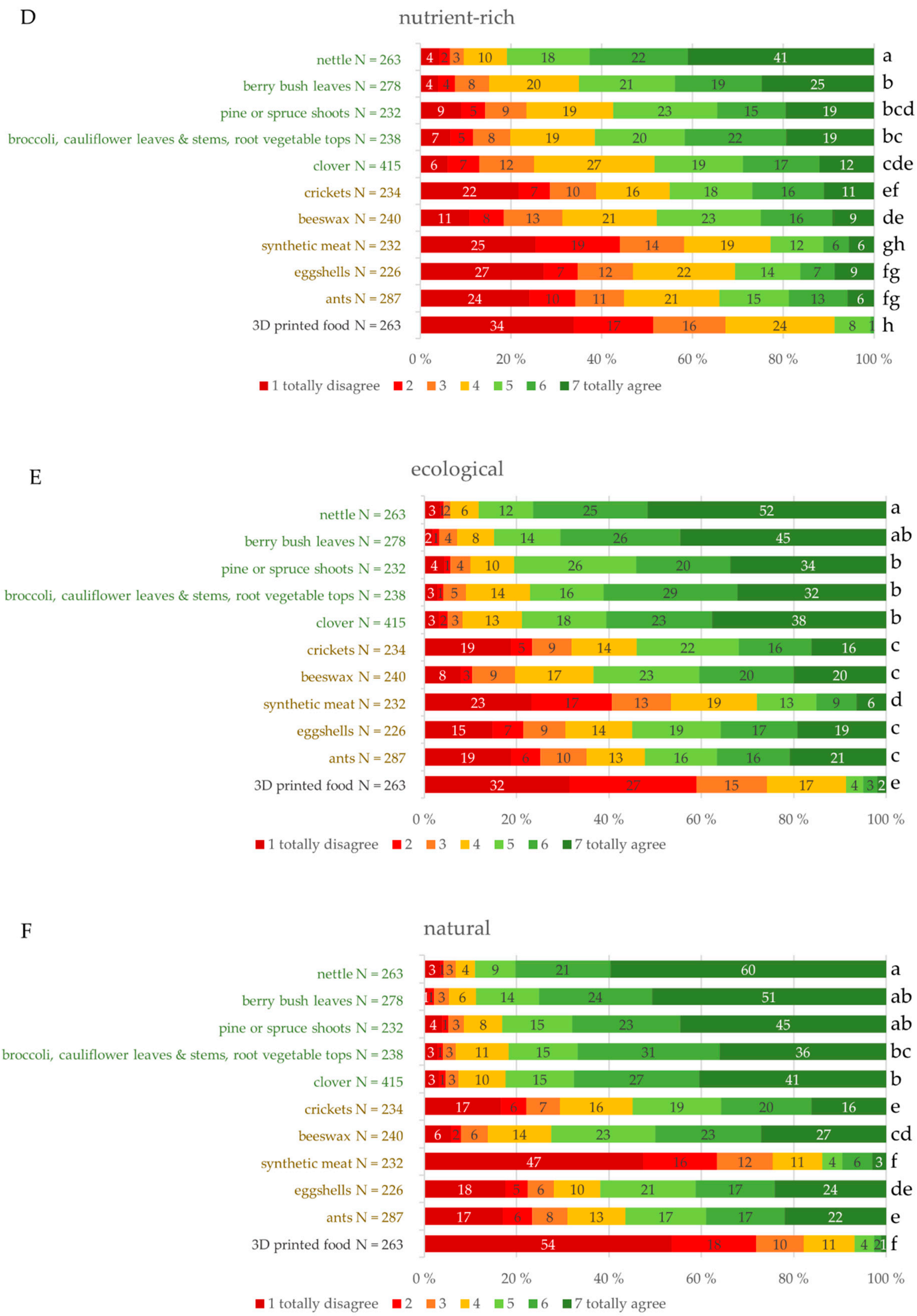


Figure 2. *Cont.*



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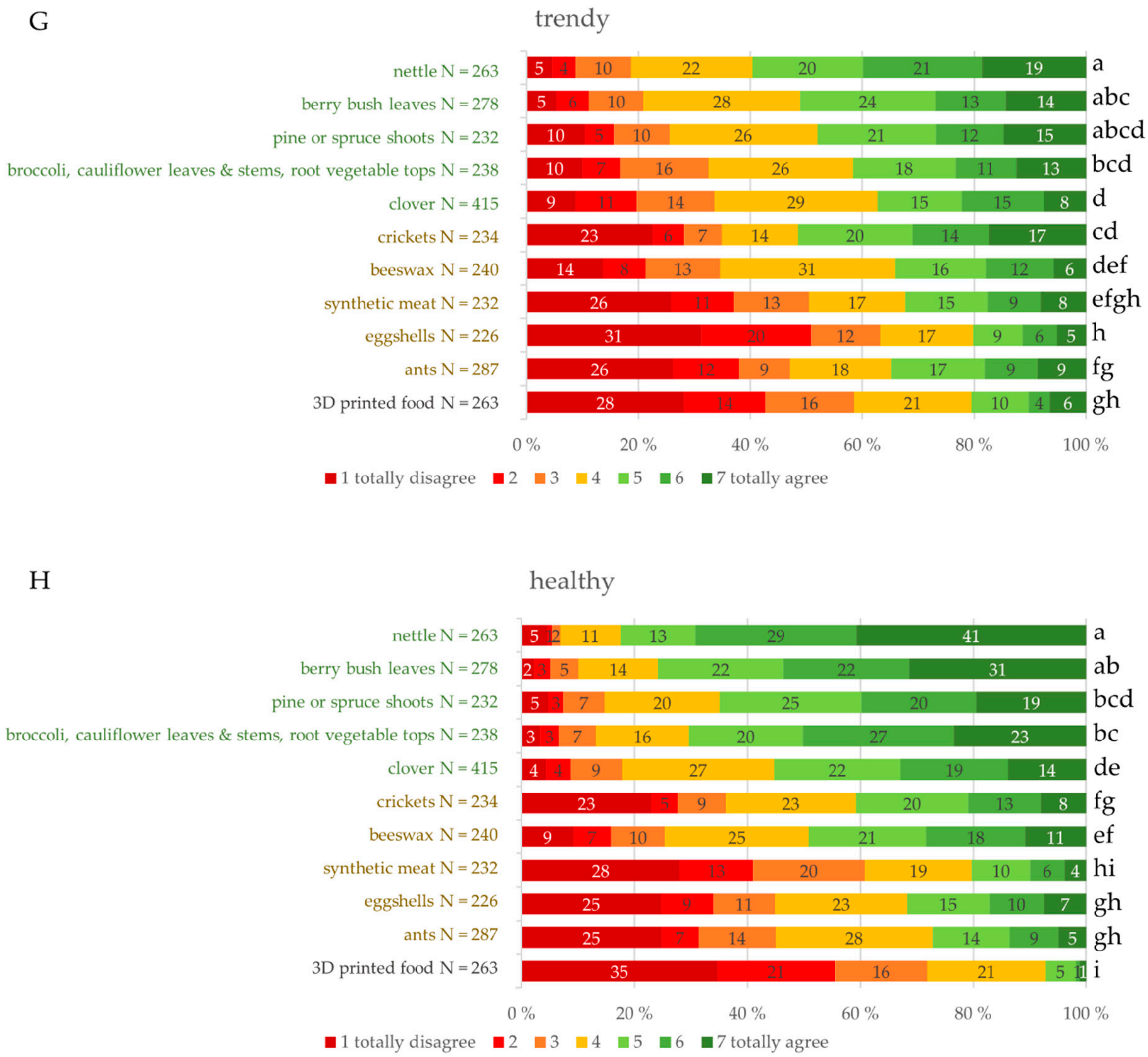

Figure 2. (**A**–**H**) Distribution (%) of the consumer opinion on possibility to use, interest to try and conceptual characteristics of the raw materials. Raw materials with significantly different distributions are marked with different lower-case letters. Significance level $p < 0.05$.

Based on the results of consumer survey 1, differences in consumers' opinions between plant-based and other ingredients were assumed. This hypothesis was not thoroughly verified by the results of consumer survey 2. Beeswax deviated from other raw materials of insect or animal origin. Beeswax is currently used in food as a coating agent for certain foods. However, it is assumed that the majority of average consumers are not aware of this. Distribution of agreement on the statement "I could eat or cook food made of this raw material" was the same with crickets, synthetic meat, eggshells, ants and 3D-printed food. The majority of the respondents at least somewhat disagreed with the statement regarding these ingredients (Figure 2A). Consumers' opinions on nettle and berry bush leaves were the opposite. The majority of consumers at least somewhat agreed that they could eat or cook food made with nettle (70%) or berry bush leaves (71%). Consumers are responsive to nettle, since 42% of the respondents totally agree they could eat or cook food from that. Finnish consumers were not ready to adopt insects into their everyday diet. Only 23% of the respondents to some extent agreed that they could eat crickets and 43% totally disagreed. Similar responses were given for ants—only 17% agreed to some extent and 47% totally disagreed. There was a distinct difference to other raw materials of insect or animal origin in disagreement with the statement. Regarding beeswax, 14% of consumers totally disagreed whereas, regarding ants, crickets, eggshells and synthetic meat, 47%, 43%, 36% and 27% totally disagreed, respectively—i.e., they would not eat the raw material in question.

Finnish consumers are not ready to adopt 3D printing as a food manufacturing practice. The majority (62%) of respondents at least somewhat disagreed that they could eat 3D-printed food. They were not even willing to try 3D-printed food. Over a third (36%) of the respondents totally disagreed—i.e., they would not be willing to try 3D-printed food (Figure 2B).

Willingness to try (Figure 2B) shows similar differences for the non-plant-based raw materials, as assessed via the statement "I could eat or cook food . . . " (Figure 2A). Consumers are not willing to try crickets, ants, eggshells, synthetic meat or 3D-printed food. Slight differences in the opinions on the plant-based raw materials were discovered compared to the statement regarding whether they could eat or cook those materials. Nettle and berry bush leaves were considered as the most credible (Figure 2C). For nettle, 73% of the respondents and 69% for berry bush leaves stated at least somewhat agreed to their credibility. These raw materials are already marginally used for food, which might explain the higher credibility. Insects are not seen as credible for usage as food. The allowance of crickets to be sold as food might explain the slightly, though not significantly, higher credibility compared to ants. However, the majority of the respondents consider insects as not credible food; 54% of respondents at least somewhat disagreed that crickets are credible and 66% that ants are credible. Distribution of replies regarding beeswax and credibility is similar to "could eat" and willingness to try. Finnish consumers do not consider 3D printing as a credible technology for food preparation; 3D-printed food was regarded as least credible together with synthetic meat, eggshells and ants. Only 11% of the respondents agreed to some extent that 3D-printed food is credible.

Consumers' opinion on the nutritional value of the raw materials was investigated. Any information about the nutrient content of the raw materials was not given in the questionnaire. Distinction between plant-based and other raw materials was not conspicuous. Nettle was considered as most nutrient-rich (81% at least somewhat agree), significantly different from all others (Figure 2D). According to consumers' opinion, clover was less nutrient-rich compared to nettle and berry bush leaves and beeswax and crickets were considered as nutrient-rich as clover. Consumers did not regard 3D-printed as nutritious food. Synthetic meat and 3D-printed food were considered comparable and the least nutritious compared to the raw materials which are not produced but are derived by growing or as side streams of food preparation.

Nettle and berry bush leaves were also regarded as the most ecological raw materials (Figure 2E). The raw material representing side streams, broccoli and cauliflower stems and leaves and root vegetable tops were regarded as equally ecological compared to wild vegetables apart from nettle. Plant-based raw materials were highly regarded as ecological and more ecological than others; 79–89% of respondents at least somewhat agreed that the plant-based raw materials are ecological. Insects together with beeswax and eggshells formed the next ecological group; 53–63% of respondents at least somewhat agreed they are ecological. Synthetic meat was less regarded as ecological than the two previous groups but more than 3D-printed food. The raw materials which can be picked from the nature were also considered as natural and plant-based raw materials above others (Figure 2F). Only 5–7% of the consumers disagreed to some extent that the plant-based raw materials are natural. Insects were also regarded as natural but significantly less so than the plant-based raw materials. Over half (55–56%) of the respondents regarded insects as natural. As assumed in the wording, synthetic meat was not regarded as natural by consumers. In total, 75% of the respondents disagreed with the statement. Additionally, 3D-printed food was not regarded as natural, as only 82% of the respondents disagreed to some extent with the statement.

Based on the public discussion, it was assumed that insects could be considered trendy. Crickets were one of the first insects approved [11]. Half (51%) of the respondents at least somewhat agreed that crickets are trendy (Figure 2G). However, 23% of the respondents totally disagreed with the idea that crickets are trendy. Wild vegetables, except clover, were considered the most trendy. Eggshells, which are part of Finns' everyday cooking, were considered the least trendy but this was not significantly different from synthetic meat or 3D-printed food.

Nettle was regarded as the most nutrient-rich (Figure 2D) and was also one of the raw materials regarded as the most healthy (Figure 2H). Similarly, synthetic meat and 3D-printed food were considered the least healthy. Beeswax is used as a coating agent and has been reported not to interact with human digestion at all [39]. However, 50% of the respondents at least somewhat agreed that beeswax is healthy. Synthetic meat and 3D-printed food were considered as the least nutrient-rich and also the least healthy; only 10% and 7%, respectively, to some extent agreed that they are healthy.

3.2.3. Consumers' Image of Sensory Properties

Participants evaluated the pleasantness of the raw materials without any additional information given in the question. The responses to the questionnaire were based on either a recollection of the raw material if the person had previous experience of it or an image if the respondent had no experience of the raw material. Appearances of all the plant-based raw materials were evaluated as more pleasant compared to the raw materials of insect or animal origin apart from beeswax. Additionally, 3D-printed food was seen as less pleasant than plant-based raw materials and beeswax. The appearance of clover and berry bush leaves was the most pleasant (Figure 3A). Most (82%) of the respondents regarded the appearance of clover as at least somewhat pleasant. A proportion (71%) of respondents regarded the appearance of berry bush leaves as at least somewhat pleasant. Pine or spruce shoots, nettle, broccoli and cauliflower leaves and stems and root vegetable tops were regarded as pleasant—over 50% of the respondents evaluated these as at least somewhat pleasant. The appearance of beeswax was evaluated as not pleasant nor unpleasant, but the difference to nettle or broccoli and cauliflower leaves and stems and root vegetable tops was not significant. Eggshells were evaluated as slightly unpleasant; 47% evaluated t as somewhat unpleasant. Synthetic meat and 3D-printed food were also regarded as slightly unpleasant and were not significantly different from eggshells. The 3D printing of food has, to date, been uncommon and it was assumed that most of the consumers had no experience of 3D-printed food. Nevertheless, it was assumed that consumers would have thought food can be printed as any kind of form and therefore the appearance was evaluated as pleasant. This assumption was as discovered false. The appearance of ants was perceived as at least somewhat pleasant by 79% and extremely unpleasant by 40% of the respondents and crickets by 73% and 46%, respectively.

Pleasantness of the aroma and flavor (Figure 3B) of the raw materials of different origins deviated similarly as related to the pleasantness of appearance. Beeswax was at the same level as plant-based raw materials in terms of pleasantness of aroma and flavor. Three-dimensional-printed food was evaluated as less pleasant than plant-based raw materials and beeswax. Aroma and flavor of berry bush leaves were evaluated as somewhat pleasant (50%) or as extremely pleasant (27%). Insects, synthetic meat, eggshells and 3D-printed food were the least pleasant. The proportion of responses of the unpleasant categories was significantly larger. Respondents who evaluated the aroma and flavor of insects as pleasant were a small minority; 16% indicated some degree of pleasantness to the aroma and flavor of crickets and only 9% for ants. Over a third (39%) of the respondents evaluated the aroma and flavor of crickets as extremely unpleasant and 43% did so for ants. Participants were not quite as critical about synthetic meat and eggshells. Distribution of these two raw materials was very similar. Pleasantness of aroma and flavor was not significantly different from crickets but was more pleasant compared to ants. Synthetic meat and eggshells were not regarded as having pleasant aromas and flavors. One-fourth of respondents evaluated the pleasantness of aroma and flavor as extremely unpleasant. Only 18% of respondents indicated some level of pleasantness to synthetic meat and 19% to eggshells. Finnish consumers are not familiar with 3D-printed food and opinions regarding this raw material are not as strong. One-third of the participants evaluated the aroma and flavor of 3D-printed food as not pleasant nor unpleasant. However, it was one of the most unpleasant raw materials in the study. One-fourth (26%) of respondents regarded the aroma and flavor of 3D-printed food as extremely unpleasant.

Participants evaluated how pleasant the feel of the raw material in fingers and mouth is (Figure 3C). There was no information about the preparation of the raw material, but the questionnaire regarded raw materials in food and cooking. Thus, participants could imagine the raw material in question either as raw or prepared in some way. In relation to nettle, some of the respondents might have imagined the plant as raw and for that reason regarded it as very unpleasant. In total, 43% of the respondents regarded the feel of nettle as at least somewhat unpleasant. Berry bush leaves, clover and broccoli and cauliflower leaves and stems and root vegetable tops were the most pleasant raw materials in terms of feeling. Berry bush leaves were evaluated as pleasant by 63% of the respondents, clover by 59% of respondents and broccoli and cauliflower leaves and stems and root vegetable tops by 56% of the respondents. The pleasantness of the feel of beeswax was at the same level with nettle, pine or spruce shoots and broccoli and cauliflower leaves and stems and root vegetable tops. The pleasantness of the feel of raw materials of insect or animal origin together with 3D-printed food were evaluated as less pleasant compared to others. The feel of synthetic meat, eggshells and 3D-printed was equally pleasant. The majority of the respondents evaluated these raw materials as unpleasant; 58% regarded 3D-printed food as unpleasant, 60% did so for synthetic meat and 66% for eggshells. According to Finnish consumers, ants feel the most unpleasant of the investigated raw materials together with crickets. Ants feel unpleasant according to 77% of respondents and crickets do to 81% of respondents.

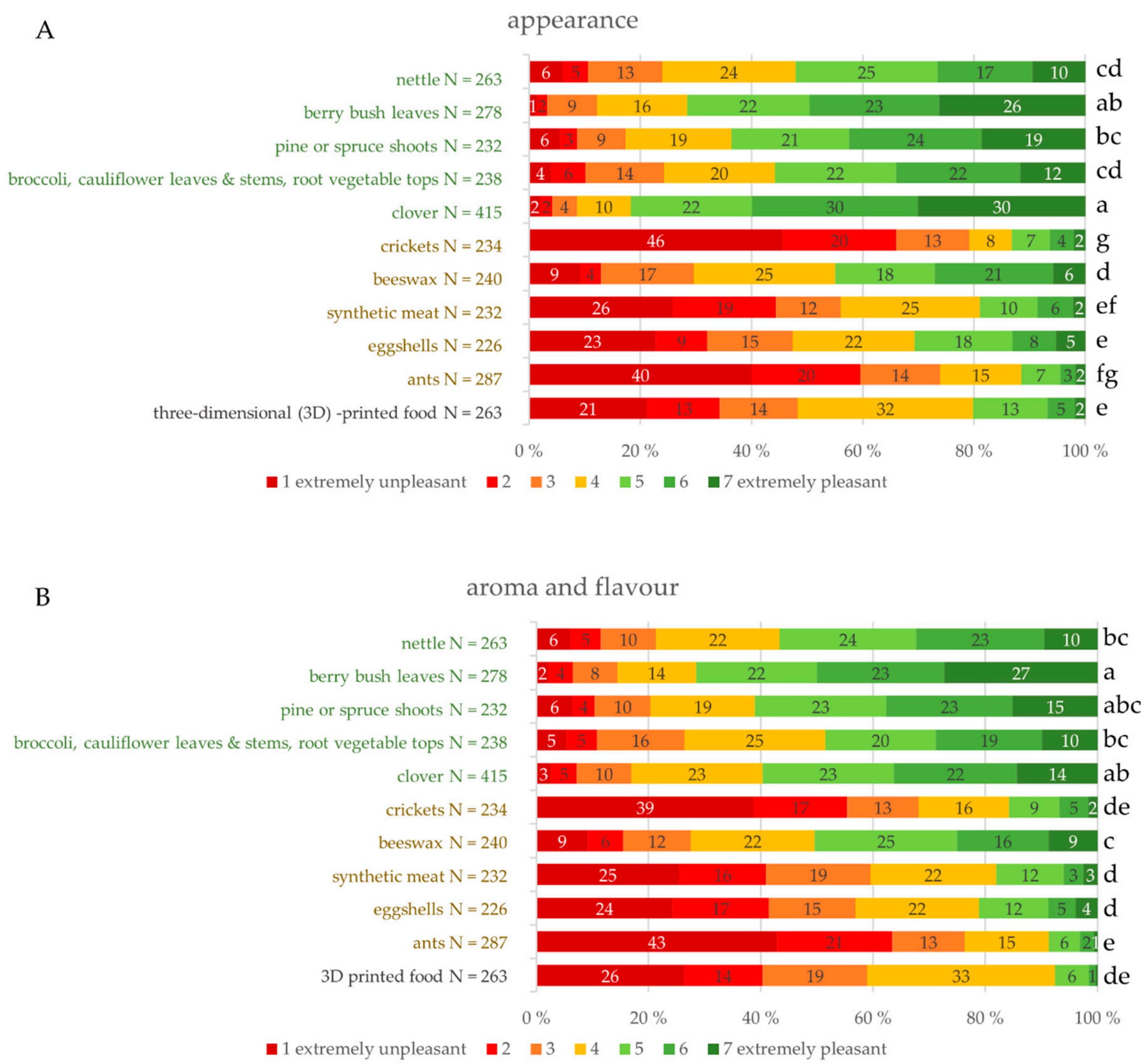

Figure 3. *Cont.*

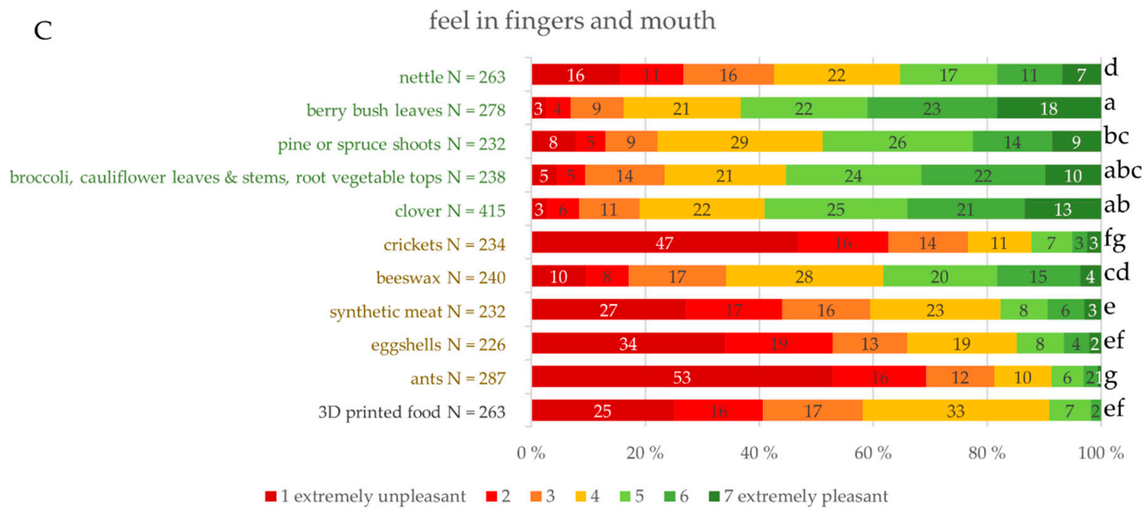

Figure 3. (**A**–**C**) Distribution (%) of the consumer opinion on pleasantness of appearance, aroma and flavor and feel in fingers and mouth. Raw materials with significantly different distributions are marked with different lower-case letters. Significance level $p < 0.05$.

3.2.4. Differences between Opinions' of Consumer Groups

Differences in responses between consumer groups were examined. Consumer groups with different demographic backgrounds were compared. Gender, education level, part of Finland living in, type of neighborhood living in, type of household and diet were used for grouping. Furthermore, differences between groups formed by food neophobia scores were investigated. It was assumed that picking and growing food ingredients oneself could affect opinions regarding investigated raw materials. Therefore, this background information of the respondents was also used to form consumer groups for comparison. The number of the respondents who specified gender as other or did not want to specify gender was small and this group was not compared as a group of gender. The group of other diets was small and heterogenic including diets from different reasons (i.e., weight control and allergies), thus respondents who indicated diet as other were not compared. Number of lacto-ovo-vegetarian and vegans among respondents was low, therefore these groups were not included in the comparison of diets. Results of comparison of respondent groups are presented in Appendix A Tables A1–A11. There were only few significant differences between consumers living in different parts of Finland or representing different types of households. Therefore, results of these groups are not presented in tables, but are explained in writing.

Women were more interested in trying nettle as a food and they were also more willing to eat or cook food with it. They also regarded nettle as more credible, nutrient-rich, ecological, trendy and healthy. There were also differences between age groups regarding attitude towards nettle. Respondents of age 50–64 more strongly, compared to 18–34 and 35–49-year-old groups, agreed they could eat nettle. Younger adults (18–34 years old) considered nettle as less nutrient-rich, healthy and ecological compared to the 50–64-year-old group. They also evaluated the appearance of nettle as less pleasant compared to the 50–64-year-old group. Nettle was most credible to the 50–64-year-old group. Participants with a higher education level were more willing to eat or cook food nettle. Respondents living in rural areas evaluated the aroma and flavor of nettle as more pleasant compared to others. Respondents having plant-oriented mixed diet were more willing to try and eat nettle and evaluated it as more pleasant regarding sensory properties compared to respondents with regular mixed diet. They regarded nettle as more credible, nutrient-rich, trendy and healthy. A food-related closer connection to nature, i.e., growing food oneself, using raw materials or picking them from nature, has an impact on opinions regarding this type of raw material. Respondents who pick food ingredients were more willing to try and eat nettle and consider it more pleasant compared to those who do not pick it. They also regarded nettle as more credible, nutrient-rich and healthy. Food neophobics were less willing to try and eat nettle and consider it less credible, nutrient-rich, ecological, natural, trendy and healthy. Furthermore, food neophobics evaluated nettle as less pleasant regarding appearance, aroma and flavor, compared to food neophilics and the median group, and feel in fingers and mouth less pleasant compared to food neophilics. Comparison of different consumer groups' opinion on nettle are presented in Appendix A Table A1.

Women were more willing to try and eat berry bush leaves and consider them more credible, nutrient-rich, ecological and trendy (Appendix A Table A2). Moreover, female respondents evaluated the appearance, aroma, flavor and feel of berry bush leaves as more pleasant. The youngest group was significantly different from the 50–64-year-old group regarding whether they could eat, or were interested in trying berry bush leaves, considering whether they are credible or trendy and the pleasantness of feel, whereas both younger age groups were different from the 50–64-year-old group regarding nutrient richness and pleasantness of aroma and flavor. Respondents living in the western part of Finland were not as willing to try berry bush leaves in food as respondents from other parts of Finland (Kruskal–Wallis H = 16.469, $p = 0.001$ with mean ranks of 107.99 for West, 143.50 for South, 159.01 for East and 148.92 for North). Respondents from rural areas evaluated the aroma and flavor and feel of berry bush leaves as more pleasant compared to respondents from the center of large cities. The only difference between respondents from different types of household was in naturalness; respondents from adult households regarded berry bush leaves as more natural compared to single households (Kruskal–Wallis H = 7.633, $p = 0.022$ with mean ranks of 121.70 for single households, 149.16 for adult households and 145.50 for families with children). Respondents who grow food ingredients themselves considered berry bush leaves as more ecological and natural. Furthermore, consumers who pick food ingredients from nature were more willing to try and could eat berry bush leaves, considering them more credible, ecological, natural and trendy, and evaluating them as more pleasant. Food neophilics evaluated the sensory characteristics of berry bush leaves as the most pleasant and healthy. All the FNS groups were different in relation to the statement "I could eat or cook food made of … ", "I consider this credible", "This raw material is natural". Food neophilics most strongly agreed and neophobics least strongly agreed with these statements. Food neophobics were less interested to try berry bush leaves as food and consider them less ecological compared to the other FNS groups. Food neophilics regarded berry bush leaves as more nutrient-rich and trendy compared to food neophobics.

Female respondents were more willing to try pine or spruce shoots and evaluate them as more pleasant in appearance (Appendix A Table A3). Furthermore, they regarded this raw material as more credible, nutrient-rich, natural, trendy, healthy and pleasant. The 50–64-year-old respondents, compared to 35–49-year-old respondents, were more willing to try pine or spruce shoots and also more strongly agree with the idea of eating or cooking food made of it. They also considered pine or spruce shoots as more nutrient-rich and ecological compared to others. Younger adults do not consider pine or spruce shoots as healthy as 50–64-year-old people. Representatives of adult households regarded pine or spruce shoots as more ecological compared to representatives of single households (Kruskal–Wallis H = 9.313, $p = 0.010$ with mean ranks of 98.97 for single, 128.43 for adult household and 108.32 for families with children). Consumers having plant-oriented mixed diet regarded pine or spruce shoots as more nutrient-rich and natural. Respondents who grow or pick ingredients for food themselves had more positive attitude towards pine or spruce shoots. Food neophilics were more willing to try and eat pine or spruce shoots, and consider them more credible, nutrient-rich, natural, trendy, healthy and pleasant compared to other FNS groups. Food neophilics and the median group regarded pine or spruce shoots as equally ecological but more than food neophobics. Food neophobics regarded pine or spruce shoots as less ecological than others. All FNS groups were different from each other in terms of whether they could eat or cook, willingness to try, credibility, trendiness and healthiness.

Women were more willing to try the leftover parts of vegetables as food raw material over men and also regarded them as more credible, nutrient-rich, ecological, natural and trendy (Appendix A Table A4). Furthermore, pleasantness of aroma, flavor and feel were evaluated higher among women.

The age group of 50–64 years old regarded the leftover parts of vegetables as more credible and nutrient-rich compared to the age group of 35–49 years old. Moreover, they evaluated the leftover parts as more pleasant regarding sensory properties and were more willing to try than the 35–49-year-old group. Respondents with a higher education evaluated the leftover parts of vegetables as looking and feeling more pleasant. Respondents living in the center of a larger city were more willing to try the leftover parts of vegetables and could eat and cook food made of them compared to respondents in rural areas. Furthermore, they regarded this raw material as more credible. Consumers from rural areas did not regard the leftover parts of vegetables as pleasant as others. Representatives of families with children considered this raw material as more ecological (Kruskal–Wallis H = 7.824, $p = 0.020$ with mean ranks of 103.78 for single households, 123.56 for adult households and 136.53 for families with children) and natural (Kruskal–Wallis H = 13.190, $p = 0.001$ with mean ranks of 100.88 for single households, 122.25 for adult households and 144.73 for families with children) compared to representatives of single households. Consumers from adult households evaluated the aroma and flavor (Kruskal–Wallis H = 9.991, $p = 0.007$ with mean ranks of 104.54 for single household, 133.95 for adult households and 109.70 for families with children) and feel (Kruskal–Wallis H = 7.137, $p = 0.028$ with mean ranks of 105.87 for single households, 131.49 for adult households and 113.46 for families with children) of this raw material as more pleasant compared to consumers living in single households. Consumers having a plant-oriented mixed diet were more willing to try and eat the leftover parts of vegetables. They considered this raw material as more credible, nutrient-rich and pleasant in aroma, flavor and feel. Respondents who grow or pick food ingredients from nature themselves evaluated the leftover parts of vegetables as more pleasant and nutrient-rich. There was a significant difference between pickers and non-pickers in willingness to try and eat, credibility, trendiness and healthiness. Leftover parts of vegetables were most pleasant and trendy to food neophilics. FNS groups differed similarly in willingness to try and credibility. Food neophobics had significantly lower agreement to statements “I could eat . . . ”, “This is nutrient-rich”, “This is natural” and “This is healthy”.

There was a significant difference in opinions on clover between consumer groups based on gender in all the studied variables apart from nutrient-rich, trendy and healthy variables (Appendix A Table A5). The youngest group was less willing to eat or cook food made of clover compared to 50–64-year-old consumers. Furthermore, the youngest group regarded it as least pleasant in sensory properties. The 35–49-year-old group regarded clover as the most nutrient-rich and natural. Respondents with higher education level indicated higher willingness to try and eat clover compared to basic education. Moreover, highly educated participants regarded clover as more ecological and natural. Clover is commonly growing in gardens in Finland. It is assumed that this plant is well-known by the consumers living in town houses. This might be one reason why consumers living in the center of a smaller city or municipality were more willing to try and eat clover in food compared to the consumers living in housing estates. There was a parallel difference between these two groups in credible, ecological, trendy and healthy variables. Consumers having plant-oriented mixed diets were more willing to try and eat clover and consider the raw material more pleasant. There was a difference between diets in all the investigated variables. Respondents picking or growing ingredients regarded clover as more nutrient-rich and more pleasant in appearance. The median group was more willing to try and eat clover compared to food neophobics and food neophilics more than median group and food neophobics. Furthermore, there was similar difference between FNS groups in ecological, natural and trendy variables. Food neophobics regarded clover as less credible, nutrient-rich and pleasant in appearance compared to others. Food neophilics evaluated the aroma, flavor and feel of clover as more pleasant compared to other FNS groups.

There was no difference between genders in willingness to try or whether they could eat crickets (Appendix A Table A6). However, male respondents evaluated the appearance and feel of crickets as more pleasant compared to females. The youngest adults (age 18–34) were more willing to try and consider crickets as a possible part of their diet compared to 50–64-year-old participants. Respondents with a higher level of education regarded crickets as more credible and ecological compared to respondents with a basic education. Representatives with a higher or intermediate level of education regarded crickets as more nutrient-rich, natural, trendy and healthy. Crickets were evaluated as looking, smelling and tasting more pleasant by respondents with higher education levels. Consumers living in the center of large cities in Finland were more willing to try and adopt crickets in their diet compared to consumers living in a rural area. Furthermore, they considered them as more credible and nutrient-rich. Representatives of families with children could more likely eat crickets compared to single household representatives (Kruskal–Wallis H = 6.280, $p = 0.043$ with mean ranks of 107.86 for single households, 116.48 for adult households and 136.41 for families with children). Participants with plant-oriented mixed diets regarded crickets as more credible, nutrient-rich, ecological, trendy and healthy. They also evaluated the appearance of crickets as more pleasant. Consumers who pick food ingredients from nature regarded crickets as more nutrient-rich and healthy. Food neophilics were more willing to try and eat crickets compared to the median group and median group more than food neophobics. A similar difference was also in all the other variables except trendy where the median group was not different from food neophobics.

Beeswax was regarded as more ecological and natural by women (Appendix A Table A7). The 50–64-year-old respondents evaluated beeswax as more appealing in all the sensory properties compared to the 35–49-year-old group. Pleasantness of feel of beeswax was evaluated higher also by the oldest age group (65–80 y) compared to 35–49-year-old participants. Representatives of families with children regarded beeswax as more natural compared to single (Kruskal–Wallis H = 7.295, $p = 0.026$ with mean ranks of 105.56 for single, 122.23 for adult household and 132.89 for families with children). Respondents having plant-oriented diet were more willing to try and eat beeswax. Moreover, they regarded it as more credible, nutrient-rich, natural, trendy and healthy. Pleasantness of aroma and flavor was higher according to respondents having plant-oriented diet. Respondents who grow or pick food ingredients themselves are more willing to try and eat beeswax. Furthermore, they consider beeswax as more nutrient-rich, trendy and healthy as well as more pleasant aroma and flavor. Moreover, respondents who pick food ingredients from nature regarded beeswax as more credible, ecological, natural and evaluated it as looking and feeling more appealing compared to those who do not pick. Food neophobics were not as willing to try and eat beeswax as median group and neophilics. They regarded beeswax less credible and natural as well as aroma, flavor and feel of beeswax as less pleasant compared to other food neophobia groups. Food neophobics evaluated beeswax as less nutrient-rich, ecological, trendy, healthy and appearance of beeswax less pleasant compared to food neophilics.

Youngest (18–34 y) consumers were more interested in trying synthetic meat and more willing to adopt it as a part of their diet compared to the 35–49-year-old group (Appendix A Table A8). Furthermore, the youngest consumers regarded it as more credible and the aroma and flavor as more pleasant compared to the 35–49-year-old group. Respondents with a higher education level regarded synthetic meat as more trendy compared to respondents with a basic education. Consumers living in southern part of Finland agree more with the statement “I could eat … ” than consumers from the north (Kruskal–Wallis H = 10.251, $p = 0.017$ with mean ranks of 130.55 for South, 111.08 for West, 129.76 for East and 98.57 for North Finland). Respondents who stated their place of residence as the center of a large city are more willing to try synthetic meat and regarded it as more credible compared to respondents living in a housing estate or rural area. Consumers from large cities regarded synthetic meat as more ecological compared to representatives of rural areas. Respondents having plant-oriented diets regarded synthetic meat as more credible and natural. Food neophobics are less interested in trying synthetic meat compared to others. Furthermore, they regarded synthetic meat as less ecological, trendy, healthy and pleasant compared to others. Food neophilics regarded synthetic meat as more nutrient-rich compared to others and more credible compared to food neophobics.

Consumers from East Finland could more potentially eat eggshells (Appendix A Table A9) compared to consumers from the north and regarded eggshells as trendier (Kruskal–Wallis H = 9.564, $p = 0.023$ with mean ranks of 111.26 for South, 104.72 for West, 138.31 for East and 105.20 for North

Finland) and feeling more pleasant (Kruskal–Wallis H = 15.828, $p = 0.001$ with mean ranks of 121.79 for South, 100.74 for West, 140.84 for East and 98.68 for North Finland) compared to consumers from the western and northern parts of Finland. Consumers who pick food ingredients from nature regarded eggshells as more natural, healthy and feeling more pleasant and they could more potentially eat eggshells as a part of their diet. Food neophilics are more willing to try and eat eggshells compared to others. Furthermore, they regarded eggshells as more nutrient-rich, ecological, trendy and healthy and looking, smelling and tasting less pleasant compared to other FNS groups. Food neophobics evaluated the pleasantness of feel of eggshells lower compared to food neophilics. Food neophobics regarded eggshells as less credible compared to others. Opinions on naturalness of eggshells were different between all the food neophobia groups.

Men were more willing to try and eat ants compared to women (Appendix A Table A10). Men evaluated the appearance, aroma, flavor and feeling of ants as more pleasant. Furthermore, male respondents regarded ants as more credible, nutrient-rich, ecological, natural and healthy. Participants with higher education levels could more potentially eat or cook food made of ants, evaluated ants as more pleasant and regarded them as more nutrient-rich and trendy compared to participants with a basic education. Respondents with a basic education regarded ants as less credible, ecological, natural and healthy compared to other participants. Respondents living in South or East Finland consider ants trendier compared to respondents from the western part of Finland ($p = 0.015$, mean for West 3.25, East 3.55, South 3.64 and North 3.74). There were no significant differences between consumer groups based on age, place of residence, diet or growing or picking ingredients by oneself. Opinions of food neophobia groups regarding ants were significantly different in all the investigated variables. Food neophobics were less willing to try and eat ants and evaluated them as less pleasant compared to others. Food neophilics regarded ants as more credible, ecological, natural, trendy and healthy compared to others. Food neophilichs considered ants as the most nutrient-rich and food neophobics as the least nutrient-rich.

Men regarded 3D-printed food as more nutrient-rich, ecological and natural (Appendix A Table A11). Furthermore, men evaluated the appearance, aroma and flavor of 3D-printed food as more pleasant. Unlike assumed, the oldest (65–80 y) consumers regarded 3D-printed food as more natural compared to the 35–49-year-old group. Respondents living in adult households regarded 3D-printed food as feeling more pleasant compared to respondents living with children ($p = 0.018$, mean for families with children 2.53, single households 2.76 and adult households 3.11). Contrary to other raw materials in the research opinions of food neophobia groups, these results were more similar. However, food neophilics were more willing to try and eat 3D-printed food and evaluated the appearance as more pleasant compared to food neophobics.

4. Discussion

In this study we explored the attitudes of Finnish consumers towards possible ingredients for future food. Differences in opinions between female and male respondents were noteworthy. Females were more open to plant-based raw materials and also regarded the conceptual characteristic higher. In accordance with previous research, men were more interested in trying ants and perceived crickets as more pleasant compared to women [40].

The group of 50–64-year-old respondents was more open to plant-based raw materials compared to the youngest group. Differences between education levels were not as comprehensive. A higher level of education indicated more openness to nettle, clover, leftover parts of vegetables and insects. Growing food ingredients by oneself or picking ingredients from nature for food and cooking indicates a close relation to nature and close relation to food ingredients and their origin. This might be a reason for more open attitude towards the raw materials that can be found from nature—i.e., wild food plants and insects. All the raw materials are novel or presumably quite unfamiliar to most of the Finnish consumers since they are not widely used at present. Therefore, it was assumed that food neophobia would contribute to attitudes towards investigated raw materials. This was comprehensively correct for all the investigated raw materials. Furthermore, food neophobia also affects the conceptual characteristics, not only willingness to try, but also the potentiality to use in food and cooking or pleasantness.

Based on the findings of our study, Finnish consumers are open to using nettle and berry bush leaves as a part of their diet. These ingredients were also regarded as the most ecological, natural, trendy, healthy and nutrient-rich by the respondents. This might be explained by the tradition of the use of these ingredients, though the use at present is marginal [26]. Pleasantness or willingness to try and using wild greens have not to our knowledge been studied and these results give valuable insights on their usage as novel ingredients in the future. Reception of clover as food ingredient is not as positive as nettle and berry bush leaves. Nevertheless, 58% of consumers show some degree of interest to try this ingredient. Similarly, as a grass protein, clover might have potential as a protein source for novel foods [41,42]. Leftover parts of vegetables are also perceived as potential novel ingredients by Finnish consumers. Women are more willing to try leftover parts of vegetables. Previous studies have shown women express higher motivation towards avoiding and reducing food waste [43,44], which explains the gender effect.

Finnish consumers are very cautious about synthetic meat, as only 25% of the participants indicated some degree of willingness to try synthetic meat. This is in contrast with previous research on synthetic meat. Almost the same proportion of Belgian participants indicated strong interest in trying cultured meat [45]. Weinrich et al. [46] reported German consumers to be unenthusiastic to try cultured meat while 57% of the participants indicated interest to try. More than half (54%) of the Italian respondents were willing to try cultured meat [47]. However, Belgian, German and Italian respondents received, at the least, basic information about cultured meat before indicating their interest [45–47].

Similarly, Finnish consumers do not express high interest towards 3D-printed food, since 36% of the consumers totally disagree with the statement "I would be interested in trying food made of 3D-printed food". This is in contrast with the results of Manstan and McSweeney [25], where consumers showed higher interest towards 3D-printed food over conventional. Akin to Finns, Swiss consumers have negative attitude towards 3D-printed food [16]. However, well-designed communication has been shown to have the potential to positively shape consumers' attitudes towards 3D-printed food [16]. Finnish consumers did not consider 3D-printed food as healthy, whereas Canadians perceived 3D-printed food as healthier compared to conventional counterparts [25].

Crickets and ants were representatives of insects in this study. Finns are not willing to adopt insects into their diet. Almost half of the respondents disagreed with the idea trying either crickets or ants. This finding is in line with previous research of the attitudes of Western citizens towards insects [17,40,48,49].

The origins of the novel ingredients included in the study varied very much. Some ingredients, e.g., wild food plants, are traditionally used and thus might be more familiar to some consumers whereas other ingredients, such as insects or 3D-printed food, might be very unfamiliar to most. Information of the familiarity or prior knowledge and experience of the ingredients would have given valuable insights for the interpretation of the results, since food exposure and familiarity is shown to affect liking and consumption of food products [37]. Previous research indicated that information changes the attitude towards unfamiliar food [50].

Information of the place of residence was given but not any further specific information about the place where the participants live. This might have also given background to the familiarity of the ingredients of natural sources. Clover, nettle and berry bush leaves commonly grow in gardens and even people living in housing estates or in the city center of a smaller city might have them in their own backyard. This information might have supplemented the information about the familiarity of the ingredients.

Our results were obtained from participants' image of potential novel food ingredients. The image is a pre-existing factor that food producers need to understand when considering which previously unfamiliar or lesser used ingredients to incorporate into new food products or meals. Furthermore, consumers' beliefs and perceptions about certain conceptual characteristics of ingredients, such as naturalness or nutrient richness, might affect how they are accepted in differing product categories or brand positionings. Further research is needed to investigate the perceived pleasantness of the ingredients which could potentially be used in future food.

5. Conclusions

Our results showed that consumers differed in their opinions about possible ingredients of edible products and meal. Based on our research, females, 50–64 years old, and neophilic respondents were more open to plant-based materials than others. Study participants were cautious about synthetic meat, 3D-printed food and insects in their diet. The number of consumers with basic education was not equal to other levels, which was a limitation of the study. However, the educational qualifications are high among adults in Finland. Variation of the ingredients led to difficulty of presenting comparable pictures of the ingredients. Although appearance is a significant determinant in the opinion-formation process, we decided not to give any additional information apart from the name of the ingredient. However, participants had the opportunity to search information while completing the questionnaire since the questionnaire was completed online and this was not reported. In general, plant-based ingredients were more agreed to by the consumers regarding conceptual characteristics than the other ingredients. From this point of view, they may have potential for future food ingredients.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Significant differences between participant groups in distribution of responses regarding nettle. Means (ANOVA and *t*-test) or mean ranks (Mann–Whitney U) are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	151	149.35a	152.08a	148.04a	148.13a	145.09a	144.28a	149.66a	148.97a	145.25a	144.25a	141.79a
Male	112	108.61b	104.93b	110.38b	110.26b	114.36b	115.44b	108.19b	109.12b	114.14b	115.49b	118.80b
Age												
18–34	57	116.77ab	ns	116.38b	106.81b	117.54b	121.32b	ns	106.20b	104.52b	ns	ns
35–49	73	117.09b	ns	119.34b	127.64ab	124.51ab	124.47ab	ns	127.42ab	133.35ab	ns	ns
50–64	81	148.44a	ns	150.85a	152.82a	151.51a	152.58a	ns	149.46a	144.74a	ns	ns
65–80	52	144.01ab	ns	137.54ab	133.31ab	127.97ab	122.22ab	ns	139.52ab	140.38ab	ns	ns
Education												
basic	21	99.21b	ns	97.69b	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	128	128.29ab	ns	128.42ab	ns	ns	ns	ns	ns	ns	ns	ns
higher level	114	142.21a	ns	142.34a	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	70	ns	ns	ns	ns	ns	ns	ns	ns	ns	115.28b	ns
housing estate	74	ns	ns	ns	ns	ns	ns	ns	ns	ns	127.99b	ns
center of a smaller city or municipality	81	ns	ns	ns	ns	ns	ns	ns	ns	ns	125.78b	ns
rural area	53	ns	ns	ns	ns	ns	ns	ns	ns	ns	165.93a	ns
Diet												
mixed diet	210	113.82b	113.91b	114.66b	115.75b	ns	ns	4.70b	115.00b	4.32b	113.75b	3.56b
plant-oriented mixed diet	28	162.11a	161.39a	155.79a	148.96a	ns	ns	5.71a	153.29a	5.36a	162.59a	4.75a
Growing or picking ingredients												
grow	84	151.79a	149.10a	150.43a	148.60a	151.54a	145.97a	147.37a	149.30a	154.86a	147.05a	4.11a
do not grow	179	122.72b	123.98b	123.35b	124.21b	122.83b	125.44b	124.79b	123.88b	121.27b	124.94b	3.59b
pick	173	141.99a	136.86a	140.53a	141.84a	ns	ns	ns	141.48a	141.40a	142.81a	4.00a
do not pick	90	112.79b	118.82b	115.61b	113.09b	ns	ns	ns	113.78b	113.93b	111.23b	3.29b
Food neophobia group												
food neophilics	59	155.50a	161.83a	150.81a	153.08a	146.13a	146.62a	149.04a	152.26a	154.01a	159.84a	4.2a
median group	130	145.78a	141.83a	144.37a	140.18a	145.77a	143.47a	138.59a	140.08a	135.38a	139.99a	3.78ab
food neophobics	74	89.05b	90.94b	95.28b	100.82b	96.54b	100.19b	106.38b	101.65b	108.51b	95.77b	3.35b

ns no significant difference.

Table A2. Significant differences between participant groups in distribution of responses regarding berry bush leaves. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	160	152.885a	148.89a	151.35a	149.48a	149.42a	ns	4.82a	ns	153.81a	148.97a	149.18a
Male	118	121.36b	126.76b	123.43b	125.97b	125.97b	ns	4.19b	ns	120.10b	126.66b	126.38b
Age												
18–34	60	119.07b	116.11b	119.08b	126.13b	ns	ns	4.23b	ns	ns	109.57c	118.87b
35–49	73	142.21ab	126.01b	134.95ab	127.40b	ns	ns	4.60ab	ns	ns	124.68bc	127.32ab
50–64	79	158.47a	166.20a	162.11a	163.42a	ns	ns	4.99a	ns	ns	165.43a	159.70a
65–80	66	132.37ab	143.73ab	136.03ab	136.41ab	ns	ns	4.26b	ns	ns	152.07ab	147.55ab
Education												
basic	46	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	115	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
higher level	117	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	70	ns	ns	ns	ns	ns	ns	ns	ns	ns	129.19b	129.19b
housing estate	74	ns	ns	ns	ns	ns	ns	ns	ns	ns	129.68ab	129.68b
center of a smaller city or municipality	81	ns	ns	ns	ns	ns	ns	ns	ns	ns	138.19ab	138.19ab
rural area	53	ns	ns	ns	ns	ns	ns	ns	ns	ns	170.32a	168.83a
Diet												
mixed diet	234	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
plant-oriented mixed diet	23	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Growing or picking ingredients												
I grow	81	ns	ns	ns	ns	155.51a	155.83a	ns	ns	ns	ns	ns
I do not grow	197	ns	ns	ns	ns	132.92b	132.78b	ns	ns	ns	ns	ns
I pick	173	149.25a	151.87a	149.82a	ns	153.02a	151.71a	4.71a	ns	154.40a	151.46a	150.83a
I do not pick	105	123.44b	119.11b	122.50b	ns	117.23b	119.38b	4.29b	ns	114.95b	119.80b	120.84b
Food neophobia group												
food neophilics	53	173.66a	170.88a	172.72a	162.87a	162.87a	165.05a	4.98a	169.40a	172.75a	171.33a	176.92a
median group	150	140.28b	143.80a	140.16b	142.60ab	144.82a	143.12b	4.52ab	135.72b	133.16b	140.51b	137.18b
food neophobics	75	113.79c	108.72b	114.70c	116.79b	112.27b	114.21c	4.31b	125.93b	128.68b	114.98b	117.69b

ns no significant difference.

Table A3. Significant differences between participant groups in distribution of responses regarding pine or spruce shoots. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	135	123.95a	127.07a	4.77a	129.11a	ns	123.60a	4.67a	129.95a	130.94a	ns	ns
Male	97	106.13b	101.78b	4.05b	98.95b	ns	106.62b	3.98b	97.78b	96.40b	ns	ns
Age												
18–34	55	108.28ab	114.63ab	ns	101.44b	102.52b	ns	ns	107.00b	ns	ns	ns
35–49	65	107.79b	106.00b	ns	107.83b	107.10b	ns	ns	109.10b	ns	ns	ns
50–64	63	139.21a	137.83a	ns	146.40a	140.98a	ns	ns	139.85a	ns	ns	ns
65–80	49	108.07ab	105.11ab	ns	106.47b	113.19ab	ns	ns	106.96ab	ns	ns	ns
Education												
basic	26	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	96	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
higher level	110	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	42	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
housing estate	66	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	77	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
rural area	47	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	192	ns	ns	ns	104.07b	ns	102.04b	ns	ns	ns	ns	ns
plant-oriented mixed diet	21	ns	ns	ns	133.83a	ns	152.36a	ns	ns	ns	ns	ns
Growing or picking ingredients												
I grow	72	126.85a	122.97a	ns	136.48a	142.06a	131.10a	ns	129.40a	ns	131.94a	129.76a
I do not grow	160	111.84b	113.59b	ns	107.15b	105.00b	109.93b	ns	110.70b	ns	109.55b	110.53b
I pick	156	124.44a	ns	4.73a	125.61a	127.76a	125.35a	4.56a	125.60a	125.48a	ns	122.84a
I do not pick	76	100.21b	ns	3.93b	97.80b	93.39b	98.34b	4.03b	97.20b	98.07b	ns	103.49b
Food neophobia group												
food neophilics	47	160.04a	161.84a	159.34a	145.91a	140.50a	149.03a	147.36a	149.23a	152.48a	165.96a	158.37a
median group	130	114.53b	116.77b	114.28b	114.47b	119.98a	114.01b	118.45b	117.18b	111.28b	109.67b	111.58b
food neophobics	55	83.95c	77.12c	85.14c	96.15b	87.77b	94.58b	85.53c	77.12c	77.12b	90.39b	92.35b

ns no significant difference.

Table A4. Significant differences between participant groups in distribution of responses regarding broccoli and cauliflower stems and leaves and root vegetable tops. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	140	ns	129.93a	126.94a	125.99a	129.45a	127.30a	4.42a	ns	ns	4.66a	4.75a
Male	96	ns	101.84b	106.19b	107.57b	102.54b	105.66b	3.81b	ns	ns	4.04b	4.27b
Age												
18–34	52	ns	116.39ab	118.75ab	110.55ab	ns	ns	ns	ns	107.82ab	4.33ab	110.17ab
35–49	55	ns	101.24b	99.67b	103.56b	ns	ns	ns	ns	94.76b	3.87b	97.32b
50–64	72	ns	139.82a	135.46a	137.34a	ns	ns	ns	ns	139.74a	4.76a	140.51a
65–80	69	ns	114.47ab	119.17ab	120.47ab	ns	ns	ns	ns	128.16ab	4.58ab	122.75ab
Education												
basic	31	ns	ns	ns	ns	ns	ns	ns	ns	90.65b	ns	94.94b
intermediate	97	ns	ns	ns	ns	ns	ns	ns	ns	111.25b	ns	114.55ab
higher level	110	ns	ns	ns	ns	ns	ns	ns	ns	134.90a	ns	130.79a
Neighborhood												
center of a large city	38	145.33a	151.53a	143.88a	ns	ns	ns	131.53ab	ns	4.89a	ns	ns
housing estate	71	121.36ab	120.89ab	123.60ab	ns	ns	ns	127.74a	ns	4.90a	ns	ns
center of a smaller city or municipality	84	120.95ab	116.43b	117.55ab	ns	ns	ns	121.61ab	ns	4.58a	ns	ns
rural area	45	93.57b	95.99b	96.09b	ns	ns	ns	92.41b	ns	3.80b	ns	ns
Diet												
mixed diet	193	107.04b	105.23b	106.88b	106.71b	ns	ns	ns	ns	ns	4.32b	107.07b
plant-oriented mixed diet	27	135.20a	148.17a	136.39a	137.57a	ns	ns	ns	ns	ns	4.96a	135.02a
Growing or picking ingredients												
grow	77	ns	ns	ns	132.18a	ns	ns	ns	ns	135.37a	4.75a	139.60a
do not grow	161	ns	ns	ns	113.44b	ns	ns	ns	ns	111.91b	4.25b	109.89b
pick	153	127.67a	129.33a	127.63a	126.45a	ns	ns	4.38a	126.76a	4.85a	4.68a	132.77a
do not pick	85	104.79b	101.81b	104.86b	106.98b	ns	ns	3.79b	106.43b	4.09b	3.94b	95.61b
Food neophobia group												
food neophilics	46	152.86a	153.95a	154.02a	139.51a	138.72a	140.80a	4.98a	144.40a	154.53a	5.20a	5.35a
median group	130	125.25a	124.49b	123.38b	126.80a	126.33a	125.41a	4.16b	125.37a	120.67b	4.48b	4.68b
food neophobics	62	82.70b	83.48c	85.75c	83.94b	90.92b	91.31b	3.58b	88.72b	91.06c	3.71c	3.71c

ns no significant difference.

Table A5. Significant differences between participant groups in distribution of responses regarding clover. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	238	225.91a	226.17a	4.52a	ns	221.14a	220.99a	Ns	ns	234.53a	223.16a	226.66a
Male	177	183.92b	183.56b	4.00b	ns	190.33b	190.54b	Ns	ns	172.33b	187.61b	182.91b
Age												
18–34	75	177.71b	ns	3.91bc	3.85c	ns	202.61ab	ns	ns	170.37b	147.06b	172.29b
35–49	125	219.41ab	ns	4.44ab	4.68a	ns	221.54a	ns	ns	207.39ab	210.43a	205.89ab
50–64	141	227.27a	ns	4.67a	4.54ab	ns	216.48ab	ns	ns	221.04a	226.98a	216.67ab
65–80	74	182.71ab	ns	3.73c	3.97bc	ns	174.43b	ns	ns	222.33a	229.50a	231.25a
Education												
basic	38	165.22b	161.61b	ns	ns	135.43b	164.49b	ns	ns	ns	ns	ns
intermediate	190	198.81ab	202.32ab	ns	ns	202.79a	207.47ab	ns	ns	ns	ns	ns
higher level	187	226.03a	223.20a	ns	ns	228.04a	217.38a	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	74	205.18ab	216.91ab	187.87b	ns	216.20ab	ns	3.92ab	185.18ab	190.86bc	178.86b	201.44ab
housing estate	109	187.17b	176.62b	188.65b	ns	178.13b	ns	3.77b	188.07b	165.09c	192.14ab	179.28b
center of a smaller city or municipality	81	229.81a	228.72a	235.42a	ns	229.90a	ns	4.35a	227.29a	219.75ab	223.47a	221.94a
rural area	151	197.96ab	203.47ab	201.31ab	ns	199.88ab	ns	4.02ab	219.71ab	258.40a	227.12ab	226.67a
Diet												
mixed diet	333	184.80b	182.30b	185.21b	4.22b	186.40b	187.19b	3.90b	182.96b	185.44b	4.78b	4.66b
plant-oriented mixed diet	51	242.76a	259.10a	240.09a	4.98a	232.30a	227.17a	4.86a	254.78a	238.59a	5.59a	5.86a
Growing or picking ingredients												
grow	114	ns	ns	ns	4.66a	ns	ns	4.35a	ns	226.99a	ns	ns
do not grow	301	ns	ns	ns	4.24b	ns	ns	3.95b	ns	200.81b	ns	ns
pick	269	ns	ns	ns	4.52a	ns	ns	ns	ns	216.93a	ns	ns
do not pick	146	ns	ns	ns	4.06b	ns	ns	ns	ns	191.55b	ns	ns
Food neophobia group												
food neophilics	106	252.86a	261.01a	4.72a	4.72a	245.08a	250.98a	4.42a	5.18a	244.34a	239.23a	239.56a
median group	210	214.46b	210.44b	4.38a	4.42a	212.72b	209.54b	4.08ab	4.72b	212.17a	205.11b	211.34b
food neophobics	99	146.26c	146.07c	3.67b	3.83b	158.29c	158.71c	3.64b	4.15c	160.24b	180.70b	167.13b

ns no significant difference.

Table A6. Significant differences between participant groups in distribution of responses regarding crickets. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	140	ns	ns	ns	ns	ns	ns	Ns	ns	110.73b	ns	108.19b
Male	95	ns	ns	ns	ns	ns	ns	Ns	ns	128.72a	ns	132.45a
Age												
18–34	51	137.24a	142.20a	ns	ns	ns	ns	ns	ns	ns	ns	ns
35–49	79	126.62ab	123.74ab	ns	ns	ns	ns	ns	ns	ns	ns	ns
50–64	52	103.76b	102.49b	ns	ns	ns	ns	ns	ns	ns	ns	ns
65–80	53	111.58ab	111.27ab	ns	ns	ns	ns	ns	ns	ns	ns	ns
Education												
basic	31	ns	ns	84.90b	81.45b	88.87b	87.40b	82.47b	83.13b	102.02ab	93.87b	ns
intermediate	92	ns	ns	116.39ab	117.80a	117.80ab	122.27a	118.55a	116.97a	107.21b	109.07b	ns
higher level	112	ns	ns	128.49a	128.28a	126.23a	122.96a	127.38a	128.50a	131.29a	132.02a	ns
Neighborhood												
center of a large city	55	136.12a	144.25a	133.57a	4.45a	135.43a	ns	ns	ns	ns	ns	ns
housing estate	54	109.80ab	112.83ab	118.35ab	4.02ab	112.12ab	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	83	121.77ab	116.01ab	121.10ab	3.93ab	122.25ab	ns	ns	ns	ns	ns	ns
rural area	43	97.85b	95.31b	91.65b	3.21b	94.90b	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	179	ns	ns	3.17b	102.65b	102.10b	ns	4.07b	102.89b	103.94b	ns	ns
plant-oriented mixed diet	35	ns	ns	4.11a	132.33a	135.10a	ns	4.74a	131.10a	125.70a	ns	ns
Growing or picking ingredients												
grow	48	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not grow	187	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pick	147	ns	ns	ns	4.17a	ns	ns	ns	4.05a	ns	ns	ns
do not pick	88	ns	ns	ns	3.56b	ns	ns	ns	3.45b	ns	ns	ns
Food neophobia group												
food neophilics	44	167.22a	170.20a	173.76a	170.91a	163.88a	164.19a	157.01a	160.27a	152.01a	168.40a	157.67a
median group	110	126.69b	124.73b	118.80b	119.45b	120.56b	124.02b	118.60b	123.65b	122.54b	122.95b	124.13b
food neophobics	80	78.36c	79.38c	85.54c	86.25c	88.67c	83.74c	95.23b	86.45c	92.63c	82.58c	87.26c

ns no significant difference.

Table A7. Significant differences between participant groups in distribution of responses regarding beeswax. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	139	ns	ns	ns	ns	127.45a	127.60a	ns	ns	ns	ns	ns
Male	99	ns	ns	ns	ns	108.33b	108.12b	ns	ns	ns	ns	ns
Age												
18–34	61	ns	ns	ns	ns	ns	ns	ns	ns	119.76ab	122.42ab	120.60ab
35–49	52	ns	ns	ns	ns	ns	ns	ns	ns	97.25b	94.06b	96.03b
50–64	68	ns	ns	ns	ns	ns	ns	ns	ns	134.01a	131.59a	130.32a
65–80	59	ns	ns	ns	ns	ns	ns	ns	ns	126.18ab	129.04ab	130.64a
Education												
basic	26	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	110	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
higher level	104	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	51	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
housing estate	71	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	78	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
rural area	40	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	188	3.97b	104.77b	104.28b	4.21b	ns	104.36b	3.83b	4.36b	ns	4.30b	ns
plant-oriented mixed diet	28	4.75a	133.55a	136.80a	4.89a	ns	136.32a	4.61a	5.11a	ns	4.89a	ns
Growing or picking ingredients												
grow	78	4.54a	4.54a	ns	4.56a	ns	ns	4.26a	4.81a	ns	4.67a	ns
do not grow	162	3.72b	3.86b	ns	4.05b	ns	ns	3.70b	4.17b	ns	4.15b	ns
pick	150	4.27a	4.41a	4.13a	4.55a	128.15a	128.64a	4.16a	4.69a	4.47a	4.61a	4.23a
do not pick	90	3.51b	3.51b	3.62b	3.67b	107.74b	106.93b	3.42b	3.86b	3.91b	3.83b	3.61b
Food neophobia group												
food neophilics	41	4.46a	141.27a	138.96a	141.80a	142.37a	134.59a	4.22a	4.85a	144.07a	137.72a	4.34a
median group	115	4.30a	129.39a	127.82a	122.80ab	125.28ab	130.09a	4.09ab	4.50ab	121.50ab	128.30a	4.23a
food neophobics	84	3.33b	98.19b	101.47b	109.96b	103.29b	100.50b	3.44b	3.98b	107.62b	101.42b	3.50b

ns no significant difference.

Table A8. Significant differences between participant groups in distribution of responses regarding synthetic meat. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	127	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Male	103	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Age												
18–34	54	138.89a	140.10a	136.23a	ns	ns	ns	ns	ns	ns	139.15a	ns
35–49	55	99.39b	97.00b	96.93b	ns	ns	ns	ns	ns	ns	99.27b	ns
50–64	69	110.38ab	115.82ab	114.88ab	ns	ns	ns	ns	ns	ns	119.78ab	ns
65–80	54	119.36ab	113.63ab	118.77ab	ns	ns	ns	ns	ns	ns	107.20ab	ns
Education												
basic	31	ns	ns	ns	ns	ns	ns	96.37b	ns	ns	ns	ns
intermediate	94	ns	ns	ns	ns	ns	ns	111.96ab	ns	ns	ns	ns
higher level	107	ns	ns	ns	ns	ns	ns	127.15a	ns	ns	ns	ns
Neighborhood												
center of a large city	53	ns	138.25a	137.87a	ns	141.25a	ns	ns	ns	ns	ns	ns
housing estate	56	ns	101.48b	102.64b	ns	111.08ab	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	81	ns	121.01ab	122.24ab	ns	115.90ab	ns	ns	ns	ns	ns	ns
rural area	42	ns	100.39b	96.94b	ns	93.65b	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	184	ns	ns	103.62b	ns	ns	103.94b	ns	ns	ns	ns	ns
plant-oriented mixed diet	29	ns	ns	128.43a	ns	ns	129.24a	ns	ns	ns	ns	ns
Growing or picking ingredients												
grow	63	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not grow	169	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pick	140	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not pick	92	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Food neophobia group												
food neophilics	44	142.05a	144.00a	138.67a	146.40a	135.63a	ns	131.36a	139.24a	141.98a	144.19a	142.89a
median group	116	122.15a	120.63a	120.27ab	115.93b	123.19a	ns	123.16a	121.81a	125.77a	124.12a	125.63a
food neophobics	72	91.79b	93.05b	96.88b	99.15b	94.04b	ns	96.69b	94.05b	85.99b	87.30b	85.66b

ns no significant difference.

Table A9. Significant differences between participant groups in distribution of responses regarding eggshells. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	122	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Male	104	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Age												
18–34	57	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
35–49	65	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
50–64	60	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
65–80	44	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Education												
basic	26	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	93	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
higher level	107	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	57	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
housing estate	51	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	74	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
rural area	44	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	183	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
plant-oriented mixed diet	23	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Growing or picking ingredients												
grow	58	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not grow	168	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pick	143	120.63a	ns	ns	ns	ns	122.02a	ns	3.75a	ns	ns	4.23a
do not pick	83	101.22b	ns	ns	ns	ns	98.82b	ns	3.12b	ns	ns	3.61b
Food neophobia group												
food neophilics	45	149.33a	147.91a	142.14a	144.86a	155.24a	151.56a	142.62a	147.77a	4.22a	138.83a	137.07a
median group	116	112.41b	114.67b	112.74a	112.41b	110.96b	114.66b	114.25b	111.66b	3.34b	113.79b	111.35ab
food neophobics	65	90.64b	87.59b	87.59b	93.74b	89.13b	85.08c	92.00b	93.06b	3.11b	95.45b	101.02b

ns no significant difference.

Table A10. Significant differences between participant groups in distribution of responses regarding ants. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level $p < 0.05$.

Respondent Group	N	I Could Eat or Cook	Willingness to Try	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	178	128.40b	128.21b	131.68b	3.35b	4.10b	135.73b	ns	3.16b	129.57b	129.49b	128.21b
Male	109	169.47a	169.78a	164.12a	3.89a	4.64a	157.51a	ns	3.92a	167.56a	167.69a	169.78a
Age												
18–34	56	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
35–49	59	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
50–64	98	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
65–80	74	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Education												
basic	51	116.34b	ns	109.15b	113.16b	114.36b	114.20b	114.47b	2.75b	122.65b	111.91b	118.48b
intermediate	122	140.00ab	ns	142.32a	145.70ab	142.19a	147.86a	143.80ab	3.53a	136.58ab	142.29ab	137.57ab
higher level	114	159.30a	ns	158.08a	155.30a	158.08a	152.85a	156.53a	3.67a	159.86a	159.01a	160.68a
Neighborhood												
center of a large city	68	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
housing estate	77	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	90	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
rural area	52	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	230	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
plant-oriented mixed diet	35	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Growing or picking ingredients												
grow	71	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not grow	216	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pick	177	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not pick	110	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Food neophobia group												
food neophilics	53	172.75a	172.74a	177.07a	4.42a	193.90a	195.96a	4.17a	4.25a	161.72a	168.95a	174.72a
median group	144	148.25a	149.93a	143.27b	3.64b	141.61b	142.23b	3.43b	3.48b	151.48a	151.74a	149.19a
food neophobics	90	120.27b	117.59b	125.69b	2.92c	118.78b	116.42b	3.23b	2.92b	121.59b	116.92b	117.61b

ns no significant difference.

Table A11. Significant differences between participant groups in distribution of responses regarding 3D-printed food. Means or mean ranks are presented. Significantly different respondent groups are marked with different letters. Significance level was minimum 0.05.

Respondent Group	N	I Could Eat or Cook	I Am Interested in Trying	Credible	Nutrient-Rich	Ecological	Natural	Trendy	Healthy	Appearance	Aroma and Flavor	Feel
Gender												
Female	151	ns	ns	ns	2.41b	4.10b	123.63b	ns	ns	ns	2.66b	2.70b
Male	112	ns	ns	ns	2.79a	4.64a	143.29a	ns	ns	ns	3.08a	3.10a
Age												
18–34	57	ns	ns	ns	ns	ns	130.91ab	ns	ns	ns	ns	ns
35–49	73	ns	ns	ns	ns	ns	111.62b	ns	ns	ns	ns	ns
50–64	81	ns	ns	ns	ns	ns	133.91ab	ns	ns	ns	ns	ns
65–80	52	ns	ns	ns	ns	ns	158.84a	ns	ns	ns	ns	ns
Education												
basic	21	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
intermediate	128	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
higher level	114	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Neighborhood												
center of a large city	51	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
housing estate	74	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
center of a smaller city or municipality	88	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
rural area	50	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Diet												
mixed diet	210	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
plant-oriented mixed diet	28	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Growing or picking ingredients												
grow	84	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not grow	179	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pick	173	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
do not pick	190	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Food neophobia group												
food neophilics	59	145.41a	148.97a	ns	ns	ns	ns	ns	ns	3.69a	ns	ns
median group	130	136.17ab	132.62ab	ns	ns	ns	ns	ns	ns	3.18ab	ns	ns
food neophobics	74	113.98b	117.39b	ns	ns	ns	ns	ns	ns	3.03b	ns	ns

ns no significant difference.

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Is It All about the Price? An Analysis of the Purchase Intention for Organic Food in a Discount Setting by Means of Structural Equation Modeling

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Abstract: In recent years, discount grocery retailers have expanded their global reach and added to their traditional no-frills offerings to also cater to hedonic consumer needs. In addition to a larger product assortment and a more pleasant shopping experience, they now sell organic food, which commands a price premium compared to non-organic alternatives. To understand organic food in a discount setting, this study sets out to examine the factors that influence discount grocery shoppers' purchase intention for organic food. To study this relationship, this paper tests several factors in a structural equation model, finding a positive relationship between hedonic shopping values, environmental concern, as well as health consciousness and the purchase intention for organic food. In our model, based on a US consumer survey (n = 394), price consciousness exhibited a direct and negative relationship with the purchase intention for organic food. Furthermore, this study found that that the impact of environmental concern, health consciousness, and hedonic shopping value is greater on the purchase intention of organic food than that of price consciousness, even in this discount setting. This study concludes by discussing these results and attempting to outline potential areas for future research, as well as managerial implications.

Keywords: organic food; discount supermarket; purchase intention; structural equation model (SEM); grocery retailing

1. Introduction

The success story of discount grocery retailing has been widely studied in the last two decades: from studies on their business model and internationalization strategies [1,2] to consumer price attribution [3], loyalty [4], and shopping value [5]. Historically known for low prices, traditionally undercutting other supermarkets and hypermarkets by 15 to 30 percent [1], limited product assortments, and efficient operations [6–8], the industry is now undergoing substantial changes. Over recent decades, the two leading companies in this industry, Aldi and Lidl, have shaped and cultivated the image of the "hard discounter" with little convenience, products piled in boxes, low price, private label products, and limited investment in technology [9]. With these characteristics, the concept has proven widely successful. From conquering Europe in the 1990s [1,6] to the current expansion overseas [10], both Aldi and Lidl have written a global success story. Through their business models, they have been able to make swift gains of market share in mature markets dominated by supermarkets with a strong brand and service orientation, for example, the United States [1]. Both companies have managed to appeal to what is now a very broad range of consumers, from the initial lower-income bargain hunters to today's "hybrid consumers" [11], with higher incomes and selective spending preferences. Nevertheless, in their European core markets, Aldi's and Lidl's success has begun to slow down considerably. Therefore, discount grocery retailers have adjusted their business model in recent years—notably, by offering a broader and deeper product assortment, by introducing new (more premium) private label (PL) tiers, and by a steady increase in national brands (NBs) available to shoppers [2,12]. In addition to changes in their product assortment, many discount grocery retailers have moved toward a greener image, from investments in sustainability [13] to offering an increased number of organic food product choices [14,15].

It is thus critical for practitioners and scholars alike to understand what this organic food offering means for discount grocery retailers. The question is whether they can appeal to their core customers with this organic offering and whether they can win over environmentally-minded consumers preferring organic food, who might otherwise not frequent their stores. As consumer demand for organic food has increased in the past two decades, researchers have extensively studied the purchase behavior associated with organic food (see [16] for a systematic review). This behavior, however, has very rarely been studied in a discount retailing context, but rather, from a price-sensitivity [17,18] or frugality [19] perspective. In a study that examined organic food in a discount retail setting, Gottschalk and Leistner [20] found that discount grocery shoppers tend to be more price-sensitive when buying organic food, whereas repeat buyers are more strongly influenced by other product characteristics. They also found that the availability of organic food generally triggers a purchase, hinting at "supply [creating] its own demand" [20]. To add to these findings, this study aims to evaluate the drivers that influence discount grocery shoppers' purchase intention for organic food, building a framework and testing it using a structural equation modeling (SEM) approach. Up until now, no comparable studies focusing on purchasing drivers for organic food within a discount grocery setting and using the SEM approach seem to have been published. Therefore, we aim to contribute to the literature by focusing on purchasing drivers for organic food within a discount grocery setting and using an SEM approach to help better understand customers' purchase intention for organic food in discount grocery stores.

This study is structured into four distinct sections. It commences by outlining the conceptual model developed for this study, as well as the hypotheses to be tested. Next, the methodology employed is detailed, and the experimental design discussed. Thereafter, the results are presented, and the study is concluded with a discussion of the said results, potential future research avenues, managerial implications, and limitations.

2. Conceptual Model

There are numerous context-dependent factors that can influence consumers' purchase intention and behavior in a shopping situation. To understand how the discount grocery retail setting might affect consumers' purchase intention for organic food items, we draw on commonly cited drivers of purchase behavior traditionally associated with discount grocery retail (price consciousness), common drivers of organic food purchase intention (environmental concern and health consciousness), and an emerging factor in discount grocery retailing—hedonic shopping value. These form the basis of our conceptual model. Such an attitudinal approach to determining the drivers for purchase intention is grounded in the theory of reasoned action (TRA) developed by Fishbein and Ajzen [21], as this theory can be effective in explaining psychological and cognitive antecedents to decision-making [22] as well as attitudes serving as an important predictor of behavioral intention [23]; it is therefore frequently used in the organic food context [24,25]. These four individual drivers, as well as their hypothesized relationship with the purchase intention for organic food for this study's model, are discussed in detail below. Figure 1 summarizes the conceptual framework for this study.

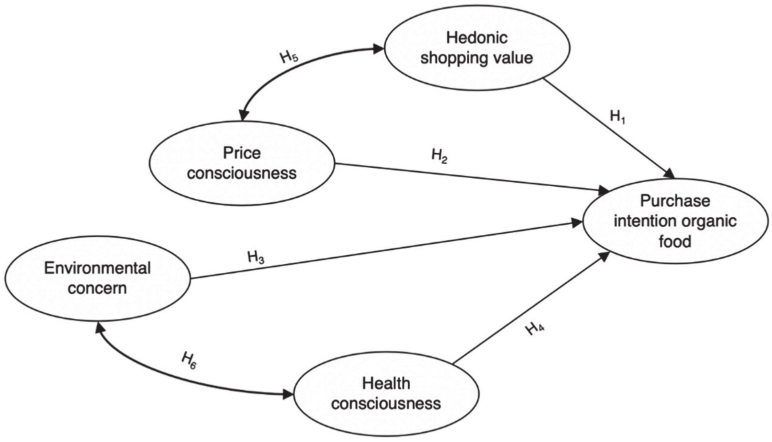

Figure 1. Conceptual framework. Note: H_1 to H_6 denote the stated hypotheses.

2.1. Hedonic Shopping Value

Discount grocery retailers, traditionally known for low prices and a no-frills service offering, have moved from only offering utilitarian shopping value to its consumers to also catering to hedonic needs [5] by offering a more stimulating in-store atmosphere and a broader product assortment. Nevertheless, the question of providing utility and value still forms the traditional basis of discount grocery retail. Utilitarian shopping value can be described as a task-oriented way of shopping, focusing on efficient outcomes without many emotions involved [26]. In the context of discount grocery retailing, this means giving consumers the impression of buying good value at low prices in a shopping environment that is not overly complicated (e.g., by providing limited in-store stimuli). In contrast to this, hedonic shopping value results from fun, enjoyment, and entertainment—that is, "hedonically rewarding shopping experiences are not akin to a negative sense of work" [26]. As organic food is often a more premium (i.e., more expensive) alternative to non-organic options, shoppers may not directly derive value in a cost or efficiency sense. However, with regard to organic food, consumer value perception may be based on a variety of factors other than price, i.e., they may derive hedonic shopping value. Generally speaking, discount grocery shoppers perceive the products they are able to buy to be of good value [27], and in this discount context, the said value perception generally holds a positive effect on purchase intention [10]. Therefore, we aim to understand what effect hedonic shopping value might have on organic food purchase intention in a discount grocery setting as a premium food category like organic could be considered a departure from the low-cost, no-frills commercial strategy. We propose that

H_1. *Hedonic shopping value has a direct and positive effect on the purchase intention for organic food in a discount grocery setting.*

2.2. Price Consciousness and Purchase Intention for Organic Food

Ever since their inception, discount grocery retailers such as Aldi and Lidl have attracted customers with low prices; their main customer base was, and probably still is, price-conscious consumers [6]. While, in general, grocery consumers tend to base their purchase decisions not only on price, but on a variety of attributes, such as quality [28], price consciousness can play a substantial role in purchase decisions [29], especially for the majority of shoppers who frequent discount grocery retailers [30]. As organic food items are generally more expensive than their non-organic alternatives [31], a high price can not only lead to a decreased purchase intention for organic food [32] but can also potentially act as a barrier to consumption all together [33]. Given the price sensitivity of discount grocery shoppers, we, therefore, hypothesize the following relationship:

H_2. *Price consciousness has a direct and negative effect on the purchase intention for organic food in a discount grocery setting.*

2.3. Environmental Concern and Purchase Intention for Organic Food

Environmental concern, defined by Schultz and colleagues [34] as a concern about environmental challenges caused by human behavior, is an oft-cited driver for organic food purchase behavior with a positive influence on purchase intention [35], actual purchase behavior [36], and the willingness to pay a price premium [37,38]. This may be explained by the finding that organic food consumers also engage in eco-friendly behavior, such as food waste reduction [39] and recycling [40]. As environmental concern evolved to be a more mainstream topic of public discourse [41], discount grocery retailers started to shift toward a greener image. Given the effects of consumer environmental concerns, we would like to understand its impact on the purchase intention for organic food in a discount grocery retailing setting. Thus, we propose that

H_3. *Environmental concern has a direct and positive effect on the purchase intention for organic food, even in a discount grocery setting.*

2.4. Health Consciousness and Purchase Intention for Organic Food

Health consciousness can be an important factor in consumer food purchase decisions [42], especially with regard to organic food items. Several studies have not only found health consciousness to be a driver for organic food purchases [43,44], but also a strong influence on consumers' willingness to pay an organic premium [44,45], perhaps explained by consumers perceiving organic food alternatives to deliver greater health benefits [46]. Analogous to environmental concern, we aim to understand the role of health consciousness in the context of discount shopping behavior for organic food. Therefore, we hypothesize the following relationship:

H_4. *Health consciousness has a direct and positive effect on the purchase intention for organic food, even in a discount grocery setting.*

2.5. Other Interactions

In addition to these main effects, we aim to understand the interaction between the proposed main drivers in a grocery discount setting, i.e., hedonic shopping value and price consciousness, and the interaction between the established main drivers for the purchase intention for organic food. Given that discount grocery retailers main customer base was and probably still is price-conscious consumers [6], we suspect that this diminishes the hedonic shopping value that may be derived for consumers in such a discount setting even in light of the aforementioned move of discount grocery retailers to also cater to hedonic needs [5]. Furthermore, we expect that the other proposed drivers for discount grocery shoppers' purchase intention for organic food exhibit a positive relationship given their importance in organic food consumer behavior in general [16], especially given the findings of Tsakiridou et al. [47], as well as De Magistris and Gracia [48], who uncovered a link between attitudes towards one's health and the environment in organic food consumers. Nevertheless, this might be contrasted by Gschwandtner [31], who found that only health but not environmental friendliness leads to a higher organic food willingness to pay.

We thus propose that

H_5. *Hedonic shopping value is negatively correlated with price consciousness in a discount grocery setting.*

H_6. *Environmental concern is positively correlated with health consciousness in a discount grocery setting.*

Altogether, the conceptual framework of this study leads to Figure 1, visualizing the hypothesized relationships between the independent and dependent variables.

3. Methodology

3.1. Data Collection

For this study, we employed a questionnaire survey to collect data to analyze the developed conceptual framework. The research setting was the United States, a country with a diverse grocery retailer landscape. Data was collected through Amazon Mechanical Turk (MTurk), a frequently used crowdsourcing platform for human tasks such as surveys. MTurk allows researchers to anonymously recruit study participants based on pre-selected criteria such as country of residence and is frequently used in consumer survey research in the organic food sector [49]. To ensure reliable and valid results, we followed previous researchers' guidelines [50,51] for recruiting respondents through MTurk and employed measures such as restricting survey-takers to respondents with high MTurk approval ratings. The shopping behavior at discount supermarkets (in this study, i.e., Aldi and Lidl) was self-reported at the end of the survey, leading to an eligible initial sample of 411 participants. This self-reported shopping behavior was elicited by asking respondents to select their most frequented grocery retailers to ensure that discount grocery shoppers were adequately captured. Of this initial sample of 411, 17 respondents were excluded due to failing an attention check, for straight-line answer patterns, or for not completing the majority of the survey, resulting in a final sample of 394 (response rate = 95.9%). The sample is skewed toward the more educated share of the US population, but is in line with the median household income [52] and mean age (38.2 years) [52]. Table 1 provides an overview of the demographics of the sample.

Table 1. Sample descriptive statistics.

Demographics	Sample (n = 394)	
Gender		
Male	221	56%
Female	173	44%
Age range		
≤25	55	14%
26–30	91	23%
31–35	87	22%
36–40	70	18%
41–45	30	8%
46–50	28	7%
>50	33	8%
Mean	35.4	
Education		
High school diploma	77	20%
Vocational training	21	5%
Bachelor's degree	234	59%
Master's degree or PhD	57	14%
Other	5	1%
Annual household income		
up to USD 20,000	39	10%
USD 20,001–40,000	87	22%
USD 40,001–60,000	108	27%
USD 60,001–80,000	80	20%
USD80,001–100,000	50	12%
over USD 100,000	40	10%

3.2. Measurement Instruments and Analysis

To employ valid measurement instruments, the scales used in this study were adapted from previous studies. The scales used were measured on a 7-point Likert scale, with a score of one denoting "strongly disagree" and a score of seven denoting "strongly agree". The statistical analysis was conducted using the software solutions SPSS (Statistical Package for Social Sciences, version 26) and AMOS (Analysis of Moment Structures, version 26, Mount Pleasant, SC, USA). First, an exploratory factor analysis (EFA) was conducted to test the factorial structure of the selected items from the questionnaire to develop reliable multi-item scales. The environmental concern (Cronbach's α = 0.736) scale, adapted from Wei, Ang, and Jancenelle [49] and De Magistris and Gracia [48], was operationalized with four statements, as was price consciousness (Cronbach's α = 0.801), the items of which were adapted from Gil and Soler [53].

Health consciousness (Cronbach's α = 0.902), which was adapted from Michaelidou and Hassan [54], was operationalized with six statements, as was hedonic shopping value (Cronbach's α = 0.955), using the items developed by Babin et al. [26]. Lastly, the purchase intention for organic food was adapted from Yadav and Pathak [55] and operationalized with five statements.

The details of the measurement instruments, as well as their sources, are shown in Table 2. Following the EFA, we conducted a confirmatory factor analysis (CFA), validating the measurement model, as well as testing, fitting, and modifying the structural model. The developed hypotheses were tested by way of standardized regression coefficients (β) and *p*-values (*p*). The results are discussed in detail in the next section.

Table 2. Measurement of constructs.

Item	Factor Loading
Environmental concern (EC) (Cronbach's α = 0.736), *adapted from Wei, Ang, and Jancenelle* [49] *as well as De Magistris and Gracia* [48]	
EC1: Environmental problems are not affecting my life, personally. *	0.766
EC2: I can think of many things I'd rather do than work toward improving the environment. *	0.702
EC3: The current development path is destroying the environment.	0.739
EC4: Unless we do something, environmental damage will be irreversible.	0.797
Health consciousness (HC) (Cronbach's α = 0.902), *adapted from Michaelidou and Hassan* [54]	
HC1: I reflect about my health a lot.	0.760
HC2: I'm very self-conscious about my health.	0.794
HC3: I'm alert to changes in my health.	0.881
HC4: I'm usually aware of my health.	0.797
HC5: I take responsibility for the state of my health.	0.731
HC6: I'm aware of the state of my health as I go through the day.	0.869
Hedonic shopping value (HSV) (Cronbach's α = 0.955), *adapted from Babin et al.* [26]	
HSV1: A shopping trip is truly a joy.	0.908
HSV2: I usually continue to shop not because I have to, but because I want to.	0.856
HSV3: Compared to other things I could do, the time I spend shopping is truly enjoyable.	0.945
HSV4: I enjoy shopping trips for their own sake, not just for the items I may purchase.	0.901
HSV5: During shopping trips, I feel the excitement of the hunt.	0.908
HSV6: While shopping, I feel a sense of adventure.	0.906
Price consciousness (PC) (Cronbach's α = 0.801), *adapted from Gil and Soler* [53]	
PC1: I try to buy food items that are on sale.	0.845
PC2: I pay attention to good deals.	0.793
PC3: I remember the prices I've paid before.	0.638
PC4: I compare food prices from different brands.	0.797
Purchase intention for organic food (PI) (Cronbach's α = 0.935), *adapted from Yadav and Pathak* [55]	
PI1: I will purchase organic food for personal use.	0.889
PI2: I am willing to purchase organic food for personal use.	0.859
PI3: I will make an effort to purchase organic food.	0.886
PI4: I have been purchasing organic food on a regular basis.	0.902
PI5: I have purchased organic food over the past six months.	0.920

* reverse-coded.

4. Results

Generally, the respondents answered highly for price consciousness (mean = 5.757, SD = 0.912) questions, as well as showing a positive attitude toward their health (mean = 5.581, SD = 0.955) and toward the environment (mean = 4.806, SD = 1.235). The purchase intention for organic food was also slightly positive (mean = 4.838, SD = 1.523). The participants' responses for the hedonic shopping value factor (mean = 4.230, SD = 1.672) were close to neutral. Figure 2 visualizes the responses received, showing a homogenous response pattern for all constructs except for environmental concern, which may be explained by employing two reverse-coded items, which tend to act as cognitive "speed bumps" for respondents, behaving differently from the normal (positively) coded items [56]. The two reverse-coded items were used to reduce social desirability bias for the resulting environmental concern construct, which exhibits good validity (Cronbach's α = 0.736).

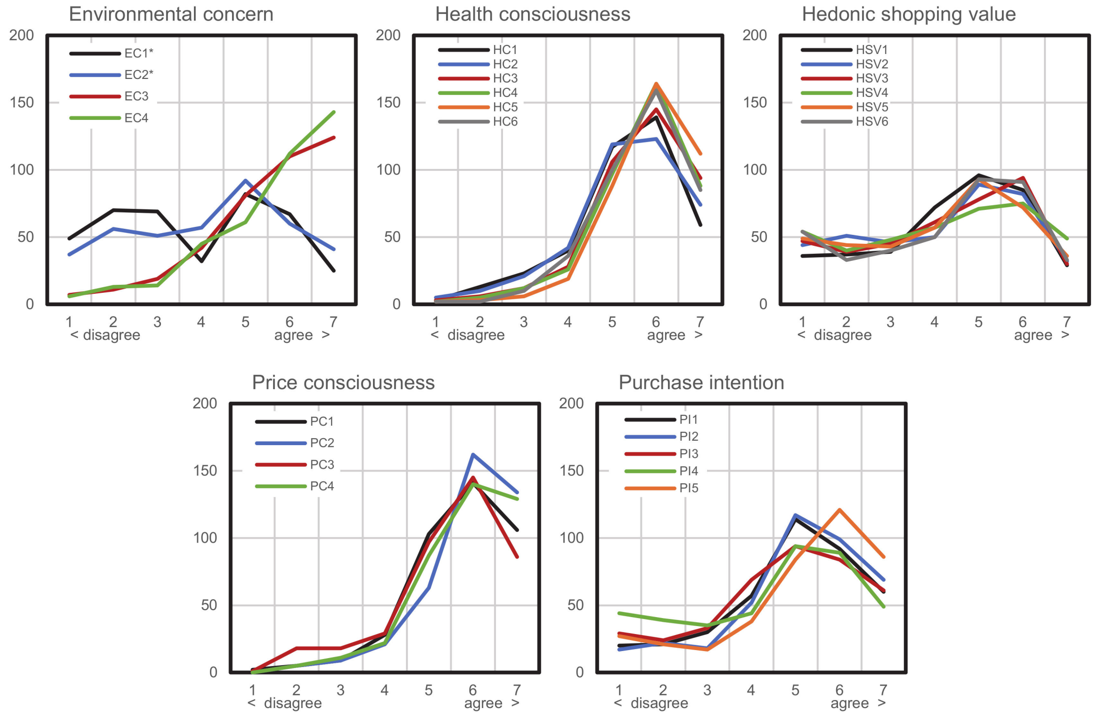

Figure 2. Overview of responses (n = 394). Notes: y-axis: number of responses; x-axis: 7-point scale (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neither agree nor disagree, 5 = somewhat agree, 6 = agree, 7 = strongly agree); * reverse-coded items.

4.1. Measurement Model

The CFA model was operationalized after deleting one environmental concern item (EC2, "I can think of many things I'd rather do than work toward improving the environment"), which improved the average variance extracted (AVE) for the environmental concern construct above the 0.500 threshold proposed by Hair, Black, Babin, and Anderson [57]. The resulting measurement model exhibited good fit indices: χ^2 = 712.034, degrees of freedom (df) = 242, Tucker-Lewis Index (TLI) = 0.924, comparative fit index (CFI) = 0.933, root mean square error of approximation (RMSEA) = 0.070, and standardized root mean square residual (SRMR) = 0.054. The regression coefficients corresponding to all the measurement items were significant (p < 0.001). This is in line with the recommended cutoff values for SEM [57,58].

Next, reliability and validity were assessed. Regarding convergent validity, all factors exhibited good composite reliability (CR), with values ranging from 0.772 to 0.956, and higher than the AVE, which for all factors was above the 0.500 threshold. Regarding discriminant validity, all AVEs are greater than the maximum shared variance (MSV), and the square root of the AVEs is greater than the inter-construct correlations. Table 3 provides an overview of reliability and validity measures.

Table 3. Overview of reliability and validity measures.

	CR	AVE	MSV	HSV	HC	PI	PC	EC
HSV	0.956	0.785	0.120	0.886				
HC	0.905	0.613	0.249	0.263	0.783			
PI	0.937	0.748	0.249	0.346	0.499	0.865		
PC	0.811	0.521	0.155	0.014	0.394	0.093	0.722	
EC	0.772	0.555	0.092	0.008	0.245	0.203	0.303	0.745

To account for method bias [56], we conducted an additional CFA for the constructs and an added common latent factor. The results show that the latent factor accounts for 24% of the total variance, below the typical method variance found by Williams, Cote, and Buckley [59]. This model also exhibited good fit indices (χ^2 = 707.425 df = 241, TLI = 0.924, CFI = 0.934, RMSEA = 0.070, SRMR = 0.060).

4.2. Structural Model

The results of the structural model exhibited good fit indices ($\chi 2$ = 712.034, df = 242, TLI = 0.924, CFI = 0.933, RMSEA = 0.070, SRMR = 0.054). The first hypothesized relationship was the direct and positive relationship of hedonic shopping value with the purchase intention for organic food. H_1 of our model is supported (β = 0.226, $p < 0.001$). In addition to this relationship, the hypothesized (H_3) direct and positive relationship of environmental concern with the purchase intention for organic food was supported (β = 0.128, p = 0.016). Similarly, we found a direct and positive relationship between health consciousness and the purchase intention for organic food (β = 0.459, $p < 0.001$), supporting H_4. Next, we examined the relationship between price consciousness and the purchase intention for organic food, finding a negative and significant relationship (β = −0.130, p = 0.022), thus supporting H_2. Lastly, we examined the hypothesized interactions between the exogenous variables. While we did not find empirical support for H_5, the hypothesized negative correlation between hedonic shopping value and price consciousness (r = 0.014, p = 0.809), we found a significant positive correlation between environmental concern and health consciousness (r = 0.245, $p < 0.001$), supporting H_6. Overall, our predictors managed to explain a sizeable portion of the purchase intention for organic food (R^2 = 0.321). Figure 3 and Table 4 summarize the results for the structural model.

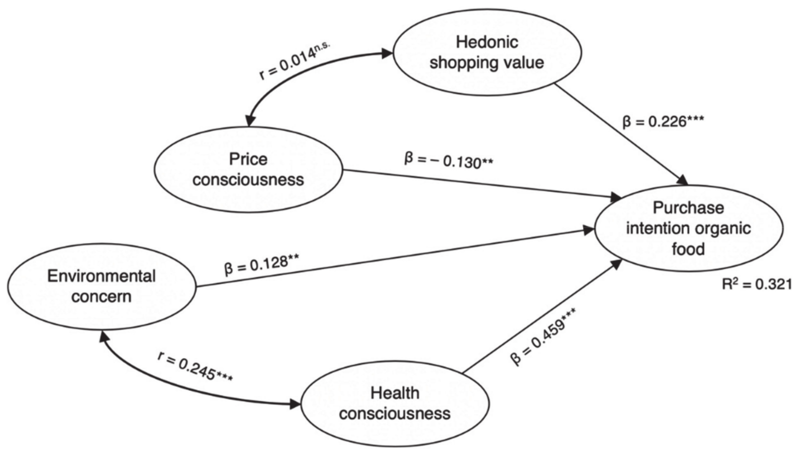

Figure 3. Results for structural model. Notes: β = standardized regression coefficient; R^2 = coefficient of determination; *** $p < 0.01$; ** $p < 0.05$; n.s. = not significant.

Table 4. Results for the structural model.

Hypothesis and Path				Std. Regression Weights/Correlation		*p* Values	Supported
H_1	Hedonic shopping value	⟶	Purchase intention organic food	β =	0.226	$p < 0.001$	yes
H_2	Price consciousness	⟶	Purchase intention organic food	β =	−0.130	$p = 0.022$	yes
H_3	Environmental concern	⟶	Purchase intention organic food	β =	0.128	$p = 0.016$	yes
H_4	Health consciousness	⟶	Purchase intention organic food	β =	0.459	$p < 0.001$	yes
H_5	Hedonic shopping value	⟷	Price consciousness	r =	0.014	$p = 0.809$	no
H_6	Environmental concern	⟷	Health consciousness	r =	0.245	$p < 0.001$	yes

Model fit: χ^2 = 712.034, df = 242, TLI = 0.924, CFI = 0.933, RMSEA = 0.070, SRMR = 0.054. Explanatory power of model: purchase intention for organic food: R^2 = 0.321.

5. Discussion

In our study, we set out to understand the purchase intention for organic food in a discount grocery setting. Our findings support most of the hypothesized effects in our proposed model. The effect of health consciousness on the purchase intention is by far the strongest and is generally in line with organic food purchasing behavior found in the existing literature [41,43,60]. Similarly, our findings are in line with the literature for environmental concern and its positive relationship with the purchase intention for organic food [35,36]; this seems to also hold true in this discount grocery shopping setting. The positive effect of health consciousness ($\beta = 0.462$) that we found in this discount setting is far stronger than the effect of environmental concern ($\beta = 0.130$) on the purchase intention for organic food, perhaps hinting at a stronger self-orientation (toward one's own health) of discount shoppers rather than an altruistic focus (toward the environment). The hypothesized negative effect of price consciousness on the purchase intention was also supported. The effect—especially if viewed in conjunction with the positive relationship we found between hedonic shopping value and the purchase intention—is not overly surprising, as it hints at an underlying notion that organic food is indeed a premium product, and discount grocery shoppers act accordingly, which may also be reflected in the lack of a significant relationship between price consciousness and hedonic shopping value. Overall, the positive effect of hedonic shopping value on purchase intention supports other studies that demonstrate that utilitarian shoppers may move toward hedonic shopping behavior [5]. Additionally, the negative effect of price consciousness is in line with previous studies finding that price can act as a barrier in organic purchase situations [32,61] and holds true in the discount grocery setting of our study. In the said discount grocery setting, this leads us to conclude that price consciousness seems to still be a highly important factor in purchase decisions for shoppers—even for premium products such as organic food [47]. But when comparing the magnitude of the regression weights in our structural model, we find that health consciousness and hedonic shopping value have a far stronger impact on the purchase intention for organic food in this discount setting. This leads us to conclude that while it is an important factor, it is not all about the price.

5.1. Managerial Implications

The findings of this study hold several implications for discount grocery retailers, which lead to three courses of action. (1) As the relationship between price consciousness and purchase intention was found to be negative, discount grocery retailers might consider looking into the comparative case, that is, further cultivating the image that even premium products, such as organic food, can be bought at a lower price at their supermarkets. Additionally, however, as environmental concern and health consciousness are significant drivers of the purchase intention for organic food, discount grocery retailers might also benefit from specifically promoting these factors, even in this discount setting. (2) Our findings suggest that the greener image that discount grocery retailers have been seeking to portray may be positively received by their customers, as we found a positive relationship between environmental concern and the purchase intention for organic food in the discount setting. The implication for discount grocery retailers can be that these image investments are paying off in a low-price environment and may thus be worth maintaining. (3) And finally, our findings support the notion that addressing the hedonic side of consumers does indeed have merit in the discount setting. Nevertheless, traditional players like Aldi and Lidl should be careful to strike the right balance between a more upscale image and the traditional no-frills approach, especially as other competitors enter this new void in the German home markets by strictly focusing on the traditional no-frills (i.e., hard discount) approach, from which Aldi and Lidl are moving away.

5.2. Contribution and Future Research Areas

This paper contributes to the existing literature in a number of ways. This study looks at the purchase intention for organic food in a discount setting, linking it to price consciousness. Additionally, in this discount grocery setting, it tests the established drivers of organic purchase intention, environmental concern, and health consciousness. Furthermore, this study adds to the literature [5] by looking at hedonic value in a discount setting. Still, as a result of our findings, we would envision six potential avenues for future research: (1) We would urge researchers to conduct willingness to pay (WTP) studies in a discount grocery context to understand the organic premium consumers are willing to pay in a discount setting. (2) Similarly, and perhaps more broadly, we could envision contingent valuation studies attempting to analyze individual organic food attributes and their corresponding prices, especially in a comparative setting between discount and non-discount (i.e., full-range) grocery retailers. (3) Future studies could attempt to further understand price consciousness in the discount setting by studying its effect on different products and product categories. (4) Future research might also attempt to examine the aspect of hedonic shopping value in light of new entrants in the discount retailing market, who cultivate a more traditional, hard discount offering. (5) Additionally, we could envision other researchers expanding our model by introducing other factors related to the purchase intention for organic food. (6) Lastly, future studies could attempt to replicate the findings of this study using different countries, an experimental design in-store, or actual purchase data.

5.3. Limitations

In conclusion, some limitations of this study should be mentioned. Firstly, the choice of constructs may be a limitation. While environmental concern and health consciousness are often employed in organic food research [16], price consciousness is traditionally associated with discount grocery retailing [6], and while hedonic shopping value has played a role in the recent discount shift [5], additional and/or other constructs may be of interest in studying organic food purchases in a discount grocery setting. This, however, may be a topic for future research, as outlined in the previous section. Secondly, it should be noted that discount grocery shoppers are not necessarily distinctly different from other grocery shoppers: they may merely exhibit certain traits in a more or less pronounced manner. Lastly, for this study, we recruited US respondents, and we, therefore, acknowledge the possibility that our findings may not hold true for individuals with different cultural backgrounds for multiple reasons, such as scaling biases in the survey items.

6. Conclusions

In our study, we set out to shed light on the purchase intention for organic food in a discount grocery retail setting. In a structural equation model based on a US consumer survey (n = 394), we found a positive relationship between hedonic shopping value, environmental concern, as well as health consciousness and the purchase intention for organic food. Furthermore, our results show that price consciousness exhibits a direct and negative relationship with purchase intention. Additionally, we found that that the impact of environmental concern, health consciousness, and hedonic shopping value is greater on the purchase intention of organic food than that of price consciousness—even in this discount setting.

Author Contributions: Conceptualization, F.K.; Data curation, F.K.; Formal analysis, F.K. and O.M.; Investigation, F.K.; Methodology, F.K. and O.M.; Project administration, O.M.; Resources, F.K. and O.M.; Software, F.K. and O.M.; Supervision, O.M.; Validation, O.M. All authors have read and agreed to the published version of the manuscript.

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Role of Sensory Appeal, Nutritional Quality, Safety, and Health Determinants on Convenience Food Choice in an Academic Environment

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Abstract: The present research aims to investigate the extent to which sensory appeal, nutritional quality, safety, and health determinants influence purchase intention, consumption, and satisfaction of consumers towards convenience food. The non-probability purposive sampling approach was adopted for the recruitment of consumers. A pre-tested questionnaire was used to collect data from 501 consumers. Descriptive statistics, confirmatory factor analysis, and structural equation modeling were adopted to analyze the data. Factor loading, Cronbach's alpha, composite reliability, average variance extracted, and correlations estimate of constructs revealed good internal consistency and reliability of scale items as well as convergent and discriminant validity of the constructs. The path analysis of structural model demonstrated positive relationship between sensory appeal, nutritional quality, safety attributes, healthiness, and purchase intention of convenience food. Further, the path analysis of structural model revealed that purchase intention with consumption as well as consumption with satisfaction were positively associated for convenience food. Sensory appeal was the key determinant influencing purchase intention, consumption, and satisfaction of consumers towards convenience food. The good taste, pleasant appearance, nice smell, and appealing texture within sensory appeal were the most important factors influencing purchase intention, consumption, and satisfaction of consumers towards convenience food. Further, the consumers in emerging economies such as India focus more on sensory appeal in convenience food choice.

Keywords: convenience food; determinants; purchase intention; consumption; confirmatory factor analysis; structural equation modeling

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1. Introduction

Busy and hectic lifestyles, increase in working population and urbanization, increase in per capita and disposable incomes, diminishing trend of cooking skills and motivation, the rapid expansion of convenience food retail chains, significant improvements in food processing and packaging technologies, and significant change in food-related lifestyles have increased the demand and consumption of convenience food in both developed and emerging economies [1,2]. The global, United States, and European convenience food market is anticipated to rise at the compounded annual growth rate (CAGR) of 4.49%, 4.2%, and 4.5% respectively during 2020 to 2025. The convenience food market in the Asia Pacific region is expected to grow at a CAGR of 8.79% during 2020–2025. The Indian convenience food market generated a revenue of USD 261 million in 2017. It is anticipated to grow at a CAGR of 16.24% during 2019–2024 and reach a revenue of USD 931 million in 2024 [1]. The key market players of convenience food in India are Nestle, ITC, MTR, Capital Foods, CG Food, Haldiram, Bambino, GITS, Kohinoor, Kitchens of India, Maiyas, and Vshodaya [2].

Sensory characteristics such as taste, appearance, freshness, texture, color, and smell are essential motivating factors, driving consumers towards shopping and consumption of convenience food products. Due to advances in food processing and packaging technology, the sensory appeal of convenience food products has been considerably improved in recent years. The sensory appeals undoubtedly are believed to influence consumers' perception, purchase intention, consumption, and satisfaction towards convenience food products significantly [3–10]. Prescott et al. [11] revealed that convenience, sensory appeal, quality, safety, price, and health are the important determinants influencing consumer shopping and consumption of convenience food. However, the magnitude and importance of each determinant may vary across Japan, Taiwan, Malaysia, and New Zealand. Wang et al. [12] revealed that sensory attributes, particularly taste, were the most important motivating factors positively associated with consumers purchase intention of traditional and Western convenience food in mainland China. The quality of convenience food products also drives consumers towards its purchase and consumption. Therefore, it is directly linked to the consumers' perception, purchase decision, and consumption behavior [13–18]. The food quality certification from authorized agencies and brands provide the details of production process, ingredients, nutritional facts, shelf life, cooking instruction, place of production, sensory appeal, quality, safety, and environmental issues which are the primary concerns of consumers while purchasing convenience food [19]. Ojha et al. [20] revealed that high-pressure processing (HPP), pulse UV light, and irradiation technologies should be adopted to enhance sensory appeal, quality, and safety of convenience food products.

Food safety, another important determinant, influences the shopping and consumption of convenience food products. The consumers usually expect that the government food regulatory authorities, food processing industries, and marketing agencies take responsibility for the safety of convenience food products. Food safety is one of the most influential factors in terms of shopping and consumption of convenience food products [21–23]. The primary concerns of consumers about food safety are chemical, microbiological, and technological issues as well as the place of origin/place of products [24]. Vital demographic characteristics such as age, gender, education, marital status, and employment status considerably influence the food safety knowledge and practices [25,26]. Misra et al. [27] revealed that application of novel food processing technologies reduced processing time and energy consumption as well as assured high food safety of convenience food products. Health is one of the prime concerns of consumers while purchasing and consuming convenience food products. It is generally believed that regular and excessive use of convenience food causes obesity and other health-related problems [28,29]. Health is a multidimensional construct that influences the purchase intention and consumption of convenience food [4,30,31]. Hoek et al. [32] stated that the government regulatory authorities, responsible for the formulation of food laws and regulations, should prioritize health and health-related attributes of convenience food.

Socio-demographic trends in emerging economies have recently been indicating a major shift. These include more educated and entrepreneur youth population residing in megacities with increased proportion of monthly income on food, lack of time to spend on cooking, multiple income family, and above all the dynamic lifestyle. The confluence of these driving vectors leads to a forthcoming sprawl of convenience food. Several studies in the recent past have been carried out to seek the effect of various factors on convenience food choice, most of which focused on markets in developed and industrialized countries [4,7–9,23,26,31,33]. Due to diversity in tradition, culture, food habits, social structure, religious beliefs, and ethical values, the consumers in emerging economies might not respond to such factors in the same way as reported in aforementioned studies. Hence, it is important as well as timely to administer such research. Considering the impressive market growth and economic importance of convenience food in emerging economies such as India, the main goal of the study is to "examine the role of sensory appeal, nutritional quality, safety, and health determinants on purchase intention, consumption and satisfaction of consumers towards convenience food" in an academic environment.

2. Theoretical Background and Development of Hypotheses

2.1. Sensory Appeal

Sensory appeal plays a significant and important role on perception, purchase decision, consumption, and satisfaction of consumers towards convenience food [8,9,12]. Sensory characteristics such as taste [6,8,9]; flavor [8,34]; appearance [5,6]; freshness [5]; texture [6]; smell [6,8]; and overall liking [8] are important motivating factors driving consumers towards shopping and consumption of convenience food. Due to advances in food processing and packaging technologies, the sensory attributes have been improved considerably in recent years to motivate consumers towards convenience food choice [20]. Studies carried out in the past revealed that taste within sensory attributes was the key factor influencing consumer perception, purchase intention, and consumption of convenience food [8,9]. Considering the aforementioned research findings, the present study proposed the following hypothesis:

Hypothesis 1. *Sensory appeal is positively related to purchase intention of convenience food.*

2.2. Nutritional Quality

Nutritional quality is another most important determinant, which motivates and drives consumers towards convenience food choice as well as being directly linked with perception, purchase decision, and consumption. Nutritional quality attributes such as nutritional value [15], natural ingredients [16], protein content [16], fiber content [16,17], vitamin content [17], mineral content [16], and nutritional quality certification [12] are the important factors, which drive consumers towards purchase intention and consumption of convenience food. Mascarello et al. [33] revealed that consumer's positive perception towards quality attributes considerably influenced the purchase intention of convenience food. Based on the aforementioned research findings, the following hypothesis is proposed:

Hypothesis 2. *Nutritional quality attribute is positively related to purchase intention of convenience food.*

2.3. Safety

Food safety is another important determinant that influences the purchase decision and consumption of convenience food. Most developed countries have stringent food safety regulation to safeguard the consumers. However, in developing countries like India, food safety regulation enforcement is still in the development stage. The safety attributes such as additives [21,35], pesticides [21,23], hormones [21], color [23], artificial ingredients [23], and safety certification [16] contribute significantly in purchase intention, consumption, and satisfaction of consumers towards convenience food. Based on the aforementioned research findings, the following hypothesis is proposed:

Hypothesis 3. *Safety attribute is positively related to purchase intention of convenience food.*

2.4. Health

Health is the prime concern of consumers while purchasing and consuming convenience food. Health is a multidimensional construct that embodies overall wellbeing of consumers regarding physical, mental, and social aspects [30]. Health-related issues such as calories [36], fat [36], salt [37], sugar [37], and balanced diet [38,39] play important roles in influencing consumers for purchase intention, consumption, and satisfaction towards convenience food. Hoek et al. [32] stated that government regulatory authorities responsible for the formulation of laws and regulations should prioritize health and health attributes of convenience food. Based on the aforementioned research findings, the following hypothesis is proposed:

Hypothesis 4. *Healthiness is positively related to purchase intention of convenience food.*

2.5. Purchase Intention, Consumption, and Satisfaction

The purchase intention of consumers towards convenience is a complex process, and it is governed by a wide range of determinants. However, the importance of each determinant, which drives consumers towards purchase intention of convenience food, depends on food-related attitude and behavior. The perceived value of products, which is directly associated with convenience, sensory appeal, nutritional quality, safety, health, and price, has a positive influence on consumers' purchase intention for convenience food [40,41]. Apart from social, cultural, and economic determinants, convenience food consumption is also influenced by convenience, sensory appeal, nutritional quality attributes, safety attributes, healthiness, and price [30,42]. Consumer satisfaction is a strategic focus of consumer-oriented food industries and marketing agencies to retain and maintain the consumers for repeated purchase and consumption of their convenience food. Convenience [43], sensory appeal [9], nutritional quality [33], safety [23], healthiness [31], price [44], and physical wellbeing [45] are important attributes of convenience food, which lead to consumer satisfaction and loyalty. In light of the aforementioned research findings, the following hypotheses are proposed.

Hypothesis 5. *Purchase intention is positively related to consumption of convenience food.*

Hypothesis 6. *Consumption of convenience food is positively related to consumer satisfaction.*

The conceptual model for the current study is based on aforementioned research findings to assess the role of sensory appeal, nutritional quality, safety, and health determinants influencing purchase intention, consumption, and satisfaction of consumer towards convenience food (Figure 1).

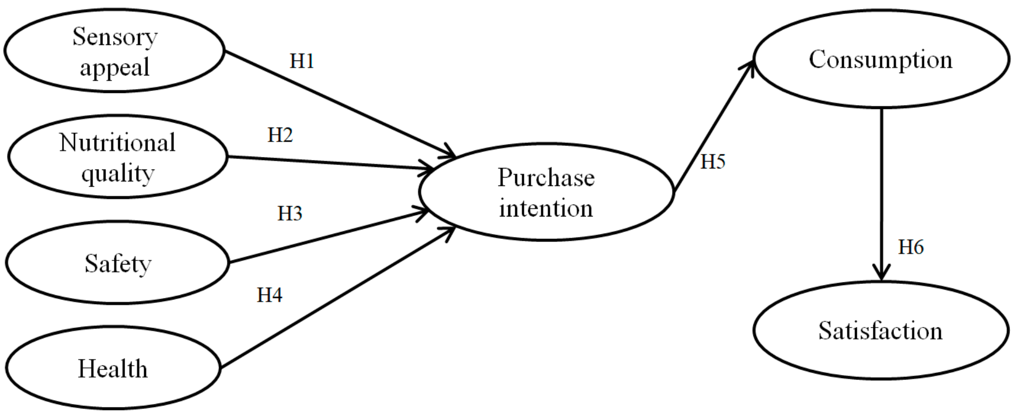

Figure 1. Conceptual model.

3. Materials and Methods

3.1. Development, Pre-Testing, and Structure of Questionnaire

A comprehensive literature review provided guidelines to develop a questionnaire to assess the role of sensory appeal, nutritional quality, safety, and health determinants on purchase intention, consumption, and satisfaction of consumers towards convenience food. Pre-testing is an important step to ensure the accuracy and reliability of the questionnaire [46]. The questionnaire was pre-tested at Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India to develop and optimize the questionnaire. The questionnaires were pre-tested with 30 participants comprising students, in-service professionals, and food processing and nutrition experts to identify and remove potential problems and ensure its comprehensibility. After completing the questionnaire, each participant was asked to give his/her feedback regarding clarity, comprehension, and potential problems to examine the role of sensory, appeal, nutritional quality, safety, and health determinants on purchase intention, consumption, and satisfaction of consumers towards convenience food. The suggestions made by the participants were included in the final questionnaire to ensure accuracy and precision in data collection [12,38,47,48].

The questionnaire was divided into eight sections. The first section was designed to collect general information of consumers such as socio-demographic characteristics, food habits, food preferences, frequency of eating convenience food, health concerns, etc. The second section of the questionnaire was designed to gather data regarding the sensory attributes (appearance, smell, texture, taste) influencing purchase intention of consumers of convenience food. The third, fourth, and fifth sections of the questionnaire were framed to collect data regarding nutritional quality (nutritive value, mineral, vitamin, natural ingredients, fiber, food quality certificate), safety (hormones, insecticides, pesticides, additives, food safety certificate), and health attributes (calories, fat, salt, sugar, balanced diet) influencing purchase intention of convenience food. The sixth, seventh, and eighth sections of the questionnaire were designed to collect data for purchase intention, consumption, and satisfaction of consumers towards convenience food (Appendix A).

3.2. Participants

The non-probability purposive sampling method was adopted for the recruitment of the participants because researchers were targeting a specific group of participants, i.e., university/college students, teaching and non-teaching staff, and professionals from corporate sector as they are the major consumers of convenience food consumption [47,49]. A total number of 550 participants were selected from four major cities of Northern India. The total population of four cities is approximately 8.25 million. The sample size of 550 participants taken in this study was higher than 400 as recommended over the population of 0.250 million with a confidence level of 95% and 5% margin of error [47,50]. A total number of 49 questionnaires were dropped due to incomplete information. The final sample size was 501, which resulted in a response rate of 91.09%.

3.3. Data Collection

The structured and pre-tested questionnaires were distributed to 550 participants in four universities, eight colleges, and twelve corporate offices in January 2019. The participants were requested to gather at the conference/meeting rooms provided by the universities, colleges, and corporate sectors. The participants were informed one day in advance regarding time and venue to achieve desired number of participants as well as to avoid inconvenience. A group of 25 participants were invited to complete the questionnaire. The researcher distributed the questionnaire to the participants and briefed them about purpose, objectives, and importance of the study. The influence of aforementioned determinants on purchase intention and consumption of convenience food were determined on five-point Likert scale (strongly disagree = 1, disagree = 2, don't know = 3, agree = 4, strongly agree = 5). The participants were directed to choose one from 1 to 5 for each question [44,47,51].

3.4. Data Analysis

The statistical software SPSS version 24 was used to determine mean, standard deviation, skewness, and kurtosis. Further, SPSS was employed to determine Cronbach's alpha to assess internal consistency and reliability of the scale items of questionnaire [47,52,53]. The AMOS software version 23 was used to perform confirmatory factor analysis (CFA) and structural equation modeling (SEM). The CFA was carried out to estimate factor loading, composite reliability, average variance extracted, and model fit indices. The composite reliability of the constructs of the questionnaire was determined to examine the reliability of scale items [38,47,48,52]. The factor loading and average variance extracted were determined to assess the convergent validity of the constructs of measurement model [12,38,39,48,52]. The correlations amongst the construct and square root of average variance extracted were used to examine the discriminant validity of constructs [54]. The statistical indices such as comparative fit index (CFI), Tucker–Lewis index (TLI), goodness of fit index (GFI), root mean square error of approximation (RMSEA), and standardized root mean-square residual (SRMR) were determined to examine the fit of measurement model [39,47,48,55]. The structural model was constructed to examine the association between sensory appeal, nutritional quality, safety, health, and purchase intention as well as purchase intention with consumption and consumption with satisfaction of consumers towards convenience food. The CFI, TLI, GFI, RMSEA, SRMR, and χ^2/df (Chi square/degree of freedom) were determined to assess the fit of the structural model [47,48,53]. The standardized estimate (path coefficient), standard error, *t*-value, and *p*-value were determined to test the hypotheses [31,47,48].

4. Results

4.1. Descriptive Statistics

Table 1 demonstrates the socio-demographic characteristics of participants. The participants were students and teaching and non-teaching staff from universities/colleges and professionals from corporate sectors. The participants comprised of 41.3% males and 58.7% females with age ranging from 18–65 years (average age = 30.37). The participants consisted of 48.9% single and 51.1% married in which 34.1% and 65.9% were unemployed and employed, respectively. The participants' education level ranged from high school to doctoral, i.e., high school (0.40%), senior secondary school (7.0%), diploma (1.4%), undergraduate (33.9%), master (34.5%), and doctoral (22.8%). The annual family income of the participants ranged from USD 700 to USD 40,000.

Table 1. Socio-demographic profile of participants.

Socio-Demographic Variables	Groups	Number of Participants	Percentage of Participants
Gender	Male	207	41.32
	Female	294	58.68
Age (years)	18–25	175	34.93
	26–35	203	40.52
	36–45	94	18.76
	46–65	29	5.79
Marital status	Single	245	48.90
	Married	256	51.10
Employment status	Unemployed	171	34.13
	Employed	330	65.87
Education level	10 *	2	0.40
	10 + 2 **	35	6.99
	Diploma	7	1.40
	Undergraduate	170	33.93
	Masters	173	34.53
	Doctoral	114	22.75
Annual family income (INR)	50,000–75,000	27	5.39
	75,000–100,000	32	6.39
	100,000–200,000	64	12.77
	200,000–500,000	140	27.94
	500,000–1,500,000	199	39.72
	1,500,000–3,000,000	37	7.39
	>3,000,000	2	0.40

Note: Total sample size = 501; 1 USD = INR 72. * 10 = high school; ** 10 + 2 = senior secondary school.

The mean participants' score for sensory appeal was higher, followed by safety, nutritional quality, and health determinants influencing purchase intention, consumption, and satisfaction of consumers towards convenience food. The mean participants score of the items revealed that the "good taste" within sensory appeal construct; "food quality certification" within nutritional quality construct; "food safety certification" within safety construct; and "balanced diet" within health construct were the most important factors in relation to purchase intention, consumption, and satisfaction of consumers towards convenience food (Appendix A; Table 2). The skewness for different items of sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction were within the threshold value of −1 to 1. The kurtosis for different items of sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction fall within the acceptable range of −2 to 2 (Table 2). The skewness and kurtosis values indicated that participants' score/data recorded for different items of sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction were normally distributed [4,53].

Table 2. Mean participants' score, factor loading, Cronbach's alpha(α), composite reliability (CR), and average variance extracted (AVE) of product determinants influencing purchase intention, consumption, and satisfaction of consumers for convenience food.

Construct	Items Code	Mean Score	Factor Loading	*p*-Value	α	CR	AVE
Sensory appeal (SEN)		4.12 ± 0.76			0.758	0.941	0.521
	SEN1	4.07 ± 0.64	0.778	***			
	SEN2	4.03 ± 0.63	0.779	***			
	SEN3	4.06 ± 0.62	0.704	***			
	SEN4	4.30 ± 0.63	0.613	***			
Nutritional quality (QUL)		3.87 ± 0.75			0.870	0.972	0.599
	QUL1	3.31 ± 1.04	0.812	***			
	QUL 2	3.16 ± 1.01	0.904	***			
	QUL3	3.16 ± 1.03	0.888	***			
	QUL4	3.66 ± 0.85	0.610	***			
	QUL5	3.52 ± 0.89	0.731	***			
	QUL6	3.80 ± 0.72	0.851	***			
Safety (SAF)		3.91 ± 0.68			0.897	0.979	0.566
	SAF1	3.55 ± 0.83	0.879	***			
	SAF2	3.63 ± 0.82	0.907	***			
	SAF3	3.61 ± 0.84	0.923	***			
	SAF4	3.61 ± 0.86	0.650	***			
	SAF5	3.61 ± 0.89	0.638	***			
	SAF6	3.48 ± 0.93	0.660	***			
	SAF7	3.83 ± 0.78	0.608	***			
Health (HEA)		3.71 ± 0.83			0.883	0.973	0.549
	HEA 1	3.02 ± 1.05	0.716	***			
	HEA2	2.88 ± 1.60	0.708	***			
	HEA3	3.17 ± 1.01	0.837	***			
	HEA4	3.45 ± 0.94	0.795	***			
	HEA5	3.52 ± 1.01	0.723	***			
	HEA6	3.38 ± 1.01	0.650	***			
Purchase intention (PI)		4.21 ± 0.91			0.780	0.900	0.576
	PI1	4.14 ± 0.81	0.628	***			
	PI2	4.17 ± 0.77	0.689	***			
	PI3	3.65 ± 1.03	0.842	***			
	PI4	3.59 ± 0.99	0.907	***			
	PI5	3.50 ± 1.03	0.754	***			
	PI6	4.20 ± 0.71	0.694	***			
	PI7	3.93 ± 0.91	0.763	***			
Consumption (CON)		3.95 ± 0.74			0.740	0.940	0.690

Table 2. *Cont.*

Construct	Items Code	Mean Score	Factor Loading	*p*-Value	α	CR	AVE
	CON1	3.83 ± 0.89	0.900				
	CON2	3.38 ± 0.89	0.767	***			
	CON3	3.79 ± 1.00	0.826	***			
	CON4	3.59 ± 0.65	0.765	***			
	CON5	3.81 ± 0.79	0.816	***			
	CON6	3.36 ± 0.74	0.912	***			
	CON7	3.67 ± 1.02	0.741	***			
Satisfaction (SAT)		4.20 ± 0.83			0.852	0.980	0.864
	SAT1	4.23 ± 0.64	0.891	***			
	SAT2	4.16 ± 0.63	0.879	***			
	SAT3	3.84 ± 0.71	0.927	***			
	SAT4	3.77 ± 0.83	0.938	***			
	SAT5	3.52 ± 0.91	0.913	***			
	SAT6	4.20 ± 0.62	0.905				
	SAT7	3.97 ± 0.66	0.963	***			
	SAT8	3.93 ± 0.66	0.948	***			
	SAT9	3.92 ± 0.67	0.962	***			
	SAT10	3.83 ± 0.74	0.940	***			
	SAT11	3.85 ± 0.70	0.952	***			
	SAT12	3.51 ± 0.86	0.898	***			

*** Significant at $p \leq 0.01$; skewness: −1.067 to 0.322; kurtosis: −1.163 to 1.865. Note: See Appendix A for detailed description of the items. Measurement model fit indices: CFI = 0. 911; TLI = 0. 903; GFI = 0. 901; RMSEA = 0.072; SRMR = 0. 074.

4.2. Measurement Model

The factor loading of all items of sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction for convenience food were significant ($p \leq 0.01$). The factor loadings for different items of sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction constructs ranged from 0.608 to 0.963, which were higher than the threshold value of 0.50 [39,48,52,55], hence all items were included for the interpretation of the factors influencing purchase intention, consumption, and satisfaction of consumers towards convenience food [39,48,55]. Cronbach's alpha for sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction constructs ranged from 0.740 to 0.897, which exceeded the threshold value of 0.70 [38,47,52]. Composite reliability for sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction constructs ranged from 0.852 to 0.979 that exceeded recommended minimum cut off value of 0.70 [47,48,52]. Cronbach's alpha and composite reliability values obtained for different constructs revealed good internal consistency and reliability of scale items of questionnaire [3,48,54,55]. The average variance extracted for sensory appeal, nutritional quality, safety, health, purchase intention, consumption, and satisfaction constructs ranged from 0.521 to 0.864, which were higher than the minimum acceptable cut off value of 0.50 [39,48,54]. The factor loading and average variance extracted values obtained for different constructs and items for each construct confirmed the convergent validity of the constructs of measurement model [39,54,55]. The square root of average variance extracted estimates (diagonal values) were higher than the correlation estimates amongst constructs (Table 3), which confirmed the discriminant validity of constructs [47,48,54].

The comparative fit index (CFI), Tucker–Lewis index (TLI), goodness of fit index (GFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) were used to examine the fit of measurement model relating sensory appeal, nutritional quality, safety, and health aspects with purchase intention, consumption, and satisfaction towards convenience food. The CFI was 0.911 ($\geq$0.90); TLI was 0.903 ($\geq$0.90); GFI was 0.901 ($\geq$0.90); RMSEA was 0.072 ($\leq$0.08), and SRMR was 0.074 ($\leq$0.08), which were within the acceptable range (Table 2). The CFI, TLI, GFI, RMSEA, and SRMR revealed that measurement model fit well with data [47,53,55,56].

Table 3. Discriminant validity of the constructs.

Constructs	Sensory Appeal	Nutritional Quality	Safety	Health	Purchase Intention
Sensory appeal	0.722				
Nutritional quality	0.243	0.774			
Safety	0.373	0.426	0.752		
Health	0.205	0.603	0.474	0.740	
Purchase Intention	0.184	0.552	0.425	0.624	0.758

4.3. Structural Model

The structural model was constructed to examine the association between sensory appeal, nutritional quality attributes, safety attributes, healthiness, and purchase intention as well as purchase intention with consumption and consumption with satisfaction of consumers towards convenience food. The CFI was 0.913 ($\geq$0.90), TLI was 0.906 ($\geq$0.90), GFI was 0.903 ($\geq$0.90), RMSEA was 0.073 ($\leq$0.08), SRMR was 0.075 ($\leq$0.08), and χ^2/df was 3.9 (<5.0), which were within the recommended acceptable range (Figure 2). The CFI, TLI, GFI, RMSEA, SRMR, and χ^2/df values demonstrated a good fit of the structural model [39,47,53,56].

The results of the structural model presented in Figure 2 and Table 4 demonstrate the extent of the relationship among sensory appeal, nutritional quality attributes, safety attributes, healthiness, and purchase intention, as well as purchase intention with consumption and consumption with satisfaction for convenience food. Hypothesis 1 (H1), which proposed positive relationship between sensory appeal and purchase intention of convenience food was accepted, because standardized estimate (ß) of the path of structural model was significant (Hypothesis 1: ß = 0.788, S.E. = 0.053, *t*-value = 5.448, $p \leq 0.01$). Hypothesis 2 that postulated positive relationship between nutritional quality attributes and purchase intention of convenience food was accepted because standardized estimate (ß) of the path of structural model was significant (Hypothesis 2: ß = 0.639, S.E. = 0.056, *t*-value = 6.094, $p \leq 0.01$). Hypothesis 3, which postulated positive relationship between safety attributes and purchase intention of convenience food, was accepted as the standardized estimate (ß) of the path of structural model was significant (Hypothesis 3: ß = 0.511, S.E. = 0.032, *t*-value = 16.063, $p \leq 0.01$). Hypothesis 4 that proposed positive relationship between healthiness and purchase intention of convenience food was accepted, because the standardized estimate (ß) of the path of structural model was significant (Hypothesis 4: ß = 0.491, S.E. = 0.031, *t*-value = 15.594, $p \leq 0.01$). Hypothesis 5, which postulated positive relationship between purchase intention and consumption of convenience food was accepted because standardized estimate (ß) of the path of structural model was significant (Hypothesis 5: ß = 0.998, S.E. = 0.016, *t*-value = 61.962, $p \leq 0.01$). Further, Hypothesis 6 that proposed positive relationship between consumption and satisfaction towards convenience food was also accepted (Table 4) as standardized estimate (ß) of the path of structural model was statistically significant (Hypothesis 6: ß = 0.728, S.E. = 0.022, *t*-value = 32.516, $p \leq 0.01$).

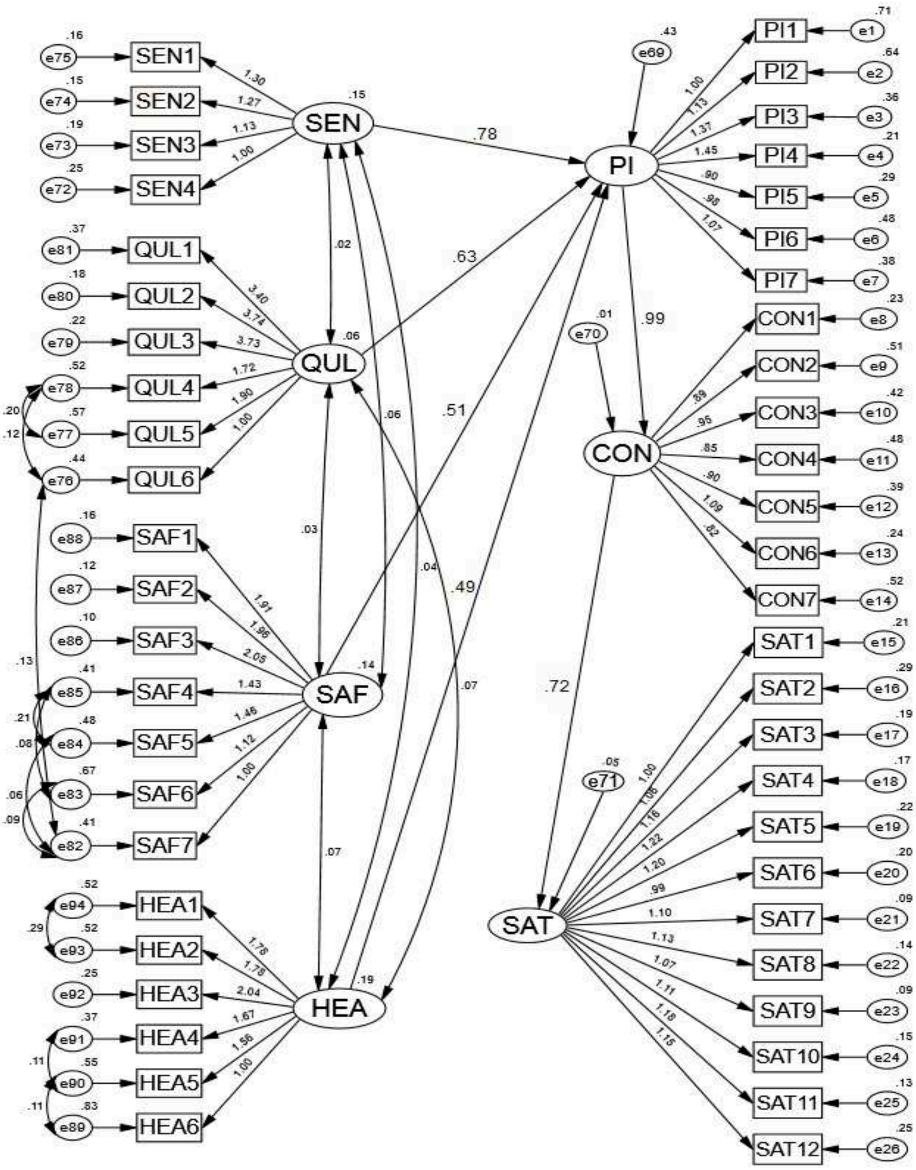

Figure 2. Structural equation modeling to assess the role of product determinants on purchase intention, consumption, and satisfaction of consumers towards convenience food. Structural model fit indices: CFI: 0.913; TLI: 0.906; GFI: 0.903; RMSEA: 0.073; SRMR: 0.075; $\chi^2/\mathrm{df} = 3.91$.

Table 4. Structural model results to examine the association of between product determinants and purchase intention, consumption, and satisfaction for convenience food.

Hypothesis	Structural Path	Standardized Estimate (ß)	Standard Error (SE)	*t*-Value	*p*-Value	Results
H1	Sensory appeal → Purchase intention	0.788	0.053	5.448	***	Accepted
H2	Nutritional quality attribute → Purchase intention	0.639	0.056	6.094	***	Accepted
H3	Safety attribute → Purchase intention	0.511	0.032	16.063	***	Accepted
H4	Healthiness → Purchase intention	0.491	0.031	15.954	***	Accepted
H5	Purchase intention → Consumption	0.998	0.016	61.962	***	Accepted
H6	Consumption → Satisfaction	0.728	0.022	32.516	***	Accepted

*** Significant at $p \leq 0.01$.

5. Discussion

The sensory appeal plays a significant role in driving consumers towards shopping and consumption of convenience food. The mean participants' score of the sensory appeal construct and the standardized estimate of the path of structural model revealed that sensory appeal was the most important determinant influencing purchase intention, consumption, and satisfaction of consumers towards convenience food (Tables 2 and 4). Further, the mean participants' score of the items indicated that taste was the key factor influencing purchase intention, consumption, and satisfaction of consumers towards convenience food as compared to appearance, smell, and texture. Previous studies carried out under a wide range of social, cultural, and economic conditions also predicted sensory appeal as the most important determinant influencing shopping and consumption of convenience food [4–7,16,57]. Previous findings revealed that convenience, sensory appeal, nutritional quality, price, and health are important determinants influencing convenience food choice; however, the magnitude and importance of each determinant varied significantly across the social, cultural, economic and food related lifestyle [3,11,58].

In recent years, consumers have been more concerned about the quality and safety of convenience food. The development of novel and advanced food processing technologies such as high-pressure processing (HPP), pulse UV light, and irradiation has improved the quality of convenience food significantly [20,27]. The standardized estimate of the path of structural model indicated that nutritional quality attributes positively influenced purchase intention, consumption, and satisfaction of consumers towards convenience food (Table 4). The mean participants' score indicated that food quality certification from a food regulatory agency was the most important among the factors under food nutritional quality construct, which drives consumers towards purchase intention and consumption of convenience food (Table 2). The findings of the previous studies also indicated that consumer perception towards quality attributes significantly influence purchase intention and consumption of convenience food [14,33,57]. Petrescu et al. [59] revealed that Belgian and Romanian consumers assign high values to quality attributes and often use taste, appearance, and freshness as an indicator to assess the quality of convenience food. The present findings also indicated that taste, appearance, and smells were key factors influencing convenience food choice, but these factors were considered under sensory appeal of convenience food (Table 2).

Food safety is another important aspect of convenience food that is directly associated with public health, food security, environmental protection, and sustainable development. The analysis of the structural model demonstrated that the safety attribute was positively associated with purchase intention, consumption, and satisfaction of consumers towards convenience food (Table 4). The mean participants' score revealed that food safety certification was the most important factor under the food safety construct which drives consumers towards purchase and consumption of convenience food (Table 2). Previous studies also reported that food safety is an influential factor, which drives consumers towards convenience food choice [21–23,26]. The novel food processing technologies, i.e., HPP, pulse UV light, and irradiation, could be utilized by food processing industries in the production process to improve food quality and safety standards of convenience food [20,27].

The health benefit greatly influenced consumers towards convenience food choice. Due to technological development in processing, preservation, storage, and marketing, the sensory appeal, nutritional quality, safety, and health attributes of convenience food have been improved significantly in recent years [20,27]. The results of the structural model demonstrated the positive association between healthiness and purchase intention of convenience food (Table 4). The mean participants' score of the health construct as well as different items within the health construct revealed that consumers are satisfied with the healthiness of convenience food. The overall results of the present study showed that the convenience food products are perceived as healthy and their consumption does not pose any threat to health (Table 2). This is due to the fact that the consumption of convenience food is not excessive, therefore the consumers have not reported any diverse effect of consuming convenience food on health. In contrast, consumers in developed and industrialized countries believe that consumption of convenience food has implication on health, diet quality, obesity, and chronic disease risk [32]. Vita et al. [57] revealed that high salt content, high fat content, and presence of nitrites had a negative impact on purchase intention of processed ham, but good taste, pleasant color, and juiciness diminishes the effect of aforementioned unhealthy compounds, which strongly support the findings of the present study in which consumers assign high values to sensory attributes as compared with quality, safety, and health attributes of convenience food.

In recent years, convenience food has spread into the lifestyle of consumers in emerging economies such as India due to time scarcity, competitive environment, and significant changes in food-related lifestyle [1,2]. Food production, processing, distribution, consumption, and waste disposal contribute largely to emission of greenhouse gasses, resources depletion, global warming, and environmental degradation [60–62]. Hence, environmentally sustainable food production, distribution, and consumption is important for sustainable development. Environmentally sustainable food consumption is the foremost important step to minimize the use of natural resources and emissions of greenhouse gasses, toxic waste, and pollutants, which in-turn enhance sustainable development and quality of life [63–65]. Convenience food involves production and transportation of raw materials, pre-processing manufacturing, packaging, distribution, consumption, and waste disposal which can be optimized in order to minimize the environmental degradation [66]. Food consumption behavior of consumers is a complex process and is strongly associated with lifestyle and socio-cultural environment. The consumers may express environmental concern, but during buying process normally ignore purchasing environmentally sustainable food products due to convenience, time pressure, availability, and price [67–69]. Previous studies carried out in developed and industrialized countries revealed that consumers should be encouraged to purchase environmentally sustainable convenience foods such as organic and minimally processed food to minimize negative effect on human health and environment [70]. Schmidt Rivera et al. [66] revealed that the environmental impact of ready to eat food was higher than equivalent home-cooked food. Further, consumers should be educated and encouraged to curtail ready-to-eat convenience food and consume more home-cooked food. In order to promote sustainable food consumption, consumers should be encouraged to purchase and consume plant-based foods because animal-based foods are more resource intensive and less environment friendly [71–73]. Environmental sustainability has become a severe concern, especially in developed and industrialized countries but in India, where the present study has been conducted, the consumers' concern towards environmentally sustainable food production and consumption is insignificant. Sharma and Jha [74], in their study conducted in India, revealed that consumers' individualism was negatively associated with sustainable food consumption. Government food regulatory bodies, non-government organizations, social and environmental activists, and policy makers should encourage and promote environment sustainable production, processing, distribution, and consumption of convenience foods in emerging economies such as India.

Though the present study provides in-depth knowledge and information regarding the role of sensory appeal, nutritional quality, safety, and health determinants on convenience food choice in emerging economies like India, the present study has some limitations. Due to time constraints, the study was carried in four cities in India which limits the generalization of the findings. Hence, future research should be carried out in different cities and countries in order to obtain more generalized and representative results. The present study concentrates on specific groups of consumers which also limits the applicability of the results. Therefore, future research should include wide range of consumers to improve overall applicability of the results. School children constitute an important consumer segment for convenience food. Hence, it is recommended to carry out similar studies for school children across cities and countries to provide them safe and healthy convenience food. Since environmental sustainability is a matter of grave concern, it is recommended to incorporate the environmentally sustainable aspects of convenience food in future studies in emerging economies, especially in India. For instance, packaging size of the convenience food would determine the amount of waste (packaging material after use) to be disposed of by a city. Similarly, it will influence the city's environmental footprint in terms of waste collection and disposal. The findings of such studies would definitely enhance the knowledge and understanding about consumers' purchase and consumption behavior towards convenience food in emerging markets.

6. Conclusions

The confirmatory factor analysis results indicated satisfactory and acceptable value of reliability of scale items and validity of the constructs of questionnaire. The model fit indices revealed that measurement and structural model relating sensory appeal, nutritional quality, safety attributes, and healthiness with purchase intention, consumption, and satisfaction of consumers towards convenience food were fitted well with data. Sensory appeal, quality attributes, safety attributes, and healthiness have a positive relationship with purchase intention, consumption, and satisfaction of consumers towards convenience food. Sensory appeal such as good taste, pleasant appearance, nice smells, and pleasant texture play the most important role in motivating and driving consumers towards purchase intention and consumption of convenience food. The overall result reveals that consumers give more importance to sensory appeal as compared with quality, safety, and health attributes during the purchase and consumption of convenience food in emerging economies such as India.

The conceptual framework and findings provide some theoretical and practical contributions. First, to the best of the authors' knowledge, the present comprehensive study expands previous research by adding consumer satisfaction to a conceptual model relating sensory appeal, nutritional quality attributes, safety attributes, and healthiness with purchase intention, consumption, and satisfaction for convenience food. Second, the empirical evidence reveals that consumers in emerging economies assign high values to sensory appeal in convenience food choice, compared to quality, safety and health attributes, which shall add new information to literature. Third, the food processing industries should ensure that convenience foods are free from hormones, insecticides, pesticides, non-permissible additives, non-permissible colors, and artificial ingredients during production, processing, transportation, and marketing of convenience food to minimize health risk. Fourth, food processing industries should ensure the recommended level of calories, salt, sugar, and fat content in convenience food to provide a healthy and balanced diet to consumers. Finally, government food regulatory agencies should have strict food laws and regulations for mandatory food quality and safety certification to enhance consumers trust on convenience food.

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Appendix A

Description of the questionnaire.

Section 1	**-**	**Socio-demographic characteristics**
Gender		
Age		
Marital status		
Employment status		
Education level		
Family income		
Food habits		
Food preferences		
Frequency of eating convenience food		
Health concern		
Section 2	**-**	**Sensory appeal (SEN)**
SEN1	-	I prefer convenience food because it has a pleasant appearance.
SEN2	-	I prefer convenience food because it smells nice.
SEN3	-	I prefer convenience food because it has pleasant texture.
SEN4	-	I prefer convenience because it tastes good.
Section 3	**-**	**Nutritional quality (QUL)**
QUL1	-	I prefer convenience food because of its high nutritive value.
QUL2	-	I prefer convenience food because it has high mineral content.
QUL3	-	I prefer convenience food because it has high vitamin content.
QUL4	-	I prefer convenience food because it contains natural ingredients.
QUL5	-	I prefer convenience food because it has high fiber content.
QUL6	-	I prefer convenience food because it has necessary quality certification.
Section 4	**-**	**Safety (SAF)**
SAF1	-	I prefer convenience food because it is free of hormones.
SAF2	-	I prefer convenience food because it is free of insecticides.
SAF3	-	I prefer convenience food because it is free of pesticides.
SAF4	-	I prefer convenience food because it doesn't contain any non-permissible additives.
SAF5	-	I prefer convenience food because it doesn't contain any non-permissible color.
SAF6	-	I prefer convenience food because it doesn't contain any artificial ingredients.
SAF7	-	I prefer convenience food because it has necessary safety certification.
Section 5	**-**	**Health (HEA)**
HEA 1	-	I prefer convenience food because it has low calories.
HEA2	-	I prefer convenience food because it has low fat content.
HEA3	-	I prefer convenience food because it has low salt content.
HEA4	-	I prefer convenience food because it has low sugar content.
HEA5	-	I prefer convenience food because it provides me with a balanced diet.
HEA6	-	I prefer convenience food because I have more energy after consuming.
Section 6	**-**	**Purchase intention (PI)**
PI1	-	I will continue to buy convenience food due to competitive price and promo tional offer.
PI2	-	I will continue to buy convenience food to save time.
PI3	-	I will continue to buy convenience food due to lack of cooking skills and motivation.
PI4	-	I will continue to buy convenience food to reduce environmental damage
PI5	-	I will continue to buy convenience food due to good quality, safety, and health attributes.
PI6	-	I will continue buy convenience food because it is readily available and easy to Prepare.
PI7	-	I will continue to buy convenience food as there are choices available for multi cuisines.

Section 7	**-**	**Consumption (CON)**
CON1	-	I consume convenience food due to convenience.
CON2	-	I consume convenience food due to minimum physical and mental effort to cook.
CON3	-	I consume convenience food due to good taste, smell, and appearance.
CON4	-	I consume convenience food due to attractive packaging.
CON5	-	I consume convenience food due to competitive price.
CON6	-	I consume convenience food due to good quality, high safety, and healthiness.
CON7	-	I consume convenience food due to my religious and ethical beliefs.
Section 8	**-**	**Satisfaction (SAT)**
SAT1	-	I am satisfied with time saving.
SAT2	-	I am satisfied with easy cooking.
SAT3	-	I am satisfied with easy storage.
SAT4	-	I am satisfied with the availability.
SAT5	-	I am satisfied with price.
SAT6	-	I am satisfied with taste.
SAT7	-	I am satisfied with the appearance.
SAT8	-	I am satisfied with the smell.
SAT9	-	I am satisfied with texture.
SAT10	-	I am satisfied with quality attributes.
SAT11	-	I am satisfied with safety attributes.
SAT12	-	I am satisfied with the health issues.

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foods

Article

Assessing Consumer Preferences for Suboptimal Food: Application of a Choice Experiment in Citrus Fruit Retail

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Abstract: Amid the trend of sustainable development, reducing food waste is a global concern and campaigns to reduce food waste have been launched. For example, the term "food sharing" has originated from Germany and promotes sharing food instead of wasting. "The Guerilla Kitchen", which originated from Netherlands, is an organization that also promotes avoiding wasting food. Consequently, more and more people are paying attention on this issue and we think it is necessary to understand people's acceptance of suboptimal food, as discarded suboptimal food represents a significant proportion of food waste. Additionally, at least one-third of the food globally produced each year is classified as suboptimal and cannot be sold in the market because of a poor appearance, damaged packaging, or near expiration date, thus presenting challenges for environmental, social, and economic sustainability. Previous studies on suboptimal food have focused more on appearances and packaging dates and less on investigating traceable agricultural and price discounts, which is where food classified as suboptimal entails a discount. Moreover, citrus product attributes such as appearance, size, freshness indicators, traceable agricultural products, and price discounts were determined in terms of consumer preference through pre-measurement here, then using a choice experiment method to clarify which attributes consumers care about most (N = 485 respondents). Conditional logistic regression and a random parameter logit model (RPL) are employed to examine the various properties of a marginal willingness to pay (WTP). RPL was also used to deduce the respondents' choices based on differences in appearance and freshness indicator. The results showed that consumers place greater emphasis on the freshness indicators (harvesting/packaging date labels) and appearance of suboptimal citrus fruits but do not focus on the size. Consumers are willing to purchase citrus fruit with a flawed appearance, although the price needs to be reduced from the original price. Although suboptimal food does not reduce health, people may still not buy it and this result in food wastage. As a result, it is essential to increase awareness regarding suboptimal foods and reduce food waste to support sustainable development.

Keywords: food choice motivations; food waste; willingness to pay; consumer behavior

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1. Introduction

According to United Nations statistics, nearly one-third of the total international output of food is wasted every year, and the annual cost of food waste disposal is as high as 940 billion US dollars [1]. Kretschmer et al. (2013) [2] highlighted that according to the data of the US Food and Agriculture Organization in 2013, about three-quarters of food is wasted at production sites, households, and restaurants, and household food waste has increased over time. About 15.9% of food waste in the USA comes from the consumer, and USA households produced 27 million tons of food waste in 2015 [3]. Additionally, on the basis of food waste, the Environmental Protection Administration of the Executive

Yuan (2018) [4] estimated that about 3.68 million tons of food materials are consumed in Taiwan every year, and an average of 158 kg is wasted per person, of which nearly 50% is discarded by individuals and families. These numbers were higher than those of other Asia-Pacific countries, thereby indicating that Taiwanese people waste too much food [4]. Stuart (2009) [5] and Bilska et al. (2016) [6] suggested that the proportion of waste at the supply chain is often higher than that at the consumer side and that the sources of food waste in the supply chain include mislabeling outer packaging, poor product appearances, being near the expiration date, and outer packaging damage. Lebersorger and Schneider (2014) [7] pointed out that a significant proportion of food is wasted at the retail stage that is disposed while in good condition, and said food is only discarded based on an expiration date that has been passed (e.g., in Austria, more than a quarter of discarded food and products are suboptimal products). Lombart and Louis (2014) [8] argued that selling suboptimal products can lead to a positive effect on the image of the store as a being responsible stakeholder, with the potential to influence consumer's retail preferences or loyalty. Plazzotta et al. (2017) [9] pointed out that fruit and vegetable waste is mainly generated before reaching consumers due to programmed overproduction and the unfulfillment of retailer quality standards. Therefore, retailers or companies may not purchase products that cannot reach their standards. Aschemann-Witzel et al. (2017) [10] stated that more than one million people in the world experience chronic hunger every year and some regions even face food crises, resulting in a serious global food imbalance. Aschemann-Witzel et al. (2015) [11] stated that food waste has an impact on environmental, social, and economic sustainability. Thus, food waste has been regarded as a moral issue due to global inequality in food access and growing food security issues [11–13], and it is indeed necessary to solve food waste challenges to achieve sustainable development in food supply chains [14].

The Homemaker's United Foundation (2016) [15] highlighted that suboptimal food, which is unmarketable because it does not meet traditional aesthetic standards, mainly includes vegetables, fruits, and meat. These items usually do not procure good sales due to their poor appearance and can only be used as feed, fertilizers, canned juices, donations for food banks, or even thrown away. Suboptimal food is divided into three categories on the basis of its characteristics, namely, appearance standards (e.g., weight, shape, and size are required to meet the ideal standards) [16], the marked expiration date (e.g., food approaching or exceeding its expiration date) [17], and the packaging (e.g., food packaging exhibiting visual damage, such as a dented can or a torn wrapper) [17]. Additionally, it is necessary to confirm that these categories/aspects do not pose any safety risks and that the food is still appropriate for human consumption [11,18,19].

Dion et al. (1972) [20] stated that when selecting foods, most consumers select foods with a perfect appearance and shape, undamaged packaging, and a long shelf life, thus resulting in suboptimal food that cannot be sold. Göbel et al. (2015) [18] suggested that the main reason for the waste of vegetables and fruits is the influence of retailers on product quality standards and specifications. White et al. (2016) [17] revealed that consumers may choose less suboptimal food because of factors such as an abnormal shape, damaged packaging, or marked date of expiration. Helmert et al. (2017) [21] also revealed that only a few consumers will choose suboptimal food when the quality or safety of suboptimal food is similar to that of optimal food. Symmank et al. (2018) [22], with the help of an example, stated that the appearance of bananas will affect German consumer purchase intentions and that they attach importance to the shelf life of bananas. Aschemann-Witzel et al. (2018) [23] highlighted that printing requests/instructions such as "no food waste" on food packaging can increase the possibility of Uruguayan consumers choosing suboptimal food. Halloran et al. (2014) [19] highlighted that food waste could be reduced through communication and improved food packaging and labeling.

Additionally, consumers will consider the price when choosing products. Helmert et al. (2017) [18] pointed out in their research that price badges can influence the attention of European consumers, cognitive processing, and purchase intentions regarding suboptimal food. Many retailers in Europe offer products close to the shelf life at lower prices to attract consumers [11]. According to Grewal et al. (1998) [24], retailer price discounts can affect consumer purchase intentions. Verghese et al. (2013) [25] also pointed out that the precondition for consumers to buy suboptimal food is a price discount. The study of de Hooge et al. (2017) [26] stated that consumers in Denmark, Germany, Norway, Sweden, and the Netherlands are willing to buy suboptimal food with price discounts. Aschemann-Witzel (2018) [27] pointed out that when the price of suboptimal food is reduced, consumers may have more incentives to buy them. De Pelsmacker et al. (2005) [28] believed that when discussing consumer purchase behaviors, they cannot be judged solely by their attitude and preference toward the product but must be analyzed in terms of their purchase intention or willingness to pay (WTP). The so-called WTP is the amount that consumers are willing to pay for a product that they think is most appropriate [29]. Tsiros and Heilman (2005) [30] revealed that consumer WTP for a product will decrease with the shortening of its shelf life. The research results of Nandi et al. (2016) [31] also pointed out that Indian consumers are willing to pay a higher WTP for fruits and vegetables grown in an eco-friendly way. Previous studies on consumer WTP for suboptimal food show that price discounts will attract purchase decisions [10,25,32]. Since there is presently no definite range for price discounts for suboptimal food in Taiwan, this study includes price discounts as an attribute variable to explore the prices that Taiwanese consumers are willing to pay for suboptimal food.

The contingent valuation method (CVM) is often used to evaluate consumer WTP for non-market goods. The CVM asks respondents about their WTP for a certain good in a hypothetical market through a questionnaire survey [33,34]; however, because the CVM has some limitations in terms of application, a strategic bias may be caused because of overestimation or underestimation. For example, respondents deliberately conceal their real preference for non-market goods for their own interests [35]. Therefore, the choice experiment method (CEM) has gradually become an important evaluation tool for measuring the value of non-market goods [36]. The CEM was first proposed by Louviere and Hensher (1982) [37] and Louviere and Woodworth (1983) [38]. Its theoretical framework is derived from random utility theory [39]. CEM has been widely used in non-market value evaluation in recent years. For example, Tait et al. (2016) [40] used a CEM approach to explore the WTP for mutton products with an environmental label certification for consumers in Britain, China, and India. Scarborough et al. (2015) [41] used a CEM to discuss British consumer preferences for products with traffic light labels in supermarkets. Ortega et al. (2015) [42] used a CEM to study Chinese retailer preferences for food quality and safety attributes. Grebitus et al. (2015) [43] used a CEM to explore the roles of human values and generalized trust on stated preferences when food was labeled with environmental footprints. Meyerding et al. (2019) [44] used a CEM to explore German consumer preferences for product attributes (e.g., place of origin and production method) and WTP for local fresh tomatoes and their processed products (e.g., ketchup). Thøgersen et al. (2019) [45] used a CEM to explore German, French, Danish, Chinese, and Thai customer preferences for product attributes (e.g., the country of origin, organic badge, and price) for organic foods produced in the corresponding countries.

In summary, previous studies on suboptimal food have mainly focused on the appearance, date, and packaging, as well as consumer preferences for different types of suboptimal food. Taiwan is known by many as the “kingdom of fruit.” According to the Yearly Report of Taiwan’s Agriculture 2018 Supply and Demand for Food by the Council of Agriculture of the Executive Yuan, citrus represents the largest fruit production category in Taiwan (524,087 metric tons). Therefore, citrus is used as the main product for investigation in this study. In addition, the appearance of citrus fruit is limited by fungal decay [46] and peel defects [47] during store retailing, affecting the willingness to pay. The contribution of this study lies in dividing the attributes of suboptimal food in terms of the appearance, size, freshness indicator, traceable agricultural products, and price discount and using a CEM to deduce the overall preferences of consumers and the consumer WTP for various product attributes for suboptimal food. This is achieved via conditional logit (CL) and random parameter logit model (RPL) analyses. It is expected that the research results can be used as a reference for retailers as well as other sales channels and enhance the public's awareness of suboptimal food. When consumers purchase citrus, the appearance, size, freshness indicator, and price discount are the primary factors which impact the purchase intention. On the other hand, a traceable agricultural seal is generally used for agricultural products in Taiwan, which is why this attribute is discussed in terms of suboptimal fruit here.

2. Materials and Methods

2.1. Survey Design

This study explores the product attributes of suboptimal citrus fruit, including the appearance (complete and defective), size (large, medium, and small), freshness indicator (labeled and unlabeled), traceable agricultural products (with and without certification), and price discount. The variety of the citrus fruit is *Citrus poonensis,* which is the most common in Taiwan. The details are shown in Table 1.

Table 1. Attributes and levels of suboptimal citrus fruit. NT: New Taiwan dollars.

Attribute	Description of Attribute	Level
Appearance	Compared with optimal citrus fruit, if fruit has spots and a rough or uneven surface then it has a defective appearance.	(1) Complete (2) Defective
Size	According to the standard for the grading and packing of fresh fruit, the size is measured by the circumference length (cm) of the fruit. Small sizes (<23 cm) are usually eliminated.	(1) Large: 25–27 cm (9 cm in diameter) (2) Medium: 23–25 cm (7.5 cm in diameter) (3) Small: 17–23 cm (6 cm in diameter)
Freshness indicator	When citrus fruits are harvested or leave the production area and packaging factory, it is required to mark the time, which can be used by consumers as the basis for measuring the freshness of the product.	(1) Labeled (2) Unlabeled
Traceable agricultural products	Besides avoiding the purchase of citrus fruits from unknown sources, certified citrus fruit has transparent information and a guarantee of origin, safety, and quality, which can be used as a reference for consumers to purchase the product.	(1) Yes (2) No
Price discount	According to a pre-test questionnaire, the discount range was set at $0–15, which was divided into four ranges, including the current situation.	(1) NT $40 (−0) (2) NT $35 (−5) (3) NT $30 (−10) (4) NT $25 (−15)

To develop an easy method for respondents to fill out questionnaires, this study adopted an orthogonal design which was submitted through Statistical Product and Service Solutions. Ninety-six (23 × 31 × 41) sets were selected, and after factoring out the redundancies, each choice set contained two random number substitutes and one status quo which included flawless appearance, medium size, no freshness indicator, uncertified traceability, and a discount price of 40 New Taiwan (NT) dollars. Each survey included three choice sets extracted from among them, with a total of 15 possible questionnaire versions.

In this study, we used judgmental sampling to survey questionnaire answers face-to-face by paper and pencil in supermarkets, mass merchandisers and traditional market. First, the study conducted a pre-test questionnaire, with the aim of understanding consumers' overall consumption preferences and WTP for suboptimal food. The questionnaires were issued from 1 March 2020 to 31 March 2020 to consumers who had purchased suboptimal food in the past six months. During the first stage, 150 questionnaires were issued, out of which 121 were valid, and the effective questionnaire recovery rate was 80.67%. The official survey was divided into three parts. Part one included the degree of importance that consumers place on the suboptimality of five cases of citrus fruit, asking consumers to rank the issue in importance from 1 to 5 according to their own personal beliefs. Part two presumes that the consumers are going to purchase citrus products with various attributes (i.e., overall superior fruit) and provides plans for citrus products based on their appearance, size, freshness indicator, and food traceability seal, then assigning a discount to be displayed to help consumers choose the one they like best based on their own personal preferences toward the attributes of suboptimal food (as shown in Figure 1).

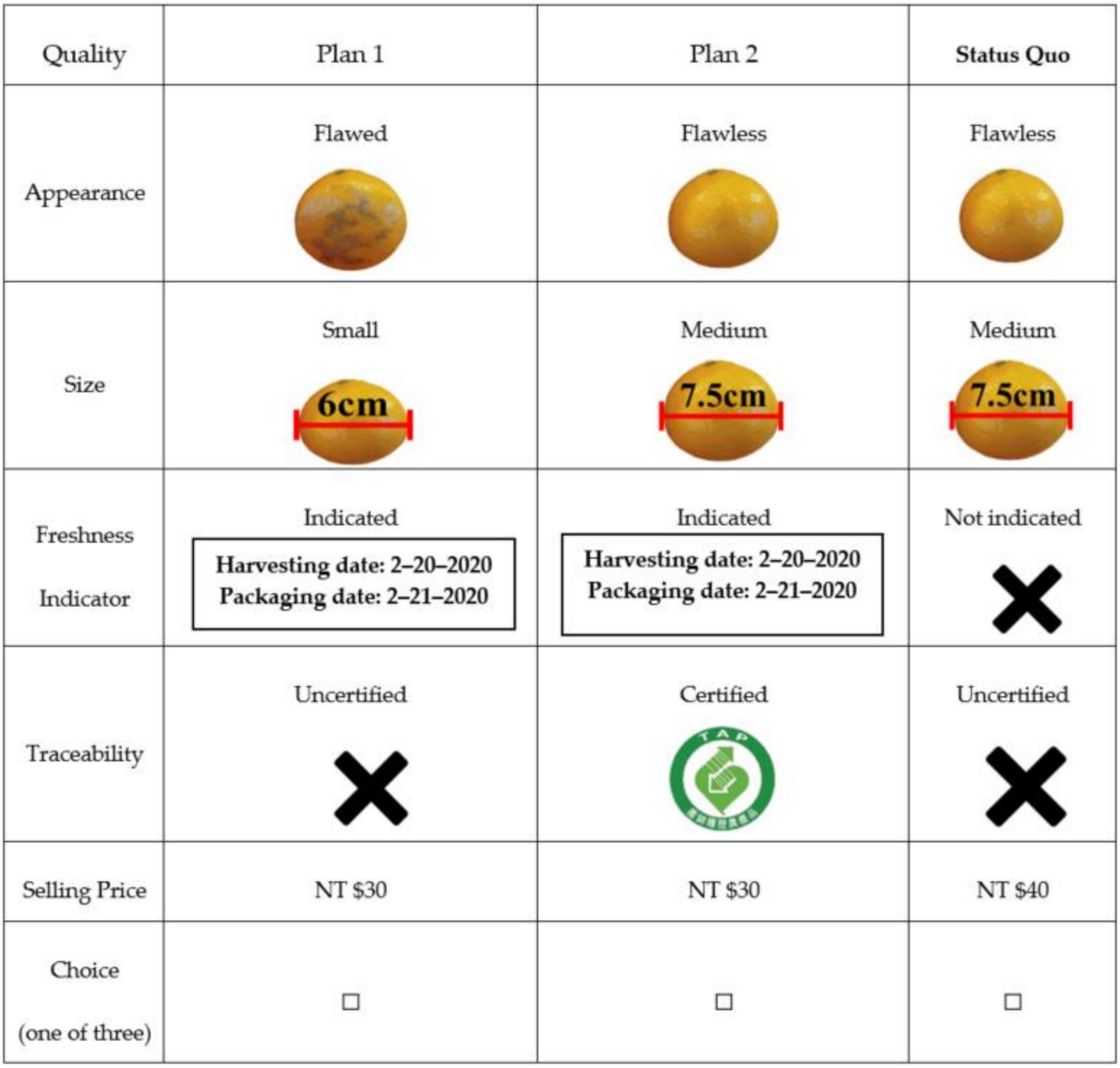

Figure 1. Example questionnaire choice set.

Part three is the demographic information of the survey respondents, which includes their gender, age, education, marital status, monthly income, and whether they would consider buying products with a traceability seal or scanning QR codes that can allow pertinent information about the product to be read.

2.2. Choice Experiment Method

A CEM approach is used to establish a hypothetical market to investigate consumer preferences for non-market goods. As the CEM has the ability to evaluate multiple attributes and levels, different alternatives are combined for the important characteristics related to non-market goods or services. Through the choice sets with different situational assumptions, respondents could select appropriate alternatives according to their preferences to avoid errors in the evaluation. In regard to the empirical model, the conditional logit (CL) regression model is used to estimate consumer average preferences for multiple attributes for fresh food, as well as their marginal willingness to pay (MWTP) for the attribute levels [48]. Secondly, the random parameter logit model (RPL) can be used to explore the preference heterogeneity and the WTP for different characteristic attributes for respondents with different socioeconomic backgrounds [49]. Bazzani et al. (2017) [50] used the CEM to explore Italian consumer preferences for various product attributes (e.g., product sources and production methods) and WTP for local and organic foods. Kallas et al. (2019) [51] discussed Spanish consumer purchase intentions and WTP for innovative patties containing black pork products enriched with porcini mushrooms as a natural source of dietary fiber or blueberries as a natural antioxidant source. Ceschi et al. (2017) [52] investigated Italian consumer preferences for product attributes for apples, for example, being organic, their color (bicolored, green, and red), origin, and import country, also evaluating their WTP.

First, this study adopted the CEM to construct a preference and utility model for suboptimal citrus fruit, then applying the CL and RPL to estimate the utility function for preferences, then finally exploring the MWTP attributes in terms of the demographic information of the respondents. In the binomial model below, "j" is the utility function that was arrived at for the hypothetical respondents "i" through a product substitution, as in Formula (1).

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

where U_{ij} represents the attribute of the *i*-th respondent facing the *j*-th option, V_{ij} represents the observable part of the utility function, and ε_{ij} represents the residual item, i.e., the unobservable random utility.

The hypothesis assumes V_{ij} to be the linear form of the substitute's observable attributes X_{ij}; thus, it is possible to take the consumer utility i contained in the k item attributes of substitute j and assume the price variable of that set of attributes to be P_j, therefore the consumer utility function i can be expressed as Formula (2):

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum_{k=1}^{k} \alpha_k X_{jk} + \beta P_j + \varepsilon_{ij} \tag{2}$$

where U_{ij} is the utility that consumer i derives from product j; X_{jk} is the *k*-th attribute of the product j, and P_j is the price of product j. In additional, α_k and β are the parameters to be estimated.

In order to explore the reasons behind respondent preferences for certain parameters for suboptimal citrus fruit, Formula (2) was expanded into Formula (3), which adds in the random utility function of the respondent demographic information:

$$U_{ij} = \sum_{k=1}^{k} \alpha_k X_{jk} + \sum_{k}^{K} \sum_{q}^{Q} \gamma_{kq} X_{jk} Z_{iq} \beta P_j + \varepsilon_{ij} \tag{3}$$

In the formula, U_{ij} is the utility that the *i*-th respondent derives from the product j and X_{jk} is the k-th attribute of the product j. Z_{iq} is the qth demographic information of the respondent i. α_k is the attribute variable coefficient. γ_{kq} is the overlap coefficient of the attribute variable and demographic information.

By separating the price variables in Formula (3), it can be seen clearly and the price that consumers are willing to pay may be more easily analyzed by Formula (4):

$$U_{ij} = V_{ij}\left(X_{ij}, S_i\right) + \varepsilon_{ij} \tag{4}$$

where V_{ij} is the utility coefficient of observable variable X_{ij} and respondent characteristic S_i, which represents the respondent's preference, and ε_{ij} is the residual item.

To measure the WTP for the product attributes, we took the total differential of Formula (2), treated the utility as a constant, and assumed that $dU_{ij} = 0$, which gave Formula (5):

$$dU_{ij} = \sum_{k=1}^{K} \alpha_k dX_{jk} + \beta dP_j = 0 \tag{5}$$

When other attribute variables remain constant ($dX_{j1} = dX_{j2} = \cdots = dX_{jk-1} = 0$), finding the consumer WTP for X_{jk} attribute(s) of product j can be carried out as per Formula (6):

$$dU_{ij} = \sum_{k=1}^{K} \alpha_k dX_{jk} + \beta dP_j = 0 \tag{6}$$

3. Results and Discussion

3.1. Sample Size and Composition

To understand the attributes of the respondent consumption preferences for suboptimal citrus fruit, this study utilized judgmental sampling to target consumers who have purchased suboptimal food. A total of 670 questionnaires were issued. After factoring out invalid questionnaires, a total of 485 valid questionnaires were obtained, representing a 72.4% questionnaire recovery rate. The screening rule for invalid questionnaires was when respondents did not ever purchase suboptimal food. In such cases, the questionnaires were classified as invalid questionnaires. The largest respondent proportion was males (51.1%). Age was primarily concentrated in the 41–50 age range (27.8%), followed by 51–60 years of age (25.8%), and 31–40 years of age (22.7%), showing that the middle-aged demographic is more likely to buy suboptimal food than other consumer groups. In terms of education level, the proportion with a tertiary education was the highest (48.5%). In terms of marital status, the majority of respondents were married (57.5%). The average monthly incomes of individuals were primarily in the NT$ 40,001–60,000 range (35.1%), followed by the NT$ 20,001–40,000 range (28.0%). More than half (57.7%) of consumers had purchased traceability-certified products, but most did not scan the QR code to read the pertinent information. The respondent purchasing locations for suboptimal food (detailed below) were mainly supermarkets (73.8%), followed by mass merchandisers (47.4%), which are companies that affordably sell large quantities of goods that appeal to a wide variety of consumers, and traditional markets (42.1%). The most purchased foods (detailed below) were vegetables (57.7%), followed by fruits (53.0%), and whole grains and tubers (51.1%).

3.2. Emphasis on Attributes

The results of the research show that the degree of emphasis placed on the various attributes was highest for freshness indicators (3.86 points), followed by appearance (3.22 points), traceability certification (2.66 points), price discounts (2.64 points), and size (2.62 points). The results of the weight comparison analysis show that consumers place greater emphasis on the freshness indicators and appearance of suboptimal citrus fruits but do not focus on the size, which is different from the results of the study by de Hooge et al. (2017) [26], which found that consumers in Germany, the Netherlands, and Norway place great emphasis on price discounts for suboptimal food. It is presumed that the aforementioned countries rely on imports due to climatic and environmental factors that affect the types and quantities of fruits and vegetables that may be locally grown, therefore emphasizing pricing changes.

3.3. Preferred Suboptimal Products by Consumers

This study analyzed the 11 most preferred attribute sets included in the suboptimal citrus fruits as selected by the respondents. The results show that the most preferred set of attributes includes a flawed appearance and moderate size with a freshness indicator, traceability certification, and a discounted price of NT$ 25 (accounting for 11.48% of respondents). The second most common set was the set with a flawless appearance, large size, freshness indicator, no traceability certification, and a discounted price of NT$ 25 (accounting for 10.65%). The least preferred attribute set by consumers was a flawed appearance with a discounted price of NT$ 25 (2.27%) and a flawed appearance with a discounted price of NT$ 35 (0.96%). It is presumed that a possible reason for this is that consumers themselves are not willing to buy citrus fruits with a flawed appearance while paying little attention to discounts and will only buy them in the hopes that, flawed appearance notwithstanding, there are other certifications that can guarantee the product.

3.4. Conditional Logit Analysis Results

Based on random utility function given by Formula (1), a utility model for suboptimal citrus fruits was established to understand consumer preferences for suboptimal citrus fruits, as in Formula (7):

$$U_{ij} = a1EDij + a2SZ1ij + a3SZ2ij + a4FRij + a5TAPij + \beta\ FUNDij + \varepsilon ij \quad (7)$$

In the formula, i = 1, 2, 3, . . . , 485, which is the total sampling of 485, and j = 1, 2, 3, . . . , 12, which represents the 12 choice sets for the suboptimal fruit attributes.

A coefficient for the attribute variable was estimated for Formula (7) through NLOGIC 4.0 Conditional Logit, and then the coefficient value was substituted into Formula (7) to find the discounted prices that were willing to be paid for each attribute. The empirical estimation results are summarized in Table 2.

Table 2. Conditional logit empirical estimation results. WTP: Willingness to pay.

Attribute Variable	Coefficient	Estimator	*t*-Value	WTP
Keep the status quo (ASC)		1.479	2.41 **	
Appearance (ED)	a1	−1.274	−11.74 ***	NT$18
Small size (SZ2)	a3	−0.244	−1.80 *	NT$36
Freshness indicator (FR)	a4	1.667	14.95 ***	NT$68
Traceability (TAP)	a5	1.376	12.60 ***	NT$63
Price discount (FUND)	β	−0.059	−5.77 ***	

***, **, and, * are significant at 1%, 5%, and 10%, respectively.

In terms of the levels for suboptimal citrus fruit attributes, appearance, freshness indicators, and traceability certifications were all at the 1% significance level, while only a small size (SZ2) was at a 10% significance level, meaning that willingness to consume is affected by whether the appearance is flawed, size is too small, and whether the product has freshness indicators and traceability certifications. Maintaining the status quo (ASC) was both positive and significant at a 5% significance level, indicating that consumers would prefer to maintain the status quo.

Second, a coefficient was estimated through the utility function from Formula (1) and was substituted into the theoretical model (Formula (6)) to calculate the WTP. The prices that were willing to be paid for the attributes were in the following order: appearance (NT$18), small size (NT$36), freshness indicator (NT$68), and traceability certification (NT$63). The results of the analysis revealed that, of the four suboptimal citrus attribute levels, the price discount for appearance is the highest, which means if sellers want consumers to buy suboptimal food, the price needs to be reduced from the original NT$40 to NT$18. Additionally, based on the results of the study, consumers are willing to pay more for citrus fruits with freshness indicators and traceability certifications, which indicates that consumers prefer these two product attributes. Furthermore, because consumers care about the freshness indicators the most, no matter how much the discounted price is, they will not purchase fruit without a freshness indicator. This is because there are no other guarantees such as freshness indicators or traceability certifications on the suboptimal products, and consumers may believe that these fruits could endanger their health. According to a study from de Hooge et al. (2018) [53], fruits, vegetables, and foods with dented packaging should not be regarded as inferior products. Although they are visibly different from the best products, visual flaws are considered a sign of authenticity. Tsalis (2020) [54] believes that retailers in most countries and regions only sell suboptimal food as a cheap product that does not legitimately generate purchase intentions. Wang et al. (2018) [55] pointed out that product certification labels can eliminate the uncertainty that consumers face when buying products. Thus, WTP for products with certification labels will increase accordingly.

3.5. Random Parameter Logit Analysis Results

Since the CL assumes that the parameters in the respondents are fixed, the average preferences of the respondents were evaluated, while the RPL is based on the attribute parameters of the respondents taking the form of a normal distribution, where the differences in preferences for the suboptimal citrus attributes can be evaluated. The results of using the CL and RPL to evaluate suboptimal citrus attributes were quite dissimilar. The RPL presented respondent preferences for appearance, larger or smaller sizes, freshness indicators, and traceability certifications, while the CL presented respondent preferences for appearance, small size, freshness indicators, and traceability certifications, except for large sizes. Additionally, the RPL also reflects the heterogeneous distribution of respondent preferences for various attribute parameters. As shown in Table 3, keeping the status quo was found at a significance level of 1%, and appearance and freshness indicators are both significant and indicate heterogeneity in respondent preferences between appearance and freshness indicators. This means that consumers cared more about appearance and freshness indicators for suboptimal products than other attributes.

Table 3. Conditional logit (CL) and random parameter logit model (RPL) empirical estimation results.

Attributes and Degrees	Conditional Logit (CL)		Random Parameter Logit (RPL)				
	Coefficient	*t*-Value	Coefficient	*t*-Value	Coefficient Standard Error	*t*-Value	WTP
Appearance (ED)	−1.274	−11.74 ***	−1.853	−9.82 ***	1.046	5.67 ***	NT$19
Large size (SZ1)	−0.053	−0.39	−0.352	−2.03 **	0.222	0.65	NT$36
Small size (SZ2)	−0.244	−1.80 *	−0.646	−3.49 ***	0.385	1.12	NT$33
Freshness indicator (FR)	1.667	14.95 ***	2.142	11.59 ***	1.218	5.86 ***	NT$64
Traceability (TAP)	1.376	12.60 ***	1.724	10.69 ***	0.520	1.63	NT$59
Price discount (FUND)	−0.059	−5.77 ***	−0.089	−6.59 ***			
Choice set count	1455		1455				
Log-likelihood ratio	−1006.131		−951.257				

***, **, and * are significant at 1%, 5%, and 10%, respectively.

The coefficient value estimated through the utility function (Formula (1)) was substituted into the theoretical model (Formula (6)) to calculate the respondent WTP. The prices for each attribute were in the following ascending order: appearance (NT$19), larger size (NT$36), smaller size (NT$33), freshness indicators (NT$64), and traceability certifications (NT$59). The analysis results show that, of the five attribute levels for suboptimal citrus fruit, a price discount for appearance ranks the highest, which means that consumers are willing to purchase citrus fruit with a flawed appearance, although the price needs to be reduced from the original price of NT$40 to NT$19. The freshness indicator and traceability certification results show that consumers are willing to pay more for citrus fruit with these two product attributes. Freshness indicators represent the highest price increase, changing from the original price of NT$40 to NT$64. Jaeger et al. (2018) [56] pointed out that the product appearance, aroma, expiration date, and overall sensory evaluation are the purchase intention determinants. Hingston and Noseworthy (2020) [57] pointed out that consumer aversion to agricultural products with an abnormal appearance depends on their personal experience with these foods. The factors which impact consumer purchase intentions for food are inferences about taste, texture, and safety. Van Boxstael et al. (2014) [58] pointed out that most consumers have different opinions on shelf life labels and expiration dates for different food types.

3.6. Exploration of Respondent Demographic Information in Suboptimal Food WTP Heterogeneity

The results of the RPL analysis show that there were random parameters for the appearance and freshness indicators. Therefore, this study compared WTP with the respondent demographic information based on the two aforementioned attributes. The results of this analysis are shown in Table 4.

Table 4. Heterogeneity of respondent demographic information in terms of WTP for suboptimal food.

Demographic Information		**Sample Size**		**ASC**		**ED**		**FR**	
				Average	***t*-Value**	**Average**	***t*-Value**	**Average**	***t*-Value**
Gender	Male	248	51%	−6.954	2.173	−21.418	−2.269	23.088	−3.193
	Female	237	49%	−7.762		−20.250		25.214	
Age	20 and below	8	2%	−8.219	2.362 ** (*F*-Value)	−19.807	2.111 (*F*-Value)	24.547	2.480 ** (*F*-Value)
	21–30	96	20%	−8.532		−19.590		26.330	
	31–40	110	23%	−7.355		−20.511		24.108	
	41–50	135	27%	−6.991		−21.043		23.267	
	51–60	125	26%	−6.809		−21.979		23.562	
	61 and over	11	2%	−6.866		−20.681		21.762	
Education	Junior high and below	4	1%	−8.973	1.948 (*F*-Value)	−18.690	1.535 (*F* Value)	24.494	3.196 ** (*F*-Value)
	High school	165	34%	−7.123		−21.375		22.778	
	Tertiary education	235	48%	−7.158		−20.864		24.567	
	Doctorate and above	81	17%	−8.283		−19.828		25.580	
Marital status	Married	279	58%	−6.957	2.455 **	−21.194	−1.561	23.860	−0.924
	Unmarried	206	42%	−7.879		−20.378		24.488	
Average monthly salary	NT$20,000 and below	74	15%	−8.245	2.598 ** (*F*-Value)	−19.587	2.657 ** (*F*-Value)	25.839	2.153 * (*F*-Value)
	NT$20,001–40,000	136	28%	−7.973		−20.149		24.384	
	NT$40,001–60,000	170	35%	−6.679		−21.689		23.751	
	NT$60,001–80,000	80	17%	−7.095		−21.141		23.549	
	NT$80,001 and above	25	5%	−7.429		−19.451		25.366	
Purchase TAP Certified products	Yes	280	58%	−7.291	0.361	−20.829	0.84	23.705	−1.470
	No	205	42%	−7.428		−20.872		24.704	
Scan QR code for information	Will	137	28%	−7.387	−0.127	−20.958	−0.268	23.368	−1.419
	Will not	348	72%	−7.334		−20.804		24.426	

**and * are significant at 5% and 10%, respectively; ASC: keep the status quo; ED: appearance; FR: freshness indicator. TAP: traceability.

There was a significant difference in terms of the average monthly income of individuals who were willing to pay for appearance. Of them, respondents with an average monthly income between NT$40,001 and NT$60,000 were willing to pay a lower price, indicating that those with an average monthly income of the middle class are less willing to buy products with a flawed appearance. Of these respondents, those aged between 21–30 years with a tertiary education or above and those whose monthly income was between NT$20,001 and NT$40,000 were willing to pay a higher price. This shows that young people and those with higher education and a monthly income from NT$20,001 to NT$40,000 more greatly emphasize product freshness and are therefore willing to pay more for products that display freshness indicators. This result is consistent with the study by Tsakiridou et al. (2011) [59] that identified the consumers who are willing to pay higher prices for fruits with food safety labels.

4. Conclusions

4.1. Concluding Remarks

The study results show that, of the suboptimal citrus fruit certification attributes, the most important is the freshness indicator, followed by appearance, traceability certifications, price discounts, and finally size. Based on the results found here, the suboptimal citrus attribute set most preferred by respondents was the following: appearance flaws, moderate size, freshness indicators, traceability certifications, and a discounted price of NT$25. The second-most preferred attribute set was the following: perfect appearance, larger size, freshness indicators, without traceability certifications, and a discounted price of NT$25. The least preferred certification plan was the one with only appearance flaws and a discounted price of NT$35, along with the one with only appearance flaws and a discounted price of NT$25. This was presumably due to consumers not being willing to buy suboptimal citrus fruits with a flawed appearance and paying less attention to price discounts, although, a flawed appearance notwithstanding, there are other certifications that can provide a quality guarantee for the products. Thus, retailers should upgrade their food preservation systems to keep products fresh. In terms of primary producers, they can used suboptimal foods in food processing such as the production of fruit jams, canned vegetables, candied fruits, etc.

4.2. Recommendations

4.2.1. Managerial Implications

This study has analyzed the importance of each fruit attribute based on respondent preferences and has found that consumers are not overly focused on size. The reason for this is presumed to be due to the fact that citrus products purchased by consumers in the market are classified through a screening mechanism before being circulated and sold in the market. The screened products are mainly medium-sized and above (25−30 cm), with smaller sizes being rejected and removed before reaching consumers. Therefore, it is recommended that relevant government agencies provide publicity and explanations for promoting suboptimal food being processed to change its form, such as making it into juice or canned food, thus greatly increasing its value. Governments should relax any regulations on the minimum sizes of fruits as consumers will still buy smaller fruits. Mass media promotion can promote consumers to buy and eat fruit, which can not only reduce losses for growers, but also reduce food waste. Besides emphasizing freshness indicators, appearance is another important attribute. The reason for this is presumably due to the inability of consumers to accurately determine the quality of fruit. Therefore, the appearance attribute is the second priority. If a product has a freshness indicator, this represents a guarantee for both the product and the consumer.

The results of the empirical analysis here show that consumers who prefer suboptimal citrus fruit with a freshness indicator and traceability certification are willing to pay more for the purchase. Therefore, it is recommended that the government not only stipulates that packaged foods need to show an expiration date, but also advocates for the popularization of freshness indicators for bulk foods or the addition of packaging. For example, using the Kanban software to indicate harvest dates and making the label certification process more transparent, i.e., label certifications and date indications can be displayed on product packaging. Meanwhile, more food-related knowledge should be spread to enhance public awareness. Under the assumption that a product is guaranteed, consumers can make discerning purchases that are not just for gifting or personal use based on their product recognition. Products with appearance flaws have the highest price discounts. Currently, there is no clear range of discounts in the Taiwanese market. Fresh ingredients in supermarkets and hypermarkets on site will be sold at discounts (20−40% off) based on their expiration dates. It is recommended to plan to establish a discount system based on the characteristics of the food category or the expiration date and provide references for retailers or other sales channels.

4.2.2. Research Limitations and Future Research Direction

There were a number of limitations in the research process here. If it is possible to expand the scope of future research, then the research framework may be perfected. This study makes the following recommendations in connection with the conclusions and limitations of this research. Only five attributes for suboptimal food (appearance, size, freshness indicator, traceability certificates, and price discounts) were set up for this study, but there are more suboptimal food-related attributes that can be added. For example, the reuse value of suboptimal citrus fruits, damaged packaging when there is packaging, etc., can be used to better understand consumer willingness in relation to price increases or discounts and preferences for different products and attributes; however, expiry dates might make foods more appealing to consumers, but they also represent a restriction for sellers, since they have to waste more unsold food, meaning that this problem has also not been solved here.

This study only explored the consumer dimension, and the results only reflect the current consumer preferences and WTP for suboptimal food. Follow-up research can be aimed at exploring the seller dimension and understanding the opinions of different respondents toward the various attributes of suboptimal food and comparing their differences.

Future research can use a latent class model to test whether there is heterogeneity in respondent preferences for suboptimal foods.

Additionally, this kind of research can apply to the subject of waste to meat and animal products, as these foods are generally the most resource-intensive foods to produce. Therefore, reducing the wastage of these foods represents significant benefits.

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European Consumers' Perceptions and Attitudes towards Non-Thermally Processed Fruit and Vegetable Products

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Abstract: In order to meet the demand for high-quality fruit and vegetable (F&V) products, a wide variety of novel non-thermal processing (NTP) technologies are under development. This study used a qualitative focus group approach to investigate consumers' perception and attitudes towards non-thermally processed F&V products among young (18–30 years old) and middle-aged (45–60 y.o.) consumers across six European countries: Denmark, Germany, Italy, Serbia, Spain, and the Netherlands. Findings show that the expected benefits and social concerns are important factors which affect consumers' attitudes toward non-thermally processed F&V. Extending shelf-life, being healthier and more nutritious, and better hygiene and safety were important benefits, whilst impacts on product quality, safety risks, higher price and environmental costs were the concerns most often mentioned by participants. However, due to a lack of knowledge and trustworthy information sources, consumers have difficulties in assessing relevant benefits and risks. Targeted communication that could explicitly and efficiently reveal benefits and risks is highly recommended to enhance consumer awareness and trust. This may especially be needed to reach middle-aged consumers who showed less confidence in NTP, compared to young consumers. Consumers from Spain, Denmark, and the Netherlands appeared more interested in consuming NTP F&V, compared to Italy, Serbia, and Germany. These findings are expected to provide recommendations to better communicate non-thermally processed F&V with consumers in the EU.

Keywords: non-thermal processing technologies; consumer perception; fruit and vegetables; food processing

1. Introduction

Fruit and vegetables (F&V) are critical elements of a healthy diet supplying essential nutrients to humans [1]. The increase in consumers' attention to the "healthy" food attributes (e.g., "freshness" and "naturalness") and the overall sustainability of processing technologies has contributed to a growing demand for non-thermally processed F&V [2].

Food processing technologies are improved on a continuous basis. Currently, a wide variety of non-thermal processing technologies (NTP) are under development [3,4]. During the processing of F&V, NTP use mild temperatures and minimal amounts of physical and chemical processing aids. Compared to conventional thermal technologies which use invasive temperature or treatments (e.g., thermal pasteurization), NTP are expected to better preserve the original quality of food products and by-products, such as maintain the nutritional value, freshness and some other sensory attributes of F&V products for a longer time, and reduce the use of added preservatives [5,6]. Moreover, the extension of shelf-life could potentially help with reducing food waste for both households and producers [7–9].

While scientists may applaud the progress of food technologies, consumers are known to have more conservative attitudes towards food processing [10]. Consumer choices are influenced not only by the intrinsic features of the product, but also by the production characteristics, including the way the products have been processed [10]. For some particular processing methods, some consumers have developed preferences or dislikes (e.g., irradiation) based on their vague understanding of these technologies [11–13].

A number of factors are known to influence consumers' perceptions of food technologies. For instance, consumers' perceived benefits and risks were found to affect consumers' attitudes towards new food technologies [6,14,15]. Consumers paid special attention to the effects of processing on food quality, safety, price, and naturalness [6,16]. Due to their lack of knowledge and familiarity with food technologies, consumers have been reported to rely on simple heuristics, such as the affect heuristic, natural-is-better heuristic, and trust heuristic, when evaluating them [3]. Moreover, individual-related factors, such as food technology neophobia level [14], sense of disgust evoked by the unfamiliar, and cultural values, further influence the acceptance of a technology [3]. These factors could lead to limited confidence and lack of acceptance in non-thermally processed products and difficulties in associating NTP with possible benefits or risks, especially when the benefits and risks were hard to be directly experienced by consumers [3,10,14].

Nevertheless, from a consumer policy standpoint, consumer-oriented communication is important to enhance social awareness and trust in products processed with novel technologies [16]. Interestingly, sufficient communication of the processing information has found to positively influence consumers' perception of novel processing methods, especially when expressed by independent scientists, consumer organizations, or food safety authorities [6,14,17,18].

In light of the growing interest in mild processing for shelf-life extension and food waste reduction, this study aims to better understand consumers' perception and attitudes towards non-thermally processed F&V, drawing on data from six European countries: Denmark, Germany, Italy, Serbia, Spain, and the Netherlands. Moreover, consumers' perceptions towards the potential effects of interactive NTP on household F&V waste reduction were also investigated. Findings from this study are expected to provide recommendations to better communicate non-thermally processed F&V with consumers in the EU.

2. Materials and Methods

2.1. Participants

In total, 12 focus groups were conducted in six European countries with 94 participants. In order to obtain a pan-European outlook of consumers' perception and attitudes, Denmark, Germany, Italy, Serbia, Spain, and the Netherlands were chosen for this research. In each country, two age groups were addressed: young-age (YA, 18–30 years old) and middle-aged (MA, 45–60 years old) population. These two groups were selected as target groups due to their known differences in purchasing power and attitudes towards novel food products and technologies [19,20]. Besides age and nationality, participants were screened by using the following criteria: (a) being responsible for grocery shopping; (b) not affiliated with the project; (c) not working professional with food and nutrition. Finally, each focus group had a balanced number of female and male participants. Table 1 shows the participants' basic demographic information on a country by country basis.

Table 1. Demographic information of the participants in the six participating countries.

Country	Participants (N)	Group *	Gender Split (M/F)
Denmark	17	10 YA 7 MA	5/5 4/3
Germany	16	8 YA 8 MA	4/4 5/3
Italy	14	8 YA 6 MA	3/5 2/4
Serbia	16	8 YA 8 MA	4/4 4/4
Spain	15	7 YA 8 MA	4/3 4/4
The Netherlands	16	8 YA 8 MA	4/4 4/4
Total	94	49 YA 45 MA	47/47

* Number of participants for YA focus group and MA focus group, YA = 18–30 years old, MA = 45–60 years old.

2.2. Procedures

All the focus groups (FGs) were conducted between November 2019 and February 2020. The same protocol was followed throughout the discussion to ensure consistency across all six countries (Table 2). FGs were conducted in the native languages of the participating countries. Each group discussion lasted about 90 to 120 min. Both video and audio recordings were collected for the subsequent data analysis.

Table 2. Interview protocol for the focus groups.

Discussion Themes	Subthemes
1. Participants' preferred quality attributes of F&V	Consumption of F&V products in general; Consumers' preferred quality attributes of F&V products;
2. Participants' perception of non-thermal processing technologies for F&V	Consumers' familiarity with/knowledge of NTP; Consumers' perceptions towards non-thermally processed F&V; Expected benefits and concerns regarding NTP; Expectations regarding the communication of processing information of non-thermally processed F&V;
3. Participants' use of processing and package information of F&V	Use of processing information and other product information of F&V during purchase and at home; Perceived importance of different information categories.
4. Participants' household storage and waste of F&V	Consumers' storage behavior of F&V at home in general; Reasons for discard of F&V at home; Consumers' behavior related to reduction of F&V waste; Ideas and expectation as to how companies could contribute to their reduction of F&V waste.

Before the FG discussion, participants received and signed an informed consent form describing the aim of the project and the use of the data, as well as a short questionnaire designed to collect their basic demographic information. The moderator started the group discussion with a brief introduction to the overall project and the procedure of the ensuing discussion. Then, the participants introduced themselves. Afterwards, the moderator followed the group interview protocol (Table 2) to discuss the themes one by one.

Participants' perceptions towards NTP (theme 2) were discussed in three stages. Firstly, the moderator asked participants if they knew any F&V processing technologies and whether they've heard about NTP before. Then the moderator introduced the NTP concept briefly as follows: *"NTP use mild temperatures and limited amounts of physical processing aids to increase shelf-life and keep the nutrients, freshness and sensory attributes of F&V products for longer time."* Afterwards, participants' perceptions and attitudes towards NTP were further collected.

In the second stage, more detailed explanations of some representative NTP were presented to consumers, supported by PowerPoint slides. The moderator summarized the NTP into categories of sanitization, preservation, stabilization, and extraction and gave examples for each category: ultrasounds, electrolyzed water, plasma-activated water, blue light, and UV light for sanitization; bioactive coating, active and intelligent packaging for preservation; ultrasounds and high-pressure processing for stabilization; ultrasounds, pulsed electric field, and membrane filtration for extraction of bioactive compounds in F&V. In-depth discussions about participants' perceptions towards NTP were followed, focusing on expected benefits and concerns regarding the NTP. The underlying reasons which caused the above concerns and expectations were explored at the end of stage 2.

The last stage focused on participants' willingness to purchase non-thermally processed F&V and their expected communication approaches of the processing information provided by different sources.

2.3. Data Analysis

Recordings of the FG discussion from the six countries were translated and transcribed into English text. NVivo 12 (QSR International, Warrington, UK) was used to code the transcriptions based on the standard content analysis procedures [21–24]. Various codes were compared and sorted into factors and categories based on similarities and differences, addressing the corresponding themes. Results are presented with a focus on the most recurrent stated factors and discussed both in general as well as based on the participants' demographic background. Representative quotes of participants from different countries are included to further support and illustrate the relevant claims and findings.

3. Results

In accordance with the focus group themes (Table 2) the results are sequentially presented in the following order: (1) participants' preferred quality attributes of F&V; (2) participants' knowledge and perceptions toward NTP; (3) participants' use of product information at the point of purchase; (4) household storage and potential effects of interactive NTP on the waste of F&V.

3.1. Preferred Features of Fruit and Vegetables at Point of Purchase

In Figure 1, the pie chart illustrates the frequency distribution of the factors that influenced the purchase of F&V products, based on the responses from all 94 participants collected at the discussion of theme 1.

The factors can be summarized into three major categories: (1) internal product features, such as sensory quality (31%), seasonality (13%), origin (12%), naturalness (10%) and nutritional value (8%); (2) external product features; and (3) personal habits and individual needs of consumers.

With regards to sensory quality, participants paid most attention to product appearance and taste. Accordingly, product appearance was mentioned as the first cue for freshness for participants. Moreover, participants reported that they sometimes tried to smell and touch the products to tell their freshness. Local products or products originating from areas with a good reputation and in the right season(s) were preferred. Participants generally thought local and seasonal products had a more natural taste and were more environmental-friendly. Many participants expressed a specific preference towards organic products and concerns over whether the products contain additives and preservatives. Compared to fresh produce, some participants tried to avoid purchasing F&V derived juices and smoothies due to the sugar and additive content in some industrial products, and instead preferred to make their own juices and smoothies. Some participants from Denmark mentioned a specific preference for products with the green-keyhole label [25], which is a Nordic certification for healthy foods.

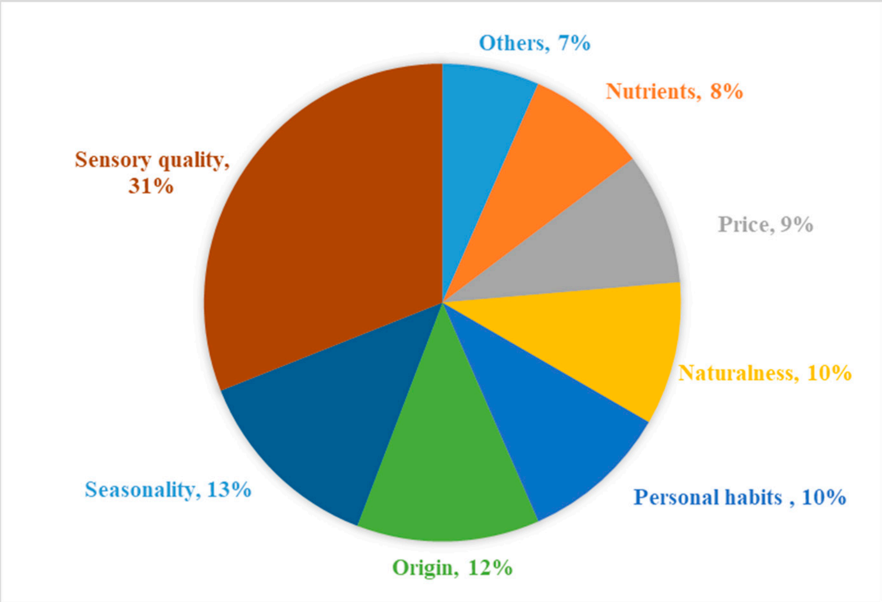

Figure 1. Frequency distribution of factors considered at point of purchase.

There were some interesting discussions about the correlation between high quality and a beautiful appearance. While some participants believed that a good appearance is an important indicator of freshness, others declared that they were less willing to buy products which look "too perfect", because they believed that too beautiful products were less natural and therefore may not taste good, as illustrated by the following quotes:

> *"The inconsistency of apple size is more appealing to me. When I went to Korea, every apple was exactly the same size and that is too perfect."* (23 years old, male, Danish)

> *"Things that are too beautiful always hide some imperfections."* (52 years old, female, Italian)

Price (9%) was the most frequently mentioned external product feature, followed by others including brand, package type (e.g., packaging materials), and the Fairtrade label (others, 7%). Participants from Denmark and Germany seemed more willing to purchase products with fair-trade certifications.

Because of differences in income and individual concerns, price was used differently as a quality cue by consumers. Some perceived products offered at particularly low prices to be of poor quality, whereas other participants preferred lower-priced products if there are no discernible differences in quality, compared to the more expensive ones, as the following quotes illustrate:

> *"The low-priced juices are full of preservatives."* (26 years old, male, Italian)

> *"A medium quality product must have an adequate price because no one gives you anything good for free. If there is a good relationship between price, quality, origin and authenticity, even if it is not branded, the product is acceptable for me."* (52 years old, female, Italian).

> *"I will take the cheaper one first, unless the other one has something recognizable at first glance, it has the organic label on it, or something like this. Otherwise I don't have the patience to compare."* (22 years old, female, German)

> *"As a student, I just prefer products that are cheaper."* (23 years old, male, Dutch)

Participants' personal habits (10%) played an important role in their F&V choices as well. Some participants preferred more convenient products, e.g., vegetables in cans, due to lack of time or interest in cooking, and paid less attention to nutrients damage or taste. Moreover, individual shopping frequency and plans determined choices of the package size and ripeness status of F&V, etc.:

> *"As for vegetables, we consume a lot of canned ones. It is more convenient than cooking the vegetables every day. You go down to the supermarket and buy several jars, and you can preserve them better."* (27 years old, male, Spanish)

3.2. Knowledge and Perceptions toward Non-Thermal Processing Technologies

The discussion of theme 2 was conducted in three stages (Section 2.2). The first two stages were focused on participants' knowledge and perceptions towards NTP.

3.2.1. Initial Knowledge and Perceptions towards NTP

At the first discussion stage, participants reported a lack of knowledge regarding the processing of F&V products in general. Most of them showed concern about what happens during cultivation, with frequent mention of pesticides. With respect to the post-harvest processing, participants thought that some F&V products were processed in order to extend the shelf-life and enhance the quality, but save for a few exceptions (e.g., a few participants mentioned that they have heard that some F&V are coated with wax or sprayed with preservatives) participants did not have much specific knowledge. With respect to the concept of non-thermal processing technologies (NTP), almost all participants had never heard of it, with both quotes and their facial expressions confirming a complete lack of knowledge.

3.2.2. Participants' Concerns and Expected Benefits of NTP

At the second stage, after being introduced by the moderators to some of the most representative NTP, a few of the participants declared that they were familiar with the concepts of some technologies, for instance, blue light and ultrasound, but not in the context of food processing.

Moreover, participants were found to have various perceptions towards different NTP types after the introduction of representative NTP technologies. Some participants found some of the NTP techniques were relatively easier to understand and more acceptable, for instance, light-based technologies and active packaging.

> *"Washing is the least bad … coating is the worst for me, you literally put it in your mouth so I wonder how good it could be."* (21 years old, female, Dutch)

Some participants felt hesitant, or even outright objected, to purchase non-thermally processed F&V. The pie chart in Figure 2 illustrates the frequency distribution of the concerns of non-thermally processed products, based on the responses from all 94 participants at the second discussion stage.

Participants' concerns regarding damages to the sensory quality of products were most frequently stated (23%). Accordingly, they stated that they would be more open to consuming non-thermally processed products if compared to conventional processing technologies, NTP did not cause loss of taste and aroma while maintaining the nutritious value and naturalness as close to the original (non-processed) products as possible:

> *"The taste is very important. I have lived in South America and the bananas there are tastier. While they have to come all the way from there to our supermarkets, you need this kind of technology."* (23 years old, male, Dutch)

> *"Everyone's producing them now not to have taste and smell, but to look pretty. I don't want to look at it, I want to eat it."* (46 years old, male, Serbian)

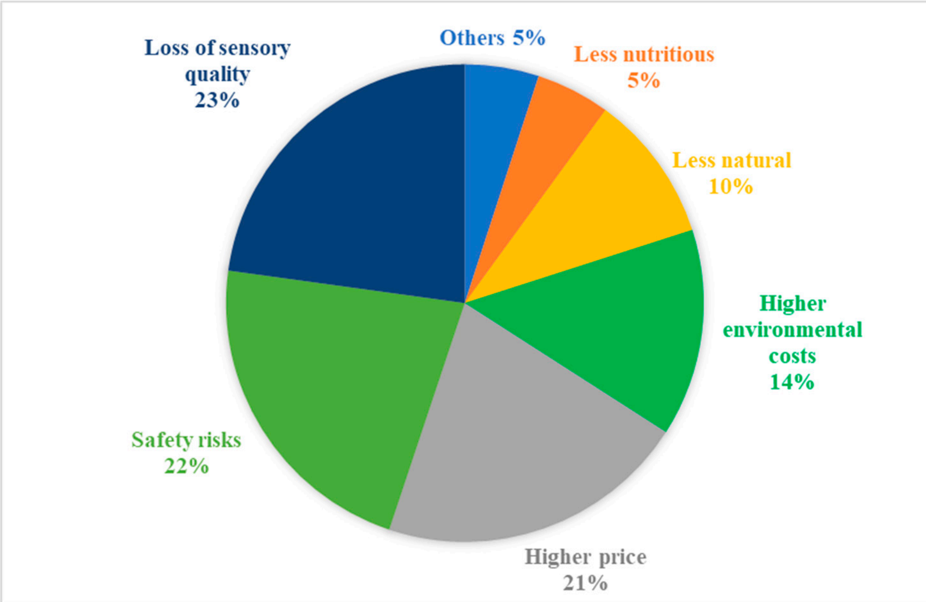

Figure 2. Frequency distribution of participants' concerns towards non-thermal processing technologies (NTP) and NTP processed fruits and vegetables (F&V).

Regarding safety and health-related concerns, even though some of the participants acknowledged that compared to conventional technologies, NTP could reduce the use of chemical additives and preservatives in the final products, they were worried that it may introduce other harmful compounds into the products:

"I think it's important to say that these procedures assure me that I won't get any kind of disease or any kind of bacteria by ingesting them." (27 years old, male, Spanish)

"How can that affect my health?" (26 years old, female, Serbian)

" . . . look not only at profit but also at the good of the consumer, if you do not think that the product is intended for use by consumers, it could be dangerous to health." (52 years old, male, Italian)

Moreover, some participants stated that if non-thermally processed F&V products were much more expensive than conventional processed or non-processed products, they would be less interested in them:

"If it cleans 99% of the bacteria instead of 90%, then I don't know if it's worth for me to pay 10 or 20 cents more." (23 years old, male, German)

Participants were concerned about energy costs and environmental impacts of NTP, for instance, whether the amount of water needed in the mild washing techniques would be higher than that of conventional washing. Interestingly, quite a few participants declared that they prefer to buy loose F&V than products with plastic packaging to reduce the environmental pollution that plastics can create, as exemplified by the following quotes:

"The recyclability of the packaging matters as well." (25 years old, female, Danish)

"Maybe (novel) water washing leads to the use of larger amount of water, but with the use of lights you can use less water and therefore improve the fight against waste from this point of view." (26 years old, male, Italian)

Moreover, a few participants associated extended shelf-life with loss of naturalness and nutrients and wondered whether too many chemical preservatives or too much treatment had been applied:

"It's not normal that something that should last for 2–3 weeks actually lasts 2 months." (46 years old, female, Serbian)

" ... with the aim of preserving its freshness to make it more durable over time, but compromising its nutritional characteristics and taste is not natural." (23 years old, female, Italian)

However, as illustrated in Figure 3, the extension of shelf-life in a "less invasive" way (25%) was one of the most important benefits expected by participants, compared to conventional processing. Moreover, they expressed positive expectations for the potential effect of NTP in the reduction of food waste due to the extended shelf-life, which could possibly enhance their interest in non-thermally processed products:

"When it comes to shelf-life, we may have less food wasted, I think it's an important item." (55 years old, male, Dutch)

"There are definitely benefits with the processing technologies. You do it for a reason. You do it to get rid of bacteria and germs to extend the shelf-life ... you throw out less food and be able to ship it further over longer distance." (25 years old, male, Danish)

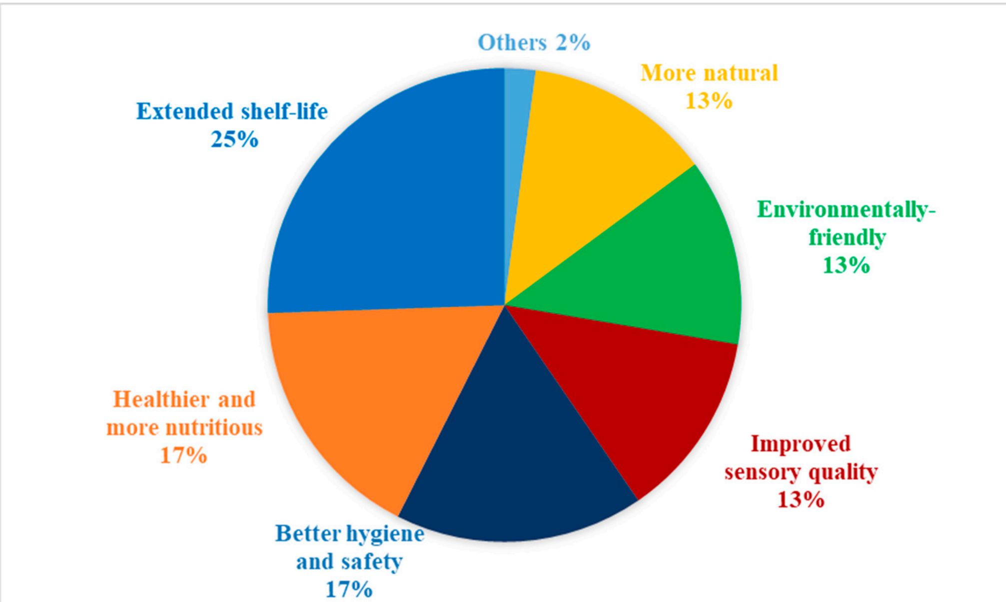

Figure 3. Frequency distribution of participants' expected benefits of NTP and NTP processed F&V.

Participants expected non-thermally processed F&Vs could be healthier and more nutritious (17%) than conventionally processed or non-processed products, due to the reduction of chemical preservatives and better maintenance of natural nutrients. Moreover, it was expected that non-thermally processed F&V could be more hygienic and therefore be safer to consume (17%), compared to non-processed F&V:

"Perhaps the preserving of nutrients." (25 years old, male, German)

"When I hear the word 'mild', I'm assuming it'll use much less chemicals ... and other additives." (58 years old, male, German)

"These technologies give me an idea of disinfected, clean food, probably without microbes." (56 years old, male, Italian)

Some participants expected that NTP could be better in the protection of products' sensory quality (13%) and be more environmental-friendly (13%), comparing with conventional processing. A few participants regarded NTP as less invasive and more natural technologies in general:

"If they are able to enhance its taste and texture and everything, then that is exciting." (52 years old, female, Danish)

"We even buy those products that are "heavily processed" already, as opposed, if it is processed by some mild version, I would probably prefer it." (30 years old, female, Serbian)

At the end of stage 2, after thorough discussions of the factors which influenced participants' perception of NTP and non-thermally processed F&V, the underlying reasons which caused the above concerns and expectations were explored. Some participants declared that their lack of knowledge and awareness due to the lack of complete and trustworthy information sources made them feel less confident in NTP and non-thermally processed products:

"I am confused about what I don't know." (26 years old, female, Danish)

"I don't feel I have the knowledge to choose. I don't know how to." (52 years old, female, Danish)

"Knowing about technologies, a person is more confident about what to buy." (22 years old, male, Italian)

3.2.3. Individual and Regional Differences

Participants could roughly be divided into four groups based on their various perceptions and interests towards NTP stated at the second stage of theme 2. The "accepting" group consisted of participants who were interested in NTP and willing to purchase non-thermally processed F&V with some prerequisites, such as that they caused no changes to the product property or added no chemicals into the products. They regarded NTP as a sign of scientific and technical progress that could improve F&V quality and reduce food waste in general:

"It is ok as it is more natural and has no addition of the chemicals and stuff, like the washing and lights." (25 years old, male, Danish)

"I just think the science is very cool." (25 years old, female, Danish)

The "neutral" group had limited interest in knowing NTP but were willing to purchase the treated products as long as the processing technology had been thoroughly tested and the quality of products was good and certified by trustworthy sources:

"I honestly don't mind processing. Just give me good, nice tasting apples, even if they've been really processed." (23 years old, male, Danish)

"It depends on how it really affects the product, if it is just to preserve it or if it can change some properties of the products, etc." (54, female, Spanish)

The "rejecting" group had neither interest nor trust in NTP and were not willing to purchase F&V treated by NTP or any kind of processing technology. They regarded NTP as a marketing ploy and preferred non-processed, natural products.

"The more a product is closer to the original status, without any processing, the better." (22 years old, male, Serbian)

Finally, there were some participants who belonged to the "mixed feeling" group since they raised both concerns and expected benefits towards NTP.

Additionally, regional differences within the EU, as well as differences between demographics, were identified (Tables 3 and 4). Overall, young participants appeared less worried and showed more interest in NTP processed F&V products, compared to middle-aged participants. "Healthier and more nutritious" was the most important benefit expected by middle-aged participants (23%, data not shown). They felt more worried about the loss in sensory quality (28%) and nutrients (9%), compared to the young participants (17% and 2%, respectively). By contrast, "extension of shelf-life" attracted young participants the most (32%), whilst they had higher concerns towards the increased price (25%) and safety risks (25%), compared to the middle-aged participants (17% and 20%, respectively). The middle-aged participants in four countries (Spain, Denmark, Netherlands, and Serbia) had more concerns towards the application of NTP, compared to the middle-aged participants in Italy and Germany.

Table 3. Relative frequency (%) of concerns and expected benefits stated by young (18–35) and middle-aged (45–60) participants in all countries.

Country	Young (18–35)		Middle Aged (45–60)	
	Concerns	Benefits	Concerns	Benefits
Denmark	44%	56%	57%	43%
Germany	92%	8%	75%	25%
Italy	94%	6%	56%	44%
Serbia	70%	30%	91%	9%
Spain	20%	80%	57%	43%
The Netherlands	56%	44%	60%	40%
Aggregated	63%	37%	66%	34%

Note: Reported figures represent the percentages of concern statements and benefit statements among all the concern and benefit statements claimed by young and middle-aged participants.

Table 4. Relative frequency (%) of concerns and expected benefits stated by female and male participants in all countries.

Country	Females		Males	
	Concerns	Benefits	Concerns	Benefits
Denmark	59%	41%	20%	80%
Germany	80%	20%	84%	16%
Italy	81%	19%	67%	33%
Serbia	68%	32%	100%	0%
Spain	0%	100%	47%	53%
The Netherlands	80%	20%	50%	50%
Aggregated	61%	39%	61%	39%

Note: Reported figures represent the percentages of concern statements and benefit statements among all the concern and benefit statements claimed by female and male participants.

Some gender differences were found in individual countries and specific benefits and concerns. Females from Spain and Serbia expressed fewer concerns towards NTP, whilst females from Denmark, the Netherlands, and Italy had more concerns, compared to males. Female participants were more interested in "better hygiene and safety" (22%) and "more natural" (17%), compared to male participants (13% and 8%, respectively). Male participants expected "extension of shelf-life" (33%) the most and showed more concerns to the price (24%) and loss in sensory aspects (24%), compared to female participants (17%, 19%, and 20%, respectively).

With respect to differences across countries (Figure 4), participants from Spain and Denmark expressed fewer concerns and more expected benefits towards NTP, and appeared more open to learning how it works, compared to Serbia and Germany:

"Suspicious. What is the actual process like? Will that affect my health and how?" (22 years old, male, Serbian)

"I think they are mostly focused on having it look pretty." (28 years old, female, Serbian)

"I just think the science is very cool. It was washed with this water technology and then we put it through some blue light. Then we have smart vegetables . . . wow, this is science!" (25 years old, female, Danish)

"I don't know if it [i.e., the processing method, A/N] is important knowledge for me and I think I would rather trust the government. Living in Denmark, if the producers are allowed to produce and sell it, I would trust that I can just buy it without any risk." (57 years old, male, Danish)

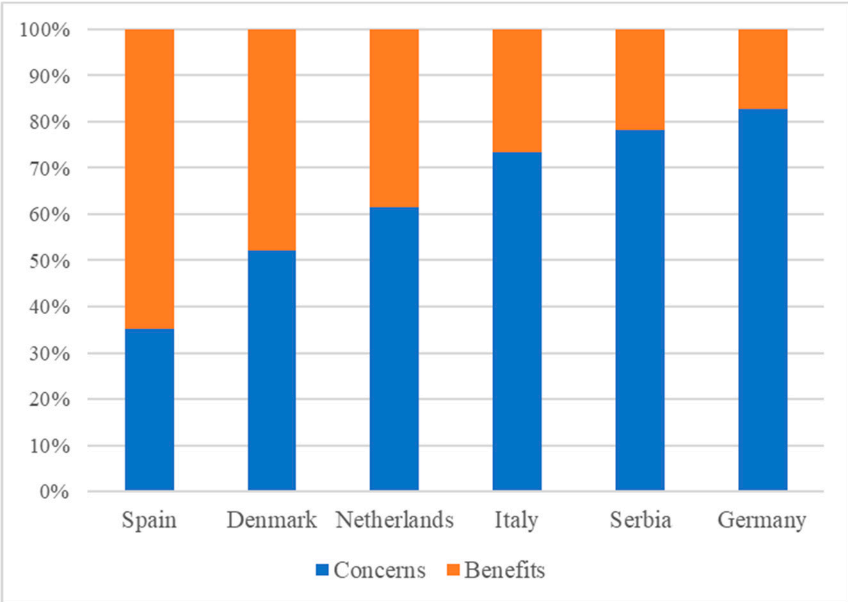

Figure 4. Percentages of concerns and expected benefits stated by participants in different countries.

3.2.4. Consumer Communication Aspects

At the third stage of theme 2, participants' expectations towards communication of the processing information were discussed. Most statements focused on the type of language, the sources of information, the focuses of information, the communication channels, and the need for labels showing endorsement or certification.

Some participants hoped to better understand NTP by themselves and expect that packaging and social media could explicitly reveal the information in an efficient way, using language that average consumers can easily understand. On the contrary, other participants would rather let the experts and researchers decide what is the good and safe processing method and trust the products with relevant certifications in the market. They expected that the information sources could be trustworthy, monitored by relevant authorities, confirmed by experts, and in compliance with rules and regulations. Furthermore, many participants consequently stated that if the effects of NTP on both the products and human health have been thoroughly studied and NTP have been widely used in the F&V industry, they would feel more confident in consuming non-thermally processed F&V in their daily life:

"I would be 90% sure if it has a certification." (26 years old, female, Italian)

"I would definitely not trust it if the benefits information was from the producer's side. They have an interest in selling more apples. So it would need to come from, for instance, an external source for it to be credible enough." (25 years old, male, Danish)

"I am not an expert. I can believe that mild processing is useful, but there must be a predisposed institute to confirm that it is a positive process." (26, male, Italian)

> *"If it is a widely used thing, then I would feel safer."* (52, female, Italian)

Some participants declared they lacked time or interest to go in-depth by themselves, thus, they expected that product labels could just include a certification logo or a few words to directly highlight the benefits and advantages of non-thermally processed products compared to conventional or non-processed products. Participants also suggested that a QR code could be put on the label so that consumers who want to learn more about the processing details could just scan and explore by themselves. Some participants mentioned that except for using labels, signs, and packages to convey the information, short videos shown on in-store displays could also be an optional channel to explain NTP to consumers. Furthermore, a few participants mentioned that supermarkets could have tasting corners for consumers to taste non-thermally processed F&V, with staff to introduce relevant information to consumers, which they believed could help consumers both understand NTP and be less skeptical if the taste is good:

> *"If put the information on a package or a product, I would not read it ... maybe put it somewhere else, a website or a QR code. If someone really wants to know and wants to go deeper, they can have that information."* (27 years old, male, Spanish)

> *"I wouldn't give it too much thought on how it was processed."* (57 years old, male, Danish)

3.3. Use of Packaging Information at Point of Purchase

In general, for fresh fruit and vegetable produces, participants paid attention to the information of product origin, date of packaging, recyclability of the package, and the presence of relevant certifications, e.g., organic labeling. Regarding F&V-derived juices and smoothies, participants gave priority to the ingredients of the products, especially the presence of additives and the sugar content, followed by the nutrient table, dates of packaging and expiration, storage instructions, recyclability of the package, and the presence of certifications. Participants who were allergic to some food compounds usually checked the allergens information.

In addition to the conventional information on the package, some participants mentioned that they would like to have information sources on the entire product value chain, from its production until it reached consumers' hands. Some participants showed interest in knowing a detailed description of the origin of the product, and the duration from its production until it was put on the shelf. Moreover, participants who were especially interested in sustainability issues would like to know the carbon footprint of the product during the planting and processing, compared to the average carbon footprint of similar products. Most participants expected easy access to such kind of information through scanning QR codes, e.g.:

> *"I looked at the organic jam and one of them had a small QR code on it, which you can scan easily. You'll see a map there. My jam came from the farmer Müller and therefore it costs 2–3 euros more. And I was so interested and decided to buy it immediately ... I have my mobile phone in my hand anyway ... I'm more involved and I found the website was very clear and well presented, much easier than looking on the long labels on the back of the package."* (22 years old, female, German)

3.4. Household Storage and Waste Reduction

Generally, participants did not have any formal knowledge regarding storage; rather, most stated that they followed the storage ways of their parents or simply replicate the same storage conditions as the supermarkets or grocery shops from where they bought the products. For fresh products, only a few participants declared that they used to check the storage instruction from the label or searched online to confirm whether they chose the best storage methods. Accordingly, the participants' behavior in terms of F&V storing was not always compliant with recommendations: for instance, some participants stored potatoes and onions inside the fridge.

Participants declared that only a limited quantity of F&V was thrown away, in general. Participants discarded different kinds of F&V, mainly due to the sensory decays of the F&V. Sometimes, they made mistakes in shopping plans and bought more amount than needed, or just forgot what they have at home beforehand. Some participants, most notably YA who lived alone, complained about the package size of some F&V being too big for their consumption needs, but they had no choices of smaller packages or loose ones.

Many participants reported increased awareness of the societal costs of F&V waste and had made some active efforts to reduce it, for example by making better shopping plans. Some used the extra amount to bake cakes, make jams and soups, or simply freeze some kinds of F&V to make smoothies or for other use in the future. Some participants mentioned that they used some apps or websites to make recipes for their leftover F&V at home.

> *"I think the perception or the knowledge and consciousness about food waste has increased. If I see myself ten years ago or just five years ago, I threw out foods without thinking … But now with this focus on food waste, I feel much more guilty when I throw out foods."* (55 years old, female, Danish)

Participants had suggestions for the industry as well. Better possibilities for purchasing loose products and/or smaller packages were expected. Supermarkets could lower the price of less fresh F&V. Producers could also suggest some recipes for their F&V in different ripeness status, by printing in their package or hiding in some QR codes.

Interactive packaging with freshness indicator attracted interest from some participants, especially for the packaging of products whose ripeness is hard to tell by touching and/or looking. They saw the advantages from the convenience, food sanitation, and waste reduction point of view, e.g.,

> *"Melon, pineapple, avocado … in products that are more complicated to know if they are ripe or not at first sight. If you have to touch them, I think it's better to put the indicator."* (27 years old, male, Spanish)

4. Discussion

To meet consumers' demand for safe F&V products of high quality, a wide variety of non-thermal processing technologies are under development [3,4]. In this study, focus groups were used to explore factors that influenced consumers' perceptions of non-thermally processed F&V products, comparing across six European countries: Denmark, Italy, Germany, Serbia, Spain, and the Netherlands. Moreover, in order to develop guidelines for the successful introduction and consumer communication of non-thermally processed F&V products, additional topics were discussed, including consumers' use of and expected food processing technology information and other packaging information at the point of purchase and during household storage. Our findings showed that from the consumers' point of view, even objectively less hazardous processes like non-thermal, mild processing could engender concerns which, if unattended, may override the benefits that the technologies could bring.

Lack of knowledge among the participants was one of the major impediments to their acceptance. Participants were found to largely rely on affect heuristic and trust heuristic when building their perceptions towards NTP [3]. When asked to evaluate the risks or benefits of NTP, participants associated with unknown food processing technologies with various food hazards, which evoked feelings of dread and influenced their benefit perceptions or risk judgments. The difficulties in assessing relevant benefits and risks could further impede the establishment of social trust and pose a barrier to the market introduction of non-thermally processed F&V [26]. One way that participants coped with their lack of knowledge is to rely on their trust in familiar brands or certified labels to reduce the complexity of making choices [18]. Regarding the individual-factors, disgust sensitivity and food culture and safety values were found to further influence the acceptance of NTP and explained the individual differences among participants [3]. Furthermore, consumers are grocery shopping with an ever-expanding perspective on overall health and well-being [19,25]. In addition to health, consumers' desires for taste, food safety, affordability, convenience, and clear labeling and transparency were identified [6,14,17], which explained the major expected benefits and concerns stated in our focus groups. The increasing environmental awareness and sustainable thinking among consumers help them associate NTP with environmental cost [10,27], which was found to be one of the important factors that influenced consumers' perceptions towards non-thermally processed F&V.

Consumer-oriented sufficient communication and early involvement of target consumers could contribute to a higher level of social trust in NTP and the likelihood of market success [4].

4.1. Recommendations on Development of Successful Consumer Communication

To counteract the effect of concerns about NTP on consumers' food choice, consumer communication and education from technology development till product launch are highly recommended [16].

Our results revealed many factors that may affect the success of consumer communication with regard to NTP and influences caused by NTP, including trust in the information source, content and focus of the information, message development in terms of language and style, and communication channels.

- *Information source*

If consumers do not trust the information source, the benefits may not be convincing. Consumers expect that information sources should be trustworthy, monitored by relevant authorities, confirmed by experts from third parties, and in compliance with rules and regulations. This finding fits with research by Siegrist [14], who reported that when benefits are endorsed by independent organizations or scientists, the communication is more likely to positively influence consumers' interests in consuming food products processed by novel technologies.

- *Information content*

Participants showed that they were hesitant to accept novel NTP mainly because they were not aware of any potential safety or health risks and clear benefits, due to lack of information. They expected that the public could be informed about the proven safety and benefits of NTP in a sufficient way, based on which they could be more likely to accept a novel food technology. This finding is in line with previous research reporting that tangible benefits based on consumer needs and expectations could reduce misunderstanding and positively affect consumers' perceptions and purchase willingness [4,28].

For the development of communication messages, it is recommended to focus on the most important perceived benefits of NTP included enhanced quality and safety, extension of shelf-life, lower environmental impacts, and maintenance of naturalness and nutrients. These findings are also in line with previous studies [10,27,29–31] and could be emphasized in consumer communication and marketing campaigns as appropriate. It should be noted that compared to benefits for consumers, industry benefits may not have a significant effect on consumers' purchase intention [14].

The extension of shelf-life is one of the major goals as well as benefits of NTP, which could potentially contribute to the reduction of F&V waste. Even though this benefit was expected by most participants in this study, some participants associated longer shelf-life with the addition of preservatives and loss of taste and naturalness. This finding should be of concern to marketers regarding the communication of benefits related to shelf-life.

- *Language style*

Companies should not assume that consumers may view specific technical terms the same way as they do [26]. In the past, consumers were regarded as passive receivers of product information. Yet, consumers were often found to misunderstand or misinterpret the information [4,14,27].

With regards to communication of non-thermally processed products, it should be of concern to marketers of non-thermally processed F&V that the phrase "non-thermal processing technologies" and "minimal processing" may have negative utility for some consumers. Indeed, NTP may only be regarded as a benefit by food technologists and nutritionists who are aware of the negative effects of thermal processing on food sensory quality and nutritional value [16,26]. By contrast, our findings indicate that for some consumers, NTP may be received as a marketing trick to increase the product price. Moreover, some consumers rejected F&V processed by any method because they saw them as less natural and would rather purchase F&V without any preservation technology. Thus, more studies need to be devoted to exploring the meaning of technically oriented terms before applying these terms in consumer communication.

- *Communication channels*

A variety of communication channels, such as product packages, in-store displays, leaflets, manufacturers' websites or other forms of social media, were mentioned by participants of the study and could be adopted by marketers. Participants suggested that a barcode could be put on the label so that consumers who want to learn more about the processing details could just scan and explore by themselves. Short videos (e.g., 1 min length) could be displayed in-store to explain NTP to consumers. In addition, participants showed specific interest in product tasting, which is shown to reduce the hesitance of consumers to trial purchase products processed by new technologies [26,28].

- *Communication targeted at different consumers*

Specific communication messages are recommended to reach targeted consumers of different socio-demographic backgrounds. The study suggests that different age groups may have different perceptions towards non-thermally processed F&V. Specifically, the middle-aged groups had relatively more concerns about the application of NTP, compared with the young participants. Although this cannot be inferred conclusively from a qualitative study, this finding is consistent with previous studies [19,20] which revealed that younger generations are relatively less neophobic with regard to novel technologies and food products.

Moreover, cross-cultural variation was observed in participants' views across the six European countries. It seemed that participants from Spain, Denmark, and the Netherlands were more interested in NTP and more open to learning how it works, compared to Italy, Serbia, and Germany. This might partly depend on the food culture and the status of food safety in different countries [3,32–34]. The importance of various basic values such as food safety and naturalness may differ across cultures and influence consumers' attitudes and behaviours in different ways [3]. Moreover, consumers' confidence in their national food safety control systems varied from country to country [32,34], which might lead to the differences of confidence towards F&V processed by novel technologies. Again, however, the results are based on a qualitative study so further research, such as a large-scale consumer study, is advised to further confirm the existence of these cross-cultural differences.

4.2. Usage of Product Information

Besides information on NTP specifically, information associated with product quality and environmental impacts caught the most attention, including product origin, date of packaging and expiration, presence of certifications, ingredients and nutrients table (for F&V derived products), storage instructions, and recyclability of the package.

In addition to the conventional traceability information (e.g., origin, date of packaging), participants who were especially interested in sustainable development wished to know more environmental information (e.g., based on life cycle assessment) of F&V products. The literature suggests that the perceived environmental friendliness, inferable from traceability information, enhanced the perceived quality of food products [35], and our findings confirm that. Consumers prefer the simple and direct presentation of traceability information, which they can easily find and understand [36]. For instance, participants in our study preferred carbon labels that allow comparisons of carbon footprints across products, and QR codes that could present the key points of a product's life cycle, which are consistent with findings reported by Hartikainen [37] and Tarjan [38], respectively.

However, it should be noted that sustainability labeling, at present, may still not play a significant role in the majority of consumers' food choices. Moreover, due to social desirability bias, the extent to which consumers' general concern about food sustainability can be turned into actual behavior is unknown [39,40]. Further studies could focus on the effects of sustainability labels on consumer perceptions and ways to promote environmentally sustainable food purchases, which could contribute to food waste reduction eventually [39].

Providing information on storage and cooking instructions was found to be potentially beneficial to F&V waste reduction through influencing consumers' household behaviors. Our results showed that participants' knowledge of F&V storage was not always optimal. Storage as well as cooking instructions, e.g., usage of F&V in different ripeness levels, could be inspiring to consumers.

4.3. Household F&V Waste Reduction and Interactive NTP

Consumers' role within the issue of food waste is especially crucial, as recently emphasized by the new "Farm to Fork" strategy of the EU Commission [41]. Food surplus and wastage at the purchase and household stages are observed in Europe [24,42], accounting for approximately 35% of all food wasted [43]. In our study, most participants reported that due to their increased awareness of food waste and its costs on society, they have been making different efforts to reduce F&V waste and achieved a decrease in household F&V waste. Consumers expected more support from the industry and retailers to further reduce household waste. For instance, a better choice for loose F&V, and package sizes appropriate for their consumption needs [44].

It could be interesting to further explore the effects of interactive NTP (e.g., intelligent packaging with freshness-indicator) on household F&V waste reduction. Participants saw the benefits of freshness-indicator with respect to convenience, food safety, and waste reduction aspects, especially for products for which it is difficult to tell ripeness from appearance. However, it was reported that freshness indicators and other similar intelligent devices might push consumers to purchase only newly displayed foodstuffs and increase the number of unsold items [45,46]. The effects of intelligent packaging on consumers' actual behavior could be further explored in future studies.

5. Conclusions

This study explored factors that influenced consumers' perceptions and purchase willingness of non-thermally processed F&V products, in six European countries: Denmark, Italy, Serbia, Spain, Germany, and the Netherlands. Lack of basic knowledge and trust among consumers was identified as the major potential impediment to their acceptance of non-thermally processed F&V products. Consumers have difficulties in assessing relevant benefits and risks, which engenders concerns and impedes the establishment of social trust. These findings suggest that an increase in public interest in novel NTP and non-thermally processed F&V products may be a long-term process. Consumer-oriented communication and education are necessary to enhance social awareness and trust. Information that incorporates benefits for the consumers could affect consumers' purchase willingness positively, especially when the information is concise and from trusted sources and the benefits are directly related to product quality and safety. Furthermore, consumers had a higher willingness in consuming F&V processed by more environmentally-friendly technologies which could save energy and provide benefits in terms of F&V waste reduction.

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Sustainable Paper-Based Packaging: A Consumer's Perspective

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Abstract: Over the last two decades, there has been growing interest from all stakeholders (government, manufacturers, and consumers) to make packaging more sustainable. Paper is considered one of the most environmentally friendly materials available. A qualitative study investigating consumers' expectations and opinions of sustainable paper-based packaging materials was conducted where 60 participants took part in focus group sessions organized in two stages. In the first stage, participants expressed their opinions about currently available packages in the market and their expectations about a sustainable packaging material. In the second stage of the study, they evaluated five paper-based prototype packages for two product categories (biscuits and meat). Too much plastic and over-packaging were the key issues raised for current packages. Price and quality were the main driving forces for consumers' purchase intent. While participants were impressed by the sustainable nature of the prototypes, the design did not necessarily meet their expectations, and they were not willing to pay more for a sustainable package. The key message that emerged from the discussions was the "3Rs"—Reduce, Reuse, and Recycle"—which should be the main points to consider when designing a sustainable packaging.

Keywords: paper-based packaging; consumers; focus groups; sustainability; environmentally friendly

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1. Introduction

The role of packaging in the safe delivery and transportation of products across the food chain cannot be overemphasized. To prevent food waste and loss, a good food package should ensure that food quality and safety is maintained from transportation through to storage of the product [1]. However, a major disadvantage of packaging is that it adds to the world's environmental footprint because it is always discarded immediately after the product is used [2]. The main types of materials used for food packaging include paper (including cardboard), wood, glass, metal, and various types of plastics.

Over the last two decades, there has been growing interests from governments, manufacturers, and consumers to make packaging more sustainable. Recent research in packaging focused on sustainability and how to make packaging materials more eco-friendly [3,4]. Technically, sustainable packaging has been defined as a packaging with a relatively low environmental impact based on life-cycle assessments (LCA) [5]. However to the average consumer, a sustainable package can be considered "a packaging design that evokes explicitly or implicitly the eco-friendliness of the packaging" [6].

Paper as a packaging material is experiencing a revival, as consumers perceive it as a high-value and environmentally friendly material [7–9]. Paper has the advantage of being bio-based, biodegradable, and recyclable. Studies from the Institute for Energy and Environmental Research (Germany) showed a significantly lower impact of paper-based packaging on the environment compared to many other materials. Globally, paper-based packaging has the potential to tackle marine debris and lead to a lower impact of packaging in the environment. This is especially necessary as the amount of packaging used is steadily increasing due to small portion packaging, urbanization, and a growing worldwide population.

In food packaging, there are various opportunities for more paper and a reduced polymer content; however, the technology has to be adapted to the production process, and the material composition has to fit to the product requirements. The possibilities of paper packaging are progressing, and solutions for barrier properties and formability are being addressed.

While life-cycle assessments (LCAs) show the sustainability value of packaging, it is important to understand consumer opinion and perception of these packages if marketing is to be successful. This is because consumer opinions and beliefs of a package which influence choice and purchase are not determined by LCA results [7,10]. The success of environmentally friendly packages is largely dependent on consumers as they are the ones who determine whether or not to buy the packages [11]. To increase consumer acceptability and purchase of sustainable packages, a detailed understanding of their opinions and perceptions of environmentally friendly packaging is needed [2].

A recent review by Ketelsen et al. [11] found only 21 out of 46 studies reviewed were focused on consumer responses to environmentally friendly packaging, showing that this area of research is not very well explored and demonstrating the need for more research in this area.

While some studies previously focused on the effect on perceived product quality of sustainable packaging [12,13], others focused on the influence of the design and labelling elements on consumer perceptions on environmentally friendly packaging [6,13]. Ertz et al. [13], in their study investigating the influence of environmental information on the reaction of 321 Canadian consumers, found that consumer perception of product quality was enhanced when environmental claims and labelling cues were well defined on the product packaging. However, when an environmental label was not accompanied by detailed self-declared environmental claims, the perception of product quality was not significantly enhanced.

Consumer awareness of the environmental impact of food packaging has been studied [9,14,15]. Participants who took part in focus group discussions and a survey in Italy considering labelling information on packaging stated that there was currently no information about environmentally friendly characteristics on packages and showed a high interest in having information about the sustainable characteristics of the packaging [15]. In their study on consumer responses to packaging design, Steenis et al. [9] reported that having sustainability cues on packaging was a key factor in determining how packages differed as evaluated by university students in the Netherlands.

A study conducted by Scott and Vigar-Ellis [16] on consumer understanding, perceptions, and behaviors in relation to environmentally friendly packaging in South Africa found that consumers had limited knowledge of what environmentally friendly packaging is, how to differentiate it from other packaging, as well as what benefits different packaging had. South African consumers stated that labels, images, and logos were the most important features used in helping them identify the environmentally friendly packaging. The packaging material and its color were other features used to judge packaging sustainability.

Consumer preference and willingness to buy or purchase products with environmentally friendly packaging was previously relatively well studied with conflicting results [17–22]. In a study conducted by Rokka and Uusitalo [17], where they compared green packaging with several product attributes and how these attributes affect consumer environmental choice, they found that one-third of the consumers participating in the study agreed that one of the most important criteria in their choice was the environmentally labelled packaging. Jerzyk [22] explored the attributes of sustainable packaging that have a positive impact on consumer behaviour and how purchasing intentions can be influenced when the packaging is sustainable among Polish and French students. They reported that sustainable packaging is not the most important factor when buying a product and that students are not willing to lose any of the functional and quality characteristics of the products because of the sustainable nature of the packaging. Concern for the environment and beliefs was shown to have an impact on purchase intent of eco-friendly packaging. Previous studies showed that consumers that are generally concerned about the environment are more likely to buy sustainable packaging [23–26].

In most cases, studies focused on environmentally friendly packaging in general rather than on specific packaging solutions [6,7,16,22,26–28]. Very few studies, however, focused on specific packaging for specific products such as paper packaging for cereal bars [13], glass packaging for foods [21] and for milk [29], and various packaging materials for tomato soup products [9]. This shows that existing knowledge on consumer responses to specific sustainable packaging solutions is limited. Thus, Ketelsen et al. [11] recommended that future research should focus on specific packaging solutions rather than environmentally friendly packaging in general to provide a deeper understanding of consumer opinions and acceptability of specific solutions. Focus groups, surveys, and interviews are some of the methodologies that were previously used to explore consumer insights in research. Focus groups which are generally used at the earlier stages of consumer research were used by several authors as they have the main advantage of allowing freedom of expression and open discussions from participants [30–32]. In light of this, the objectives of this study were to: (i) understand consumer perception of currently available food packaging; (ii) design sustainable paper-based packages for biscuit and meat products based on consumer opinions and expectations of sustainable paper-based packaging over a series of participatory focus group sessions; (iii) understand consumer opinions of the paper-based packages developed as well as evaluate and assess the characteristics and suitability of the packages. The rest of paper is divided into the following sections: research methodology and data analysis, findings of the study, and discussion of practical implications along with limitations of this research.

2. Materials and Methods

The design process of the paper-based packages was intended to be in collaboration with consumers over a series of qualitative participatory focus group workshops. To achieve this, the study was divided into two stages, with Stage 1 aimed at understanding consumer expectations from sustainable paper-based packages in general and Stage 2 involved evaluation of the prototype packages designed based on findings and information obtained from Stage 1.

2.1. Procedure

Focus groups took place in a discussion room where participants were comfortably seated around a table so that they could see each other to allow for good interactions and discussions. Following best practices for conducting focus groups [30], each focus group session was made up of 6–8 participants, equally distributed in terms of age with two-thirds of the group being female due to the higher ratio of females:males that took part in the study. At the beginning of each session, the moderator gave an overview and stated the purpose of the study and what the role of the moderator would be. Participants were encouraged to share their opinions and were assured that there were no right or wrong answers to the questions being discussed. A pre-approved semi-structured focus group guide was used to direct the conversation. The focus group sessions lasted for approximately 2 h and were facilitated by two researchers: one moderating the session and the other taking notes. All sessions were audio- and video-recorded and transcribed verbatim for further analysis.

2.1.1. Stage 1

Nine focus groups were conducted with a total of 60 participants. To get participants acquainted and comfortable with each other, foster interactions, and get them thinking about the topic to be discussed, participants were asked to introduce themselves and mention what they normally recycle. The discussions began by asking the group about their opinions of current food packaging materials available on the market. This was followed by questions around expectations and possible downsides of sustainable packaging materials.

Participants were then asked to discuss considerations when buying a product. Two currently available packages (one biscuit and one meat package: Figure 1) were presented to the participants. They were asked to open, manipulate, and discuss the advantages and disadvantages of the packages. Next, participants were presented with samples of the proposed sustainable paper-based packaging material (Figure 2) and asked to give their opinions on the characteristics of the materials. Finally, participants were asked for their willingness to buy or pay more for sustainable packaging.

(**a**): B0 (**b**): M0

Figure 1. Examples of currently available packages discussed in Stage 1: (**a**) B0: Biscuit package; (**b**) M0: meat package.

Figure 2. Examples of new paper-based packaging materials discussed in Stage 1.

2.1.2. Stage 2

A total of 56 participants from the first stage returned for the second stage of the study with a total of eight focus group sessions conducted. In this stage, participants were required to evaluate the paper-based packages partially designed based on their suggestions from Stage 1. The new paper-based prototype packages were presented one at a time to participants who were asked to discuss their opinions about them in terms of the design, material, etc. Participants were then asked to discuss if the packages met their expectations of a sustainable packaging material and the benefits and negatives compared to the current packages on the market. Next, they were asked to assess the ease of separation of the packaging film/barrier from the sustainable parts of the packaging. Finally, they were asked about their purchase intent of the products and how the percentage of sustainable material present in the package will influence their purchasing decision. In total, five new paper-based prototypes were developed and discussed during the session: two for the biscuits and three for the meat products (Table 1). In a life cycle assessment (LCA) performed on the paper-based trays with polyethylene terephthalate (PET) coating, the results showed that the paperboard tray has the smallest climate change impact compared to plastic crystalline polyethylene terephthalate (CPET) trays and recycled plastic recycled polyethylene terephthalate (rPET) trays. For the meat packages, a life cycle analysis screening was performed and showed that if the new-paper based packaging is recycled, while the expanded polystyrene (EPS) (M0) tray is not, the paper-based tray has the lower environmental impact (considering the paper tray is recycled ten times).

Table 1. Biscuit and meat packages discussed in Stage 2.

Code	Packaging Description	Image
Biscuit packages		
B0	Preformed polymer multicavity tray, polymer flow pack (horizontal)	
B1	Form-fill-seal paper-based tray with paper-based lidding film and smooth tray surface	
B2	Form-sill-seal paper-based tray with paper-based lidding film and embossed surface	
Meat packages		
M0	Preformed polymer tray with polymer lidding film with opening flap	
M1	Preformed paper-based tray with polymer lidding film identical to M0 with more depth and transparent polymer lidding film.	
M2	Form-sill-seal paper-based tray with polymer lidding film, smooth tray, and less depth with transparent polymer lidding film.	
M3	Form-fill-seal paper-based tray with paper-based lidding film, embossed tray bottom and non-transparent paper-based lidding film.	

2.2. Participants

Participants for the study were recruited from across Berkshire, UK. Recruitment emails were sent using the University of Reading general circulation list, and the volunteer databases of the Sensory Science Centre and Nutrition Unit of the Department of Food and Nutritional Sciences, University of Reading, UK. Advertisement posters were placed on various social media platforms, local shops around Reading, UK, and on notice boards within the University of Reading, UK. Interested participants were required to complete an eligibility screener. To be eligible for the study, participants had to be: above 18 years old; not allergic or intolerant to wheat, gluten, and/or dairy; interested in food packaging; available to take part in both stages of the study. The study was conducted between April and November 2019 and approved by the School of Chemistry, Food, and Pharmacy Research Ethics committee, University of Reading, UK (study number: 11/19). Informed consent was obtained from all participants prior to the focus group sessions.

Demographic characteristics of the participants who took part in the study are presented in Table 2. A total of 60 participants took part in the study in Stage 1 with 56 returning for Stage 2. The majority of the participants were female (66.7% in Stage 1 and 71.4% in Stage 2) with the mean ages of 47 and 47.6 in Stages 1 and 2, respectively. The median age of participants was 49 in both stages with an age range of 19–71 years old. More than 60% of the participants were White British and less than 4% of Black/Caribbean/Mixed ethnicity. Almost all participants (95%) who took part in the study considered themselves environmentally conscious.

Table 2. Demographic characteristics of focus group participants.

	Stage 1		**Stage 2**	
Participant Characteristics	**Number**	**Percentage (%)**	**Number**	**Percentage (%)**
Total number of participants	60		56	
Age (years)				
mean	47		47.6	
median	49		49	
min	19		19	
max	71		71	
Gender				
male	20	33.3	16	28.6
female	40	66.7	40	71.4
Ethnicity				
Asian/mixed Asian	11	18.3	8	14.3
Black African/Caribbean/Mixed	2	3.3	2	3.6
White British	39	65.0	39	69.6
White other	8	13.3	7	12.5
Environmentally conscious				
yes	57	95.0	53	94.6
no	3	5.0	3	5.4

2.3. Data Analysis

The transcribed data and notes taken during the sessions were analyzed using content analysis. The procedure followed was similar to that used by [31]. Two researchers extracted recurring themes from the transcripts of all focus groups individually, with the summary of key findings obtained by comparing the results of each researcher. For a result to be included, it had to have been mentioned in at least four out of nine (Stage 1) or eight (Stage 2) of the sessions [31,33].

3. Results

The results of the focus group discussions are presented by summarizing common themes that emerged from the focus group sessions, although the participants discussed each package individually. Some comments from the discussions are included to show how participants reflected on some of the themes.

3.1. Stage 1

3.1.1. Opinions on Available Packages Currently in the Market

The main themes highlighted by the participants in all sessions were the amount and type of packaging used to package foods. Participants stated that there was too much packaging and over-packaging of foods, most of which is unnecessary, with one participant saying, "you don't have to have individual wrappings for everything" and another, "why have a wrapping around a coconut?". The second point mentioned was that there was too much plastic (especially single-use plastics) packaging and black trays used to package products: "why use plastic except [when] absolutely necessary?"; "the amount of plastic being used is shocking and too much". Some participants stated that the reason being given for too much packaging was to protect the food for consumers which is what consumers want because they are wary of contamination. Other participants argued that consumers are constantly being told that but were wondering if it is what consumers actually want or what supermarkets need: "are shops just trying to pawn the waste to consumers to increase profits?"; "the packaging is to help the shops, not the world or consumer". Confusion on how to handle packages with more education needed was another theme highlighted across the focus group sessions: "most consumers do not understand how recycling works; do packages need to be washed before disposing them in the recycling bin?"; "clearer directions from manufacturers on how to dispose packaging is necessary"; "more universal methods of disposing packages are necessary". Some participants felt that glass was more sustainable than plastic packaging, but others argued that the production process of glass actually makes it less sustainable which showed that consumers were confused about sustainability in terms of food packaging: "glass is not necessarily more sustainable because the cost of production of recycling glass is 80% more than using fresh products". Participants called for full transparency of the packaging process; "we don't have the full story"; "consumers need information on things like the carbon footprint of packaging materials".

Overall, participants agreed that a cultural change is needed; consumers need to be more flexible with their requests on how foods are packaged; manufacturers need to change consumer attitudes and perspectives; and governments need to introduce laws which will help reduce the amount of packaging being used and give consumers no choice but to adapt. The ban on free plastic bags introduced by the UK government some years ago was highlighted as an example of how the government can help change consumer attitudes, with participants stating that more people now take their reusable bags (bags for life) with them when going to shop which has led to a sharp decline in the number of plastic bags being used. In summary, participants agreed that the "3Rs"—Reduce, Reuse and Recycle—need to be the mantra to make food packages more sustainable and environmentally friendly.

3.1.2. Considerations When Buying a Product

Price was the main driving force considered by participants when buying a product and was closely followed by the product quality, with comments such as: "the first thing I think of is whether I am getting value for money"; "for me if I am buying anything, the quality of the product is at the forefront and then I consider whether I can afford it". For most of the participants, how the product is packaged was the last thing considered during purchasing. Most people stated that they only considered that when they got home. When asked if they considered sustainability of the packaging material when making a purchase, very few consumers stated that it was on their list of considerations, with most saying that they only considered the packaging sustainability after the purchase and that it was not a driving force at the point of purchase. Other factors that influence purchase intent mentioned by participants included personal choice, habit, how much time they had to shop, and what or if alternatives were available: "if I had a choice, I will go for something in a glass instead of plastic because I feel glass is more sustainable, but sometimes you don't have a choice"; "I sometimes try to find products in more sustainable packaging, but sometimes they are not available and because I need it urgently, I end up buying anything I see"; "it depends on how much time I have got; if I had enough time, I would look around for products packaged in a sustainable way but if I didn't, I would just shove things into my basket without thinking of how they are packaged". Others said, "it depends on the cost; if loose fruits were slightly more expensive than fruits packaged in a plastic bag but within my budget, I would buy the loose fruits, but if they were over my budget, I would buy the packaged fruit"; "when I go for my weekly shopping, I generally go for brands I am used to within my price range without considering the packaging". Overall, most of the participants agreed that price and convenience trump environmental friendliness when making a purchasing decision.

3.1.3. Expectations from a Sustainable Packaging

When asked to discuss expectations from a sustainable package, the main themes mentioned by participants were functionality in terms of maintaining product quality (e.g., freshness) and shelf life: "it should do its work of keeping the product safe and maintaining its quality"; durability: "It should be strong, stress-resistant, and able to keep the product intact without splitting or breaking until I get to my destination"; aesthetic value: "the design should be very attractive and stand out from other less sustainable packages"; must be recyclable or biodegradable: "a sustainable package should be easy to recycle and would be better if it was 100% recyclable"; "there is no point in me buying an attractive package if it is not recyclable"; minimal amount of packaging should be used: "do not over package products; use just enough packaging required to maintain product quality and safety". A key point mentioned was that packages need to be clearly labeled for sustainability; "the sustainability message needs to be clear so consumers can easily see that the package is more sustainable that other packages". Other points mentioned were that packages should be resealable (though this is product-dependent) and reusable, and that they should meet the standard requirements for the product that the packaging is being used for (e.g., oxygen and moisture barriers) and transparent where possible: "if I am buying a fresh product like meat or vegetable, I would like to be able to see what I am buying so I am sure it hasn't gone bad". The key characteristics outlined for a sustainable package were functionality, clear information, aesthetic value, and product shelf life. In summary, consumers expect a sustainable package to do everything a standard package would do and not be harmful to the environment (environmentally friendly) at the same time. Participants, however, agreed that this was a lot to ask, and there were some limitations in the ability of some sustainable packaging such as paper to keep foods fresh for a long period.

3.1.4. Opinions on Currently Available Biscuit and Meat Packages Discussed in the Study

Participants were presented with a biscuit and a meat package currently available on the market (Figure 1) and asked to express their opinions of the packages. Results from the discussions were grouped into themes and presented based on those themes rather than on individual packages. Key themes that emerged were packaging material, design, size, functionality, and labelling. Participant responses were both positive and negative.

In terms of packaging material, participants commented on the flimsy nature of the outer wrapper of the biscuit package and the fact that it was made from foil-like material which was considered a negative with comments such as: "the wrapper rips up easily" and "oh you've got foil inside". The inner packaging of the biscuit, a black plastic tray, was considered in a negative light and was said to be pretty standard. Most participants disliked the feel of the polystyrene packaging of the meat including the single-use plastic lid; "this packaging is not recyclable". Both the biscuit and meat packages were considered harmful to the environment as they are not biodegradable, neither can they be reused or recycled. There were several suggestions on how the packages could made more environmentally friendly, with comments such as: "instead of the black plastic tray, the biscuits could be in a cardboard box"; "polystyrene! Can't it be cardboard?"; "why not use paper packaging and have a window on the lid so the product is visible to consumers?".

When it came to the design of the packages, participants had varying opinions on the biscuit package. While some loved the red color, found it attractive, and said it made it look expensive, others said the red color made it look cheap and unappealing and was designed to deceive the consumer; "design looks dull"; "red color of the package is designed to make us think it is a special product; if a different color was used, it won't be as appealing". Most participants loved the fact that the image of the product was on the packaging and that the product was not visible, stating that the images were a true reflection of the product inside. This was, however, disputed by others who felt the image was not a true reflection of the product. A small subset of participants loved the meat package and felt it gave the product a positive outlook, with comments such as: "gives the product a sense of freshness"; "looks like a packaging used in a Deli"; "looks like a product from a local butcher"; "love the transparent lid". Most participants, however, did not like the design of the meat package and found it unappealing and unattractive, with several comments such as: "looks very boring and dodgy"; "looks cheap and nasty"; "don't like the white color; white puts me off"; "I won't buy this if I had an option".

When discussing the size of the packages, participants found the size of the biscuit package generally acceptable when compared to the number of biscuits in the package and did not have much to say about it, with a few participants commenting that the packaging could be reduced a little if the biscuit was packed in a different way: "stacking the biscuits side by side like you have in some biscuits like digestive may reduce the amount of packaging used"; "instead of a separate outer foil and inner black tray, using a paper tray with a well-sealed top would have been better and reduced the amount of packaging". On the other hand, the meat was said to have been over-packed, with comments such as "too much packaging"; "there is too much empty space in the package"; and "the package is too big for the amount of product inside" mentioned by participants.

Another theme highlighted was "package function vs. products inside". Participants stated that the biscuit package was not very functional and did not perform the function of retaining the quality of the product: "the package is not protecting the biscuits; there are too many broken biscuits in my pack"; "package is too loose". Participants had little or nothing to say on the functionality of the meat package but had a lot to say about the labelling, with many comments related to the size and descriptions on the label: "label occupies too much space covering the product and making it not visible to the consumer"; "disposal information not visible enough"; "label should be more visible"; "different signs on the label is very confusing and unclear". Similar comments on the clarity of the label were made about the biscuit packaging. Participants found labelling instructions both very confusing and difficult to understand. Overall, participants preferred the biscuit package over the meat package mainly because they found the design of the biscuit package more appealing but felt both packages were not environmentally friendly and were "over-packed/over-wrapped", and they felt that the volume of the meat package could be reduced by up to 40%.

3.1.5. Opinions on Proposed Paper-Based Packaging Materials

The key themes that came out of the conversations around opinions on the proposed paper-based packages (Figure 2) were appearance, material characteristics and feel, functionality, ethical qualities, and emotional draw. The appearance of the packaging material was generally described as "looks natural", "biodegradable" and "recyclable" which are all positive comments and characteristics expected from a sustainable packaging material. Other characteristics mentioned included: "shiny outer coating", "looks flimsy and cheap", "doesn't look sturdy enough for transporting?", "looks boring and unappealing". Some participants worried that on the surface, the materials did not look strong enough to withstand stress: "is it strong? If you got a leak would it break?".

On touching and manipulating the material, participants described the packages as "stretchy and flexible", "a lot stronger than it looks", "strong paper: not very easy to tear" and "leak proof". Functionality was discussed in terms of the protection and preservation that the material will offer to the product packaged in it. The materials were described as "durable", "will retain its shape with moisture", "can be used to package both the biscuit and the meat as well as many other food products", and "the shiny barrier or coating will cope with greasy products".

Ethical issues mentioned were centered around the sustainability value of the products. Though participants generally agreed that the packages had environmentally friendly characteristics and commented that the packages "could be marketed as eco-friendly versions of similar products", there were concerns around it being a single-use package with comments such as: "it is not reusable" and "it's a one-off use package". There were discussions around the amount of the packaging that would be recycled, with most consumers happy to separate the non-recyclable barrier from recyclable materials and satisfied if more than 50% of the package was recyclable, while others stated that "it gets confusing if not completely recyclable". In addition, participants were worried that though the package was recyclable, it can still end up in the landfill if it is contaminated by the product inside, and they wondered at what point it gets past the stage of recycling due to contamination. Another concern about the packages was what the cost of production was, compared to current packages, as that could affect the sustainability characteristic of the package in the long run, especially as it is not reusable. The final theme discussed was around the emotional response the packages drew from consumers, with most having a positive emotional pull: "makes me feel better that part if not all of the package is recyclable". This may have a positive impact on consumer attitudes towards sustainability.

Finally, given that most sustainable packages generally cost more than their non-sustainable counterparts, consumers were asked if they would be willing to pay more for the packages made from the sustainable paper-based material presented. While consumers welcomed the idea of replacing the current packages with the new packages, most of them were unwilling to pay more for the product saying that they expected the companies to bear the cost and could not understand why they should be charged more for doing what is right and helping the environment: "doesn't make sense that we have to pay to be green—so consumers shouldn't have to pay more for it"; "the increased price needs to be justified"; "companies should take it as their social responsibility". Very few participants across the focus groups were happy to pay a maximum of 10% more for the sustainable packages but suggested that "companies must 'sell' it to the consumer—give incentives" and governments should make legislations forcing companies to use more sustainable packages and could introduce taxes/fines if other non-sustainable materials are used. Participants would like to see more government initiatives and incentives to reduce the use of less sustainable packaging materials: "make plastics less lucrative".

In conclusion, consumers felt that everyone (government, manufacturers, and consumers) had a part to play if the change to sustainable packaging is to be successful.

3.2. *Stage 2*

Following evaluation of the paper-based package prototypes (Table 1) and comparing them to the old existing packages, the following themes emerged: appearance, material characteristics, design and size, functionality, target population/market, and price/purchase intent.

3.2.1. Packaging Material Characteristics

Appearance, strength, and feel were the main packaging material characteristics discussed. In terms of appearance, the B2 prototype package was described as more appealing and preferred than the B1 package with comments such as "quite attractive—catches the eye" and "looks classy, like a quality product". On the other hand, statements such as "looks cheap and unappealing" were used to describe package B1. Comparing the current biscuit package (B0) to the prototypes, participants found B0 more attractive than both B1 and B2. When discussing the appearance of the meat packages, prototypes M2 and M3 were more preferred than M1, with M1 described as looking "very amateurish", "cheap and unattractive" and "shocking!" while M2 and M3 were described as "looking very basic in a good way". Similar to the biscuit packages, participants preferred the appearance of the existing meat package (M0) with comments such as "it looks neater than the others". One of the positive comments for the prototype meat packages, however, was that they looked more natural and environmentally friendly than M0.

Discussions around the strength of the packages revealed that participants found the B2 package to be "more sturdy" than B1, which was described as "very flimsy". B2 was considered to be "more rigid and stronger" than B0. The tray strength of meat prototype package M3 was said to be the "most rigid" of all the three prototype packages with M1 and M2 described as "very flimsy" and "less sturdy" than M3, respectively. The lid strength of the three prototypes were also discussed, with participants mentioning that the lids of M1 and M3 were "stronger" and "won't tear easily" when compared to the M3 lid, which they felt "may be easy to tear compared to the other ones". "Looks easily breakable" and "not as strong as the paper packages" were some of the ways the M0 package was described by participants.

The final characteristic mentioned was the feel of the packages. In general, participants loved the cardboard feel of all biscuit and meat paper-based prototypes. However, the "bumpy" feel of package B2 was preferred to the smooth feel of B1 with participants stating that the "bumpy" feel of B2 gave it a "better grip" and made it easier to hold than B1. One participant described the feel of B1 as "feels cheap—don't like it". Statements used to describe the meat paper-based packages included: "feels natural", "has a homemade feel, like something from the butchers".

3.2.2. Design and Size

All the biscuit and meat prototype packages were considered too big for the amount of the product they contained. While in the case of the biscuit packages, participants found the size of B0 great and just right for the amount of biscuits it contained, they said that the M0 package was too big for the portion of meat inside. Comments for the paper-based packages include "definitely a waste of space"; "why use so much packaging?"; "the fact that it is supposed to be a more sustainable package doesn't mean it should be this big; "what a waste!". On another note, participants felt that the shape of biscuit packages B1 and B2 needed to be modified, as the shape limited the number of biscuits that the packages could accommodate, referring to it as "not deep enough". Participants felt that the packages were too big, with comments such as: "packaging probably cost twice the price of the biscuits". On the other hand, while participants loved the shape of the M3 package and described M2 as "looks like a proper tray—with less packaging", participants found the shape of the M1 package to be "too big", "funny", and "not well-defined". The light weight of the paper-based prototypes was loved, with participants saying: "it is very light so will be easy to carry".

In terms of the design, the white and red color contrast of packages B1 and B2 was loved and preferred when compared to the "all red" color of B0. In addition, participants preferred the foldable pack design of B1 and B2 to the flat design of B0, though some participants found the double pack design very confusing and felt it would be better to separate the two packs. However, the "bumpy" design of B2 was favored to the smooth design of B1. When discussing the meat packages, participants found all three prototypes, M1, M2, and M3 too plain-looking. The lid of the meat packages was discussed, with participants disliking the non-transparent paper lid of M3 because it made it impossible to see the contents of the package. Suggestions mentioned included: "put a window for product visibility", but some participants disagreed, saying: "I need to see everything to know how the product inside looks like; a window doesn't work for me". Finally, participants were not impressed with the shiny barrier in the paper-based prototypes and found it off-putting, as they felt it made the packages less sustainable and more difficult to recycle with comments such as: "outer package says sustainable but inside says a different thing" and "can't tell if it is paper or plastic".

3.2.3. Functionality

All paper-based prototype packages were said to be very difficult to open compared to B0 and M0. It was suggested that "a side flap and indicator for opening" be added, just as was present in M0 that needed to be included in the design to guide consumers on where to open the packages. However, for the biscuit packages, participants found B2 a bit easier to open than B1, which they attributed to the "bumpy" nature of the tray which made it firmer to hold. The difficulty in opening the packages was seen as a positive by the participants in some way, as they felt it meant the packages were tightly sealed, improving their preservation characteristics and making them more stress-resistant. B1 and B2 packages were said to offer more protection to the biscuits than B0 due to their rigidity and foldable design, with participants saying the B2 "bumpy" design offered more protection than the smooth B1. On the other hand, participants found it difficult to split both packages, with most splits resulting in broken biscuits and opened seals, which participants found unacceptable. It was suggested that single packs would be better than duo packs and be more functional overall. Participants were nervous about contamination in M1, M2, and M3 packages, with worries that the M2 lid was touching the product which could lead to contamination, unlike in the case of M1 and M3. There were concerns over the protection of the products inside the paper-based packages if they got wet due to rain or cold storage in the case of the meat packages, with comments such as: "what happens when it gets wet or soggy?".

Though worried about the sustainability aspect of the barrier in M1, M2, and M3 packages, participants found it very functional in keeping the product safe. Participants found separating the barrier of the paper-based packages from the paper material difficult to varying degrees. For the biscuit packages, B2 was easier to separate than B1 while for the meat packages, M2 was the most difficult to separate. However, participants made it clear that they were unwilling to be saddled with the responsibility of separating the barrier before disposing the package. Some of the reasons given include: "it is a hassle"; "trying to separate the barrier in the meat package can lead to contamination"; and "if I am eating the biscuit on the go, you cannot expect me to separate the barrier". Participants felt that the design and shape of the new prototypes were not very functional for the products, as they led to too much packaging with little content inside. They suggested that the shape of the biscuit packages should be changed to something such as a rectangle, which will reduce the amount of packaging used while increasing the number of biscuits inside. It was suggested that the black plastic tray design of B0 be retained, with the plastic replaced by a paper-based tray. A major functionality missing from the paper-based prototype packages according to participants was the inability to reseal the packages after opening, with many saying that the lid should be made resealable for storage purposes.

3.2.4. Target Population/Market

Target population/market was one of the themes to emerge from the biscuit packaging discussions. While participants felt that the target market/population of the B0 package was very clear, they found the double pack of B1 and B2 to be very confusing, and the target market/population not clearly defined. It was obvious that B0 was targeted towards "family or party use", but B1 and B2 were described as having no clear target, with questions and statements such as: "is it an on-the-go product?"; "package and content is too much to be an on-the-go snack"; "is it designed for one time consumption?"; "is this aimed at younger people?"; "I cannot imagine it as a snack pack, looks more like a lunch box"; "doesn't stand out, no clear message or target". These questions and comments clearly show the confusion of the participants. In terms of where the B1 and B2 products could be sold, airports, cinemas, street corner shops, and canteens were the suggested possible places, though the location would be dependent on the target market.

3.2.5. Price/Purchase Intent

Price/purchase intent was a key theme highlighted during the discussions. While the B0 package was considered better value for money, B1 and B2 were not, with many participants saying they would probably buy them once but would not buy them again. Participants said they were generally not tempted to buy the biscuits in the new paper-based packaging but recommended the duo pack be separated into two packs and sold as single packs to improve the purchasing value with comments such as: "better to separate the two packs, think you will sell more" expressed by several participants. The M2 package was considered good value for money, but M1 was thought to be unacceptable to be introduced into the market. Participants were more open to buying the M2 and M3 packages with preference for the M2 because of the transparent lid but unwilling to buy M1 package.

With regards to purchase intent, similar to Stage 1, participants were generally not willing to pay more to be sustainable, but some were happy to pay "5 to 10%" more for the new sustainable paper-based packages, mostly because of their dislike of the polystyrene in the M0 package and black plastic tray of the biscuit package.

4. Discussion

The aim of this study was to understand consumers' expectations and opinions of sustainable paper-based packaging materials and to evaluate and assess the characteristics and suitability of the developed paper-based prototype packages. The findings from this study contribute to existing knowledge on consumer opinions and reactions to sustainable packaging materials [2,6–9,12,15,30,31,34–36]. While past studies focus mainly on surveys, interviews, and general conversations around consumer opinions and attitudes to available sustainable packages, this study goes further by involving consumers in the design process of paper-based packages not currently available on the market, with consumers having the opportunity to interact physically with the packages, which is missing from some studies [2,7].

One of the main points highlighted for both the old and prototype biscuit and meat packages assessed in this study was the use of excessive packaging or over-packaging of the products which participants found off-putting. Previous studies carried out in several countries including the UK showed that consumers have a negative reaction to the over-packaging of foods [7,14,37–39]. Though the prototype packages in this study were made from sustainable paper-based materials, participants felt the oversized nature of the packages was a form of wastage and was considered bad for the environment, suggesting that the amount of packaging used should always be commensurate to the product they contain. A study investigating consumer perception of the environmental benefit of several ecological consumption patterns found that consumers believed avoiding unnecessary packaging had a strong positive impact on the environment [38]. In another study conducted by Lea and Worsley [40] examining Australians' food-related environmental beliefs, minimal use of packaging by food manufacturers was said to be the most important way to help save the environment. Hanssen et al. [39] investigated the environmental profile of ready-to-eat meals and found that over 50% of the participants thought that the manufacturers used too much packaging. On the contrary, in another study, when asked what made a package environmentally friendly, consumers did not consider the amount of packaging as an important factor [41]. The varying positions suggest differences in consumer perception and opinions of what environmentally friendly means. As manufacturers consider moving to more sustainable packaging options, size should be an important aspect to bear in mind, as consumers consider over-sized packaging a negative characteristic of a sustainable package.

Too much plastic packaging was mentioned as a major problem in today's food packaging, with participants discussing the negative impact of these plastics on the environment. On the other hand, participants found the paper-based prototypes as a more sustainable packaging solution to the plastic and polystyrene packages currently used for the biscuit and meat products assessed in the study. The result of this study corresponds with the findings of previous research where paper and plastic were ranked by consumers as the most and least environmentally friendly materials, respectively, when comparing plastic, paper, glass, and metal [7,9]. Consumers who took part in a study in Sweden highlighted the negative environmental impact of plastic packaging, with paper reported to be more environmentally friendly [8].

Consumers are, however, still unclear as to what the most sustainable packaging is, with their judgements being mostly subjective and based on their personal perception rather than the sustainability characteristics of the product. Discussions around sustainability in the current study showed that while some participants considered paper-based packaging to be the most sustainable packaging, others felt glass was more sustainable in the ease of recycling. This was, however, disputed by other participants who stated that the cost of recycling glass made it less sustainable and environmentally friendly than assumed. These conversations reflect the limited knowledge that consumers have on what a sustainable product is and the confusion they face when determining what a sustainable product is. Participants agreed that consumers need to be better informed and educated on the production process of packaging to help them make informed decisions. van Dam [10] and Allegra et al. [42] reported that consumers rated paper-based packaging as the most environmentally friendly material. A survey of Swedish consumers revealed that consumers based their judgement of the environmental impact of food packaging on their perception but were also aware of the flaws in their judgement [7]. These results show that there is a need for better guidance to ensure that the noble intentions of consumers to be sustainable are not unknowingly thwarted by their decisions. In general, participants defined a sustainable product based on 3Rs—Reduce, Reuse, and Recycle—which are important processes within the Circular Economy [3]. In previous studies conducted in USA, UK, Germany and China [41], Denmark [43], and Sweden [7], consumers defined a package as environmentally friendly if it was recyclable and reusable, and used the minimal amount of packaging material.

Poor communication of disposal labels was another theme to come out of the focus group discussions. Participants stated that they found disposal information and communications on packages difficult to understand, which meant they ended up not disposing the packages in the right manner in some cases, and most people found this very frustrating. Results from the study highlight the challenges that consumers face as a result of poor disposal information by the manufacturers, which may lead to the benefits of the packages being lost on consumers. A study conducted by [44] on the consumer "attitude-behavioral" intention gap in relation to sustainability found that the positive environmental impact of packages is generally poorly communicated to consumers, impacting their ability to make informed decisions. The authors further underscored the importance of communication in increasing consumer awareness and knowledge of environmental aspects of a product and their influence on the consumer purchase decision. The consumer "attitude-behavioral" intention gap was further reinforced by [11] who acknowledged that consumers' sustainable intentions to act in a sustainable way, while honorable, do not normally translate to their actual behavior. Fernqvist et al. [8] stated that poor communication of the added benefit of a product may influence consumer expectations and future purchase intent negatively.

Similar to previous studies [15,28,30,34,44], price and product quality were found to be the main driving force of consumer purchase intent. In the current study, participants stated that packaging was not on their list of considerations when purchasing a product despite 95% of them saying they considered themselves environmentally conscious individuals and would like to see more sustainable packages on the market. Participants said that they are creatures of habit and would normally stick to familiar brands and only think of the package after purchase or when they got to their destination. Participants further stated that convenience and price trump everything else. More than 80% of consumers cited the environmental status of a food packaging as one of the main factors that influences their selection of a food product but the extent to which this factor influences their decision is unclear. According to Bech-Larsen [34], while consumers are concerned about the effects of packaging on the environment, that concern seldom influences their purchasing decision because there are more important factors considered; consumers are not good at distinguishing between packaging; and their purchasing process is habitualized. Several studies showed that sustainability comes secondary to other factors such as price, convenience, product quality, and shelf life, and thus is not a major driver of purchase [41,45].

Participants expect sustainable packages to have all the functionality of a package and be sustainable. Developing a package from a sustainable material such as paper, particularly for sensitive foods, might prove to be a challenging undertaking for the food industry, as it may be difficult to achieve a sustainable package that provides the required functionalities while maintaining the quality characteristics of the product inside. Participants were not wowed by the design and functionality of the paper-based packages studied. The main functions of a packaging identified by Lindh [46] were protection, communication, and facilitation of handling (which includes easy-to-open status, re-sealability, size, functional weight, shape, easy-to-grip status, etc.), and participants in this study felt the paper-based packaging did not meet most of these criteria. While they found the biscuit prototype packages innovative and different, the packaging did not perform the basic function of protecting the biscuits, with several broken pieces found inside the packages. In general, they felt the design of the packages were not eye-catching or attractive enough and stated that environmentally friendly packaging needs to stand out from other packaging on the shelf if it is to attract consumers. For the meat packages, the ability to see and judge the quality of the product inside was of particular importance to participants who preferred the M2 over the M3 package because even though they had exactly the same design, unlike M3, the M2 package had a transparent lid. Participants, however, stated that the requirement of a transparent lid is mainly applicable for fresh products (e.g., meat, fish, etc.) and does not apply to dry foods such as biscuits. A growing trend in the food industry is a shift away from just showing product images on the package to using transparent packaging materials, which allow consumers to see exactly what they are buying [47]. Previous studies showed that transparent packaging increases expected freshness, expected quality, and purchase intent in various food categories [48,49]. This suggests that transparent packaging has an effect on consumer behavior [47]. Participants also found the color of the meat packaging too plain and dull and were not tempted to buy these products. In addition to text and pictures, color has been shown to affect consumers' preference for environmentally friendly products [8]. Magnier and Schoormans [2] in their study investigating consumer reactions to sustainable packaging across two countries and products found that attractiveness and visual appearance were important factors to consider when designing environmentally friendly packaging, as this was strongly correlated with increased preference and purchase intent.

Though previous studies [7,27,41] showed that environmentally conscious consumers are often willing to pay more for environmentally friendly products, most participants in this study, though they considered themselves environmentally conscious, were unwilling to pay more for the sustainable paper-based packaging. A few people were, however, willing to pay 10–15 pence more for the sustainable paper-based packaging but stated that the packaging did not currently meet their expectations in terms of design and functionality and would have to do so if they were to pay more.

The findings of our study corresponds with the study of Ertz et al. [13], where consumers were unwilling to pay more for more sustainable packaging, and Barber [13,50], where only 28% of consumers were willing to pay more for environmentally friendly "green" wine packaging. Krystallis and Chryssohoidis [51] found that consumers are unwilling to pay more for packaging that they do not believe meets their standards. While most studies show that consumers are willing to pay more for sustainable packaging, the amount they are willing to pay varies between studies and is difficult to measure because of the difference in packaging products studied and how the cost is presented.

This study is not without its limitations. Firstly, not all of the information obtained during Stage 1 was considered in the development of the paper-based prototypes as a result of the technology used and the geometries that could be realized with the paper-based material. The prototypes developed did not have any labelling information, so this aspect was not considered in Stage 2 of the study. On another note, more than 65% of the participants that took part in the study were female which may have biased the results of the study. Previous studies showed that females have a more positive attitude towards the environment and care more about sustainable food packaging than males [23,28].

5. Conclusions

This study provides further understanding of consumer responses and opinions to sustainable paper-based packaging. While the results of this study highlight key consumer opinions of a sustainable paper-based package within the UK population, we recognize that findings may differ with a larger sample size or different demographic within the UK or in other parts of the world due to cultural and regional differences regarding sustainability perception of consumers. Focus groups have been reported as a good way to gain insights into consumer opinions regarding issues which can then be analyzed using a more quantitative methodology in the future [8]. The result of this study shows that participants who took part in the study are (i) aware of the environmental impacts of food packages; (ii) concerned about the negative impact of the unsustainable packages on the environment, and (iii) desire a change in the type and amount of materials used in food packaging. This study further confirms that price and quality remain key driving forces for consumers' purchase intent. Participants did not like the paper-based packages evaluated in this study but found the biscuit design interesting and innovative. Overall, the paper-based packages did not meet participants' expectations, but they all agreed that the design was headed in the right direction. To validate the results of this study, a quantitative study with 130 participants was conducted with results corresponding with this study [49]. In summary, the key message that emerged from the discussions was the "3Rs"—Reduce, Reuse, and Recycle —which should be the main points to consider when designing a sustainable packaging. In addition, a cultural change is needed across all stakeholders (government, manufacturers, and consumers) if success is to be achieved.

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Review

Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review

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Abstract: Growing demand for sustainable food has led to the development of meat analogs to satisfy flexitarians and conscious meat-eaters. Successful combinations of functional ingredients and processing methods result in the generation of meat-like sensory attributes, which are necessary to attract non-vegetarian consumers. Sensory science is a broader research field used to measure and interpret responses to product properties, which is not limited to consumer liking. Acceptance is evaluated through hedonic tests to assess the overall liking and degree of liking for individual sensory attributes. Descriptive analysis provides both qualitative and quantitative results of the product's sensory profile. Here, original research papers are reviewed that evaluate sensory attributes of meat analogs and meat extenders through hedonic testing and/or descriptive analysis to demonstrate how these analytical approaches are important for consumer acceptance. Sensory evaluation combined with instrumental measures, such as texture and color, can be advantageous and help to improve the final product. Future applications of these methods might include integration of sensory tests during product development to better direct product processing and formulation. By conducting sensory evaluation, companies and researchers will learn valuable information regarding product attributes and overall liking that help to provide more widely accepted and sustainable foods.

Keywords: sensory evaluation; consumer acceptance; descriptive analysis; meat analog; meat extender; plant-based; alternative protein; imitation meat

1. Introduction

1.1. Background: The Need for Sustainable Alternatives to Meat

The meat industry is currently facing one of the biggest challenges of the past century: to meet the growing demand for animal products by providing high-quality protein without exceeding the critical limit of natural resources. Current predictions estimate that the world population will reach 9 billion people by 2050 [1] combined with the rising trend of meat consumption due to income increase in industrialized countries [2], which indicates that demand for animal-source foods is likely to double by 2050. This presents an alarming threat to our planet, as meat production is an intensive and unsustainable process, causing environmental problems such as deforestation, pollution, damage to hydrogeological reserves, and loss of biodiversity [3]. The livestock sector alone is responsible for 14.5% of human-made greenhouse gas emissions [4] and uses almost 30% of the world's fresh water resources [5]. Another motivating factor is the issues surrounding animal welfare [6], with concerns regarding the unethical practices of factory farming as well as the excessive use of antibiotics used to fight new infections caused by potentially deadly pathogens.

Replacing meat with sustainable alternative proteins is one promising strategy to reduce meat consumption [7]. The environmental gains of relying on non-animal protein sources such as plants, insects, fungi, and algae, are significant. A complete switch to non-animal proteins in the human diet would reduce the use of natural resources currently dedicated to the livestock sector by 35–50% [8]. In Western countries, plant-derived proteins are more popular than other alternative proteins [9]. Soy products like tofu and tempeh, which originate from Asian countries, have been commercially available in the West since the 1960s and are now accepted by vegetarians and vegan consumers who avoid eating meat for ethical, environmental, or health reasons [10]. However, such products are not as popular among meat-eaters and flexitarians due to their low sensory appeal [11]. Many food companies have joined the alternative protein movement and promote sustainable eating by developing plant-based products with meat-like sensory attributes, often referred to as meat analogs, plant-based, or imitation meat. On a food processing level, recreating the texture and flavor of muscle meat starting from plant proteins has proved to be a challenge, often attributed to production of off-flavors typically by legumes and a lower saturated fat content that is responsible for tenderness and juiciness [12]. While there are many different processing methods to prepare meat analogs, one top-down strategy is high-moisture wet extrusion, which is highly successful in achieving a desirable structure, most resembling animal proteins [13]. Another strategy to achieve desirable texture and flavor while also reducing meat consumption is by partially replacing animal protein with plant-derived extenders. This is a common practice adopted by the food industry to improve the economical, functional, sustainability, and nutritional profile of processed meats [14].

Overconsumption of red meat in Western countries contributes to the development of cardiovascular disease due to the high saturated fat content [15]. This represents a major public health issue, specifically in the United States, where heart disease is the leading cause of death [16]. However, consumption trends observed in the last decade reveal that most Americans do not seem to be reducing their intake of red meat [2]. Identifying high-quality meat alternatives that mimic traditional meats may more effectively appease consumers without compromising the sensory qualities of meat products. Process optimization and new technologies aimed at utilizing novel plant-proteins are essential to the product development of meat analogs. Sensory evaluation, in the context of meat analogs, provides important information regarding the selection of processing methods and use of novel ingredients to achieve meat-like sensory attributes by providing both quantitative and qualitative data on taste, flavor, texture, and appearance.

1.2. Role of Sensory Evaluation in Consumer Acceptance of Meat Analogs

For meat analogs to successfully replace meat in the everyday diet, these novel products must be first accepted by the public in terms of overall liking. Sensory evaluation plays multiple roles in predicting consumer acceptance of meat analogs as this is not only influenced by the product's sensory characteristics but also by person-related factors. These depend on the ethical aspects, political values, and ecological welfare involved in the production and can act as either drivers or barriers to acceptance of meat analogs. Data collected from a consumer survey in the U.K. and The Netherlands show that, while consumers are typically aware of the ethical and political implications of their food choices, purchase intention is ultimately driven by the product's sensory attributes [11]. More specifically, the unfamiliarity with novel foods can alter expectations that may negatively impact sensory perception and overall liking [17]. To reduce consumer uncertainty to meat analogs, these are often marketed with slogans such as "tastes like meat" so that consumers can relate to their previous experience and form favorable expectations on the product's performance. Sensory evaluation methods can gather data regarding consumers' perceptions beyond the oral perception of foods. It is important to identify which product characteristics are drivers of product liking, while also taking into consideration differences between person-related factors. Integrating data of this kind with results from sensory evaluation and instrumental measurements provide a more accurate description of the physiochemical and sensory properties of meat analogs.

While the sensory properties of a food product play a collective role in forming positive expectations both before and during consumption, some may be more important than others. According to a 2019 survey of US adults, 86% of consumers considered taste to be the major driver of purchase intention [18]. In the same light, unpleasant or unexpected taste can represent a barrier to acceptance. In fact, non-vegetarians seem to be reluctant to try meat analogs due to the belief that consuming healthy products might compromise taste [19]. This obstacle can be overcome by developing products that meat-eaters will enjoy not only in terms of their individual sensory properties but also in the meal context in which they will be consumed. This includes other food components in the dish, such as rice, vegetables, and soups, as well as seasonings, spices, and sauces. A successful interaction of these ingredients depends on their sensory attributes. For instance, before consumption, shape, color, and appearance have a greater influence on consumer acceptance compared to flavor and texture [20]. This is because visual cues define the appropriateness of the meal, which is dictated by the cultural aspects of eating certain foods and by the individual preferences of the consumers. By contrast, consumers' perception of flavor and texture of meat analogs are minimized to a certain extent, due to other ingredients in the meal that can have either a masking or enhancing effect. Sensory evaluation can help to increase consumer acceptance of meat analogs by investigating the complex interaction between factors that are known to affect meal appropriateness with the goal to understand the best way to market these products based on their sensory properties.

1.3. Sensory Evaluation Methods

This narrative review focuses on two main categories of sensory evaluation that are summarized in Table 1. Consumer acceptability tests, also called hedonic of affective tests, assess the degree of liking of a product based on its sensory appeal. Untrained participants perform the test, usually greater than 100 participants, who are screened for product usage [21]. A common way to assess acceptability is through hedonic scales where the participants indicate how much they like or dislike the sample in terms of a specific sensory property, such as appearance, flavor, taste, and texture, and can also include overall liking/acceptance. The most commonly used scale is the 9-point hedonic scale that ranges from "like extremely" to "dislike extremely" [21]. Other scales include the visual analog scale (VAS), a non-marked, anchored line, and the "just about right" (JAR) scale, which is used to adjust the proportions of certain ingredients that can alter the intensity of a sensory characteristic (e.g., spiciness, saltiness). A set of check-all-that-apply (CATA) terms can also be used to collect hedonic responses. This is a format in which respondents are presented with a list of terms and asked to select all those that apply to each sample. The list of terms can be either generated by a group of trained panelists or it can be derived from the available literature. In other instances, the CATA method can be used to estimate the intensity of a specific attribute by examining the frequency in which the attribute is experienced; however, in the current review, the study utilizing this method has selected terms that are hedonic in nature and, therefore, grouped with acceptability tests. Descriptive sensory analysis provides a more detailed assessment of the product's sensory profile. It determines both a qualitative and quantitative measurement of the intensities of each sensory attribute. Descriptive analysis techniques include the Flavor Profile®, Quantitative Descriptive Analysis®, Texture Profile®, and Sensory Spectrum® [21]. Trained panelists, often 8–12, undergo extensive training on the relevant attributes [21]. Following training, panelists independently rate intensity of each attribute. These methods provide different information regarding the sensory profile of the product. Consumer data identifies which sensory attributes are needed to increase overall liking, whereas data from descriptive analysis is more accurately quantified and can significantly contribute to the direction of product development. An appropriate selection of the method is important for obtaining the desired sensory information to improve the final product.

Table 1. Summary of sensory evaluation methods used to evaluate plant-based meat analogs.

Consumer Acceptability Test	Descriptive Analysis Test
Assesses degree of liking of a product based on its sensory appeal	Provides a detailed assessment of the product's sensory profile
Uses 100 or more participants with no previous training	Uses 8–12 trained panelists
Hedonic responses are collected through 9-point hedonic scales, visual analog scales, just about right scales, or CATA questions	Sensory scores are collected through intensity scales for each attribute of interest

1.4. Organization and Scope of the Review

The application of consumer studies and descriptive analysis provides useful information about the sensory profile and consumer acceptance of foods and beverages. To the authors' knowledge, there has not been a literature review on the application of these sensory evaluation methods to meat analogs and extended meat products. This narrative review summarizes the literature evaluating the sensory attributes of meat analogs and meat extenders. Specifically, it focuses on studies that involve consumers' evaluation of products that uses hedonic and/or descriptive analysis methods. Here, the review focuses on plant-based products as these are the most commercially available and are preferred by consumers [22,23], rather than other alternative protein sources (e.g., insect, fungi, and algae). Moreover, the review includes studies of extended meat products where partial replacement of meat protein was at least 30% following the analysis of consumer data revealing a preference for hybrid products with a 50:50 ratio of plant-based to meat ingredients [24]. By reviewing the available literature, the goal is to show the advantage of evaluating the sensory properties of meat analogs to predict consumer acceptance by understanding the factors that affect hedonic preference. The purpose of this review is to summarize the changes that occur in sensory attributes resulting from the integration and innovation of processing techniques of novel plant-proteins. There is an opportunity to build a greater understanding of the impact of novel plant-proteins and processing technology on the taste, flavor, and texture profile. Achieving desirable meat-like qualities will help to increase consumers' acceptance with the long-term goal of reducing the consumption and production of animal livestock that improves human health and environmental sustainability.

2. Search Criteria Methods

Articles were searched from Web of Science and Google Scholar using keywords and restriction on publication year from 2000 to 2020. Products of interest were searched using "meat analog*", "meat substitutes", "alternative protein", "plant-based", "hybrid meat", "meat extenders", "meat replacement", and "extrusion". Consumer studies and sensory descriptive analysis methods were selected using "consumer liking", "consumer acceptance", "consumer perception", "sensory quality", "sensory characteristics", "sensory properties", and "descriptive sensory evaluation". Studies involving meat analogs made with insects, mycoproteins, algae, and in vitro meat as a protein source were removed. In the case of meat extenders, only studies evaluating products in which at least 30% of the protein content was replaced with plant proteins were selected. Studies with products containing functional ingredients as food additives but where animal protein was not replaced with plant proteins were excluded. While numerous studies on consumer perception of meat analogs were found, online surveys, questionnaires, and focus groups where data were collected based on visual or verbal information and not through tasting were excluded. Following an initial search, and secondary screening of the above criteria, the review resulted in the selection of 14 articles.

3. Literature Review

Fourteen research papers were found within the defined search query. These are summarized in Table 2. Of the 14 selected papers, 11 evaluated consumer acceptance with hedonic testing and 3 used sensory descriptive analysis. Eleven evaluated 100% plant-based meat analogs, and 3 evaluated extended meat products. Twelve evaluated the addition of ingredients and 2 evaluating processing/cooking methods. The main protein source was soy in the form of isolate, concentrate, or flour, followed by wheat gluten and peanut. All meat analogs were prepared by either extrusion processed, emulsified systems (e.g., sausage) or formed materials (e.g., nuggets, meatballs, patties). Samples were cooked in different methods (e.g., oven-baked, pan-fried) with or without seasonings or marinades, depending on what type of processed meat the product was meant to recreate. During sensory evaluation, the control samples consisted of either a commercial meat analog or a meat equivalent product. For studies testing the most adequate concentration of functional ingredients, the control sample was the one where the ingredient of interest was not added. Table 3 summarizes the reviewed articles, which are categorized by the sensory attribute of interest, by highlighting the strategies that have been tested, the type of control used, and the main finding. Table 2 shows a summary of articles employing consumer and descriptive analysis tests.

Table 2. Summary of articles employing consumer and descriptive analysis tests.

Sample	Protein Source	Target Model	Participants	Country	Reference
Descriptive analysis studies					
Meat analog	TSP	Extrudate	14	USA	Katayama and Wilson [25]
	TVP, SPI	Emulsified product	10	Korea	Wi et al. [26]
	SPI	Extrudate	9	USA	Lin et al. [27]
Consumer and hedonic studies					
Meat analog	SF	Beef fillet	73	Spain	Gómez et al. [28]
	TSP	Chicken nugget	110	Malaysia	Sharima-Abdullah et al. [29]
	DPF, PPC	Beef-like mince	60	USA	Rehrah et al. [30]
	TSP	Beef patty	55/56	USA	Wong et al. [31]
	SPC, WG	Beef-like mince	55	New Zealand	Chiang et al. [32]
	TSP	Extrudate	125	USA	Katayama and Wilson [25]
	SPI, TSP	Meat-free sausage	24	Iran	Majzoobi et al. [33]
	SPC	Extrudate	18/17	Germany	Palanisamy et al. [34]
	SPI	Meat-free sausage	30	Iran	Savadkoohi et al. [35]
	PPI, WP	Chicken nugget	42	Singapore	Yuliarti et al. [36]
Extended meat product	TSP	Meatball	60	UK	Grasso et al. [37]
	SPI, WG	Meat-free sausage	8 (trained)	India	Kamani et al. [38]

DPF: defatted peanut flour; PPC: peanut protein concentrate; PPI: pea protein isolate; SF: soy flour; SPC: soy protein concentrate; SPI: soy protein isolate; TSP: textured soy protein; TVP: textured soy protein; WG: wheat gluten; WP: wheat protein.

Table 3. Summary of findings for reviewed articles.

Sensory Attributes	Approach	Control	Findings	References
Color, appearance	Combination of *sous vide* cooking parameters for an RTE soy meat analog: time (90, 120, 150 min), temperature (70°, 80 °C) and marinade (teriyaki and beer)	RTE beef	For each combination of cooking time and temperature, both the RTE meat analog and beef sample resulted in similar lightness, redness, and color intensity regardless of the marinade type	Gómez et al. [28]
	Changing ratios of chickpea flour to TVP: 30:10, 25:15, 20:20, 15:25, 10:30	Commercial chicken nuggets	A 10:30 chickpea flour to TVP ratio resulted in the highest acceptance scores	Sharima-Abdullah et al. [29]
Taste, flavor, aroma	Addition of seasonings and spices to a PPC meat analog	Commercial soy meat analog	The highest level of spices and crushed red peppers had the most acceptable meaty flavor, the least amount of off-flavor, and the most adequate spiciness level	Rehrah et al. [30]
	Sodium reduction from 1.5% to 1.1% in three hybrid TSP/beef patty formulations with 10%, 20%, 30% TSP substitution	100% beef patty with 1.5% sodium	Substitution of beef with TSP up to 30% resulted in similar acceptability scores to the control. Sodium reduction resulted in slightly lower acceptability scores compared to control	Wong et al. [31]
	Addition of nutritional yeast to a TSP hybrid meatball	100% beef meatball	15% TSP with yeast received the highest flavor and overall acceptability scores, was most associated with the term "tasty" and less associated with "bland"	Grasso et al. [37]
	Addition of MRP at 10%, 20%, 30%, 40% to a soy meat analog	0% MRP	20% MRP resulted in the highest sensory scores for meaty aroma and meaty taste	Chiang et al. [32]
	Addition of vegetable-based "chicken" or "shrimp" flavor at 3% and 4% to four shapes of soy meat analogs prepared with two cooking methods (fried or baked)	Unflavored sample	Highest flavor concentration with frying method received higher scores in terms of flavor intensity and saltiness	Katayama and Wilson [25]
Texture	Addition of SPI and WG at 80%, 100% to a chicken sausage	100% chicken	Samples with partial and total replacement of meat with plant proteins received higher liking scores for texture due to reduced cooking loss and better emulsion stability	Kamani et al. [38]
	Addition of j-carrageenan, konjac mannan and xanthan gum at 0.3%, 0.6%, 1.0%, 1.5% to an SPI sausage	0% hydrocolloids	0.3–0.6% kappa-carrageen or 0.6% konjac mannan resulted in highest acceptability scores	Majzoobi et al. [33]
	Addition of ICGN at 0.75%, 1.5%, 2.25%, 3% to a soy meat analog	0% ICGN	1.5% ICGN was the optimal level for acceptance of texture	Palanisamy et al. [34]
	Addition of bleached tomato pomace at 1%, 3%, 5%, 7% to an SPI meat-free sausage, a beef frankfurter and beef ham	0% bleached tomato pomace	3% and 5% bleached tomato pomace in meat-free sausage resulted in the highest scores for juiciness	Savadkoohi et al. [35]
	Addition of non-animal based liquid ingredients at different concentration ranging 15–35%	N/A	Water treatment affected juiciness more than the oil treatment	Wi et al. [26]
	Extrusion of a soy meat analog with moisture content at 60%, 65%, and 70% and cooking temperature at 138, 149, and 160 °C	N/A	Moisture content had a greater effect on sensory attributes than cooking temperature	Lin et al. [27]
	Changing ratios of PPI to WP: 7:0; 13:4; 8.5:8.5; 4:13, 0:17	Commercial 100% PPI and 100% WP meat analogs	A 4:13 PPI to WP ratio resulted in highest acceptance scores	Yuliarti et al. [36]

3.1. Color and Overall Appearance

The overall appearance of a product is important for priming consumers and developing expectations prior to consumption. A disconfirmation of expectations occurs when the perceived liking after consumption is below the expected liking, which may occur when the visual cues misrepresent the taste, odor, and flavor of the product [39]. Thus, it is important to deliver high-quality sensory attributes that are perceived both before and during consumption. The overall appearance of meat analogs should resemble familiar meat products in order to set positive expectations. A combination of cooking parameters, such as time and temperature, have been tested to improve the overall appearance of meat analogs as they can impact the final visual appearance of the cooked product. Gomez and colleagues [28] tested the effect of changing cooking time and temperature on the color attributes of a ready-to-eat soy meat analog using the *sous vide* technique, which consists of cooking a vacuum-sealed product at low temperatures in a water bath. Both the meat analog and a beef equivalent were treated with two marinades, beer and teriyaki, and cooked at varying times and temperatures. The main ingredient in teriyaki marinade was pineapple juice (71%) resulting in a light-yellow color, whereas the beer marinade was made with pale lager beer (80%), resulting in a more golden color. A hedonic test was performed by 73 consumers who rated three visual parameters of the product. No significant difference in hedonic scores was detected between the samples, suggesting that the meat analogs were equally accepted as the beef samples in terms of visual appearance. In addition, results from color analysis revealed that both samples cooked with similar parameters had the same values for lightness and redness, which is the characteristic color parameter for meat products, suggesting that this cooking technique can be used to develop meat analogs with a similar appearance as their meat equivalent, regardless of the type of marinade used. Instrumental color analysis also revealed higher yellowness values in the samples cooked with teriyaki marinade compared to the beer marinade. This was attributed to the lighter yellow color of the teriyaki marinade. These results can be used to direct product development of meat analogs in terms of color depending on the desired outcome.

Certain ingredients can affect the color and appearance of meat analogs. Sharima-Abdullah and colleagues [29] developed meatless nuggets by changing the ratio of chickpea flour to texturized vegetable protein. Hedonic test showed that color and appearance scores increased as chickpea flour concentration increased. These results were explained by the presence of carotenoids in chickpea contributing to a yellow color, which was appealing to the participants. Surprisingly, increasing hedonic scores for color did not correlate with increasing overall acceptance scores. In fact, overall acceptance seemed to decrease as the percentage of chickpea flour increased. A 10:30 ratio chickpea flour to textured vegetable protein (TVP) resulted in the highest acceptance scores. This was explained by an increase in dislike of the nuggets in terms of taste. This provides evidence that multiple sensory attributes play an important role in consumer acceptance.

One processing limitation of using plant proteins is that the color of meat analogs may fade out when exposed to light or oxygen, leading to an unappetizing product [40]. Marinating can be used as a preparation method to change the color of meat analogs prior to cooking. Other ingredients used in the formulation of meat analogs can dictate the color of the final product. Teriyaki and/or beer marinades as well as chickpea flour are acceptable ingredients to obtain a bright yellow color that is appealing to consumers. Cooking parameters such as time and temperature can also affect the appearance of meat analogs. A higher moisture content in a meat analog cooked at high temperatures can lead to deeper penetration of light in the product, resulting in a brighter color. These studies demonstrate that several approaches can impact consumer ratings for the color and visual appearance of meat analogs.

3.2. Taste, Flavor, Aroma

A common disadvantage of using plant proteins in meat analogs is the generation of volatile compounds from the lipid oxidation of unsaturated fatty acids that contribute to the formation of unappealing odors and flavors [41]. To overcome this problem, food scientists develop recipes that include flavoring mixtures with seasonings, spices, and enhancers that can both replicate the typical flavor of smoked meat as well as mask the beany, grassy, or green aroma of pulses. To assess consumer acceptability of meat analogs in terms of taste, flavor, and aroma, the sample is presented in a way so that it resembles the equivalent meat product. In a study performed by Rehrah et al. [30], three formulations of peanut-based minced product were evaluated against a commercial soy-based minced product in a seasoned puff pastry application. The peanut-based meat analog was made by fortifying defatted peanut flour with peanut protein concentrate. The mixture was extruded, ground into a beef-like mince, and stuffed into a rolled puff pastry to provide a more realistic version of a commercial snack. All three formulations of textured peanut protein concentrate (PPC) were seasoned with beef flavor and soy sauce as a flavor enhancer. In addition, the first sample contained tomato powder, the second sample contained crushed red pepper, and the third sample had no modifications. A sensory panel of 60 participants rated the peanut-based sample along with the commercial soy-based control in terms of beefy flavor, off-flavor, and spiciness on a 9-point hedonic scale. Participants were also asked to determine spiciness on a just-right scale with three intensities (too little, just right, too much). Of the three formulations of peanut-based meat analog, the one containing crushed red peppers had the most acceptable meaty flavor, the least dislike of off-flavor, and the most adequate spiciness level. These results suggest that the addition of flavors, enhancers, and spices can positively affect consumer acceptance of taste of a meat analog. However, while PPC performed better than soy-based formulations in a puff pastry application, the study did not include comparisons against a traditional meat formulation, suggesting that the choice of the control is a significant variable to be considered. On one hand, if the reference and test samples consist of different plant proteins, hedonic responses may be affected by the additional spices, with the most seasoned formulation resulting in higher acceptance scores. Alternatively, using a full-meat sample as a control would help to best determine how a meat analog compares to the desirable sensory properties of a traditional animal product.

Comparing plant-based meat analogs to their meat equivalent can be adopted as a strategy during evaluation of extended meat products. Wong and colleagues [31] developed three formulations of hybrid beef patties by substituting 10%, 20%, and 30% ground beef with hydrated textured soy protein (TSP). A first hedonic test with 55 consumers showed no significant difference in overall liking scores for all formulations compared to the all-beef control. In a second hedonic test, 56 consumers evaluated the sensory properties of a hybrid beef patty with 20% TSP substitution and all-beef patty both with reduced sodium level. Liking scores for flavor were slightly lower in both the 20% TSP patty and the all-beef patty with reduced sodium compared to the all-beef control with regular sodium level. This suggests that substitution of beef with plant protein up to 30% can lead to acceptable liking scores as long as the sodium content remains unchanged. These findings reveal that maintaining a high sodium level in meat analogs is important for consumer acceptance in terms of flavor, although this may lower the nutritional quality of the final product. In another study, Grasso et al. [37] developed four types of hybrid meatballs by substituting 15% and 30% of beef with TSP in duplicates, with or without nutritional yeast, which was used as a flavor enhancer for its strong umami flavor. Sixty participants evaluated the four samples and an all-beef control by assessing degree of liking on a 9-point scale in terms of flavor, texture, and overall acceptance. In addition, participant used the check-all-that-apply (CATA) method by selecting the most appropriate terms to describe the samples. This method provides a complete description of the sensory characteristics of the samples. A list of 24 terms was chosen from the available literature on meat products. The CATA terms related to flavor were "tasty", "bland", "cheesy", "weak meaty", "strong meaty", "wheat-cereal like", "unusual", and "characteristic". Results from the hedonic test showed that addition of 15% TSP and nutritional yeast resulted in the highest liking scores for flavor and overall acceptance. Results from CATA analysis revealed that this sample was most associated with the term "tasty" and less associated with "bland", while the 30% TSP without yeast was most associated with "wheat-cereal like", suggesting that the absence of flavor enhancers in a sample with a high percentage of soy content may lead to the detection of strong off-flavors. Interestingly, the all-beef control was most frequently associated with the term "bland". This suggests that the selection of control is important in understanding and interpreting consumer acceptance of hybrid products. It is important to select a control that is liked by consumers and is a good representation of the target product, as a low-quality control product could lead to misinterpreting results. Partial replacement of animal protein with plant protein provides the opportunity to improve the sustainability of meat products while also improving the nutritional profile of processed meat. However, addition of plant proteins might affect the overall product quality. The addition of up to 15% vegetable protein is appropriate to improve healthfulness of meat products without reducing the quality of sensory attributes.

When the objective of the study is to test how different concentrations of a flavoring agent affect the sensory attributes of the final product, the sample without the added ingredient is used as a control, as opposed to using a full-meat product or a commercial meat substitute. Chiang et al. [32] added Maillard-reacted beef bone hydrolysate (MRP) at four concentrations to a meat analog made with soy protein concentrate and wheat gluten to improve its sensory attributes. Beef-bone extract, a by-product of meat processing, can be used as a flavor-enhancing agent by undergoing enzymatic hydrolysis to increase the proportion of free amino acids, followed by Maillard reaction through addition of reducing sugars to produce heterocyclic compounds. These molecules contribute to the typical flavor and aroma of smoked meat when this is cooked on the grill. Sensory evaluation by a group of 55 consumers revealed that 20% MRP was the optimal level for acceptance, resulting in the highest sensory scores for meaty aroma and meaty taste. By contrast, addition of 40% MRP received the lowest scores in all attributes due to bitter taste and a burnt appearance, while 0% MRP (the control) resulted in a weaker meaty taste and an undesirable pale brown color. The addition of MRP, under a certain concentration, helps to increase desirable "meat" flavors and increases acceptance compared to unflavored meat analog. It is not known if the addition of MRP would compare to a full-meat control. However, this product includes meat extracts, making it inappropriate for vegans and vegetarians; yet, it demonstrates the use of hydrolyzed protein materials can enhance desirable flavor attributes, which is important in increasing overall acceptance of meat analogs.

Katayama and Wilson [25] used a similar approach in their study. The aim was to determine the most acceptable concentration of vegetable-based "chicken" and "shrimp" flavors added to textured soy meat analogs prepared in four different shapes (narrow strip, wide strip, shred, and bit) and with two cooking methods (fried and baked). The use of vegetable-based flavors provides an acceptable alternative to meat-by products like beef-bone extract, which may represent a barrier for vegan consumers. In the study, "chicken" flavor was added in either powder or liquid form at 3% and 4% to all four shapes of extrudates, which were fried, while two types of "shrimp" flavor, one oyster-like, the other a combination of oyster and crab-like, were added to shred-shaped extrudates, which were baked. A trained sensory panel of 14 participants generated a list of descriptive terms based on chicken and shrimp flavors to evaluate the samples. All formulations were rated on an analog scale using unflavored samples as controls. Results showed that the presence of 4% flavoring enhanced the overall saltiness and meatiness. The size of the product sample appeared to significantly impact the "chicken" flavor in powder form as the narrow strip-shape was more intense in the oily flavor compared to the wide strip sample. This was attributed to the formation of air pockets in the former, responsible for encapsulating flavor molecules during frying. Following descriptive analysis, researchers conducted a consumer preference test with 125 volunteers for evaluating the "chicken" flavored product. Consumer results revealed that the chicken-flavored sample was most accepted when fried rather than baked. However, chemical analysis showed that the fried samples had more than 3 times higher fat content than the baked samples, suggesting that the higher fat content may increase liking. Moreover, this cooking method can negatively impact the nutritional quality of the product. In this study, researchers first used a descriptive sensory analysis to determine the best product formulation based on variables, such as type and concentration of the flavoring agent as well as shape and cooking method of the sample. Then, a consumer preference test was performed to evaluate the product based on a single variable. Performing a consumer test following descriptive analysis is a common strategy to efficiently assess consumer acceptance by combining both quantitative and qualitative data on the sensory profile of meat analogs in order to collect more specific information that can be used to apply changes in the recipe or processing method.

The formation of unappealing odors and flavors during processing of plant proteins represents a barrier to acceptance of meat analogs. Addition of spices, seasonings, and flavor enhancers is an appropriate strategy to mask the beany and grassy aroma, specifically in pulses. The nature of the added ingredient may need to comply with vegetarian and/or vegan consumers' dietary restrictions. Meat by-products such as beef bone hydrolysate can provide a "meaty" flavor to meat analogs in order to increase acceptance among non-vegetarian consumers. Yet, vegetable-based mixtures have been successful in recreating the flavor of poultry or seafood products. Use of spices, such as red pepper flakes, can increase spiciness to overcome off-flavors, while nutritional yeast can be used as an enhancer to provide a "meaty" umami taste. Sensory evaluation methods aimed at identifying acceptable flavoring ingredients can be influenced by the selection of the control product. Comparing two different kinds of plant proteins as opposed to using a full-meat control can impact conclusions drawn regarding product liking. Further research should focus on evaluating the taste and flavor of meat analogs in a meal context, as additional foods in the dish can alter the perception of oral sensation of meat analogs.

3.3. Texture

Another challenge for meat analogs is the recreation of the unique texture, mouthfeel, and juiciness of traditional meat products [41]. For meat analogs, the focus has been on the selection of plant protein to recreate the physiochemical properties of animal protein. Factors include the ability to encapsulate fat, their oil- and water- holding capacity, and gelling and emulsifying properties, which can be measured through texture analysis. Instrumentation combined with sensory evaluation, such as consumer liking, can be a helpful indicator of consumer acceptance for texture.

Choosing the right protein source is essential to develop vegetarian versions of meat products. Gluten is the main protein source in wheat, and it is commonly added to processed meats as a binding agent for its viscoelastic properties that allow to form a cohesive network in the product. Kamani and colleagues [38] used soy protein isolate and wheat gluten to develop two products, (1) a meat-free sausage and (2) a reduced-meat sausage containing only 20% of chicken. Results from the hedonic test showed no significant differences in the liking texture scores between samples containing both 80% and 100% plant proteins compared to the full-meat control. This was associated with texture analysis data, showing a reduced cooking loss and a better emulsion stability in the samples with partial and total replacement of meat. Implementing the results from sensory evaluation, which is subjective, with instrumental results from texture analysis allows to either confirm the outcome of the study or identify possible inconsistencies in the methods. However, it should be noted that Kamani and colleagues [38] collected hedonic responses using a trained panel, which goes against the standard procedure of sensory evaluation method for consumer acceptability. Thus, these results should be analyzed with caution due to methodological issues and represent a limitation of the study.

In addition to the selection of plant protein source, another way to improve the texture of meat analogs is by using food additives. Hydrocolloids have gelling, thickening, emulsifying, and stabilizing properties due to their ability to interact with water, proteins, starch, and other components in the food product. The meat industry often incorporates hydrocolloids in meat sausages to compensate for textural quality loss that occurs when part of the fat and salt is reduced. Common types of hydrocolloids for meat analogs include carrageenan, an algae-derived polysaccharide, xanthan gum, a polysaccharide produced by bacterial fermentation, and konjac mannan, a tuber-derived heteropolysaccharide. Majzoobi and colleagues [33] found that addition of either 0.3–0.6% kappa-carrageen or 0.6% konjac mannan resulted in the highest consumer acceptability scores of a soy protein isolate (SPI) sausage. These results were confirmed by textural analysis showing that sausages produced by k-carrageenan and konjac mannan had the highest water-holding capacity, leading to the production of a strong network within the sausage matrix and an increase in tenderness of the samples. Similarly, Palanisamy et al. [34]

found an improvement in textural attributes of a soy meat analog by increasing the concentration of iota-carrageenan (ICGN), with 1.5% being the optimal level for hedonic texture ratings. However, results showed that all test samples had poor overall acceptability, including the 0% ICGN control sample, as no samples included seasonings or spices, which was intentional to avoid any influence on the perception of texture. In this instance, while texture was improved, creating a desirable texture alone is not sufficient to create an overall suitable product. It is important to consider how sensory attributes together influence consumer acceptance. Moreover, it should be noted that the consumer group used in this study is small, making it inappropriate to generalize the hedonic responses regarding the product sample.

Other functional ingredients that are used as food additives to improve the texture of meat analogs include thickeners and emulsifiers. Bleached tomato pomace, a by-product of tomato processing, is rich in fiber and pectin and is used as a thickening agent. Savadkoohi et al. [35] developed three sausage formulations, namely soy, beef, and ham, which were evaluated by a descriptive sensory analysis based on the added concentration of bleached tomato pomace. Three commercial samples with no tomato paste addition were used as controls. Thirty consumers rated the liking of sensory properties on a line scale for each sample. Sensory scores showed that addition of bleached tomato pomace at 5% was the optimal level for acceptance. This was confirmed by instrumental textural analysis showing that addition of tomato pomace increased textural hardness and chewiness of the meat analog. However, analysis revealed that additive concentration greater than 5% resulted in an undesirable orange-green color compared to the control. In another study, Wi et al. [26] added non-animal-based liquid additives, including water, hydrated SPI, canola oil, and lecithin to an emulsified meat analog made with TVP and SPI. Sensory evaluation was performed by 10 panelists who rated the intensity of firmness, elasticity, stickiness, compactness, roughness, soy taste, oil taste, juiciness, and overall acceptance on a 7-point scale. Results showed that juiciness was positively affected by water treatment, whereas overall acceptance was positively correlated with emulsion treatment.

Finally, the processing methods can influence texture and mouthfeel properties of meat analogs. Lin et al. [27] tested the effects of different moisture content and cooking temperature on the attributes of an extruded meat analog made with soy protein isolate. For sensory data, a trained panel of 9 judges evaluated the samples based on 7 descriptive terms related to mouthfeel. The authors combined data from sensory evaluation and instrumental analysis, including texture profile analysis, water absorption capability, and microstructure, which was determined by scanning electron microscopy. They found that changes in moisture content had a greater effect on sensory and physiochemical properties than cooking temperature. However, while results showed a correlation between directional structure and textural attributes like hardness or chewiness, the study did not determine whether this affected consumer acceptance. In another study, Yuliarti et al. [36] developed plant-based nuggets using a freeze structuring technique, which consists in the freezing of a protein emulsion to generate a unique fibrous structure and a subsequent removal of ice crystals to generate a porous and fibrous microstructure, similar to that of animal meat. Five formulations of nuggets were developed by changing the ratio of pea protein to wheat protein. Two of the five samples were used as controls, namely 17:0 and 0:17 pea protein isolate (PPI) to wheat protein (WP). A hedonic test was conducted with 42 untrained participants who rated the analog in terms of texture on a 5-point acceptance scale. Results showed that freeze structuring technique was able to form a fibrous and layered structure of the plant-based protein nuggets, however, this technique was also dependent on the type of protein used. In fact, a 4:13 PPI to WP ratio was the most preferred analog compared to controls. Microstructure of this analog indicated fibrous and layered structure, while textural profile analysis was found to be related to the viscoelastic properties of WP and was strongly affected by the extent of cross-linking between protein molecules. A combination of hedonic tests, descriptive analysis, and analytical methods is ideal to explain the impact of processing parameters on texture and mouthfeel attributes.

The structure of muscle meat is challenging to recreate without the use of animal proteins. The selection of plant proteins with viscoelastic properties like wheat gluten can help to improve the texture and mouthfeel of the final product. In addition, ingredients like hydrocolloids, gels, and gums can be used for their emulsifying properties. Optimizing synergistic effects of different ingredient ratios can further advance texture quality perception. Extrusion parameters can be modified to obtain a desired texture, with changes in moisture content playing a greater role in physiochemical properties than cooking temperature. Freeze structuring technique can generate a fibrous and layered structure in plant-based nuggets. This strategy can be adopted when extrusion cooking is not available. Future sensory evaluation studies should explore how the texture of meat analogs is affected by other components in the meal with different consistencies, such as sauces and soups, which can alter the perception of oral sensations of meat analogs. Moreover, the application of commercial ingredients that utilize the synergistic effects of soy and gluten should be further investigated to optimize the creation of desirable textural properties of meat analogs.

4. Conclusions

This review focused on research papers evaluating the impact of ingredients and processing methods for meat analogs and meat extenders on sensory attributes and consumer acceptance. This area of research helps provide important information on the use of novel plant proteins in meat analogs, as they are known to have processing limitations. The color of plant-based products may fade out due to light or oxygen exposure, leading to an unappetizing appearance. An undesirable taste can occur due to off-flavors from lipid oxidation of unsaturated fatty acids in plant protein ingredients and products. Texture attributes such as fibrous structure, tenderness, and juiciness of muscle protein are very challenging to recreate in plant proteins due to the reduced saturated fat content. Current research in food science is investigating strategies to improve the overall quality of meat analogs. In terms of increasing consumer acceptance, studies have focused on adjusting formulations and cooking methods to improve color, flavor, and texture of meat analogs. In this regard, it should be noted that the choice of protein source is an important factor to be considered in the development of meat analogs as it can influence the perceived sensory attributes of the finished product. For instance, leguminous proteins such as soy and pea, while high in protein content, have some processing limitations leading to the production of strong off-flavors. Peanut protein has some processing advantages as it is very nutrient dense due to the high protein, fat, and fiber content. Moreover, peanut protein was found to perform better than soy in a puff pastry application in this review. Wheat gluten can be used for its viscoelastic properties to improve the texture of meat analogs, however, it has a much lower protein content than soy and peanut. Finally, soy, peanut, and wheat are three major food allergens, suggesting that the application of any of these ingredients may lower consumer acceptability of meat analogs depending on the consumer.

Sensory evaluation methods, involving untrained or trained consumers, can provide a better understanding of how different factors, such as processing and ingredients, affect quality attributes and overall consumer acceptance of meat analogs. Studies that employed more than one sensory method were able to identify the combination of parameters or ingredients that resulted in the highest acceptance scores for the sensory attribute of interest. Studies that used a qualitative approach to evaluate the samples were useful to identify the magnitude in which sensory attributes were influenced by test parameters. However, using this approach alone reduced the ability to understand the potential to impact or improve consumer acceptance values. A combination of hedonic testing and descriptive analysis provides a more holistic understanding and an ideal approach to evaluate the sensory profile of meat analogs while also being able to identify the strategies to increase consumer acceptance of these novel foods. Moreover, it is important to follow standardized procedures when choosing the appropriate sensory evaluation method, as these might compromise the reliability of scientific results. Factors such as the number of participants and training can influence the sensory scores and lead to inaccurate interpretation.

Sensory characteristics, including color, flavor, and mouthfeel of meat analogs can be modified through addition of functional ingredients and selection of processing methods. For color parameters, marinades, or other ingredients containing yellow pigments can be used to improve the overall appearance of the final product. Different flavoring agents and seasonings can either mask the undesirable odors of plant proteins or recreate the umami and "meaty" flavor. Texture can be adjusted to resemble muscle structure through the application of plant proteins as independent materials and as blends, with or without the addition of hydrocolloids to change the viscosity. Extrusion cooking or freeze structuring technique results in desirable fibrous structures. Sensory data is a key component in understanding the physiochemical characteristics of novel plant proteins to increase consumer acceptance of meat analogs in order to make a significant advancement in more sustainable and healthy foods.

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Review

Plant-Based Cheeses: A Systematic Review of Sensory Evaluation Studies and Strategies to Increase Consumer Acceptance

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Abstract: Animal protein provides unique sensory and textural properties to foods that are not easily replicated when replaced with plant-based alternatives. Food scientists and researchers are currently developing innovative approaches to improve their physical and sensory characteristics in plant-based analogs. In terms of plant-based cheese substitutes (PBCS), soy is the most commonly used plant-based protein but is associated with undesirable sensory attributes (i.e., beany and gritty). In order to determine if the approaches result in a significant improvement in sensory quality and liking, sensory evaluation is employed. The aim of this review is to summarize the original literature (n = 12) relating to 100% PBCS which utilizes sensory evaluation methods. Overall, a major theme identified in this review is the innovative strategies used to increase acceptance of PBCS, whether products are aimed at improving existing non-dairy-based cheese formulations or to more closely mimic a conventional dairy-based cheese product. Studies demonstrate processing and fermentation of soybeans and blending of non-dairy milks are potential ways to improve consumer liking of PBCS. A secondary focus is to discuss the current sensory methodology carried out in the reviewed literature. Future studies should consider using more specific measures of flavor and mouthfeel, integrate evaluation of consumer liking with instrumental textural methods, and use a larger more diverse group of consumers. The outcome of this review is to highlight the importance of integrating sensory science in order to help facilitate the improvement of the sensory and quality attributes of PBCS and streamline product development.

Keywords: non-dairy cheese; soy-based cheese; sensory evaluation; consumer acceptance

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1. Introduction

Augmented interest in plant-based foods has increased due to concerns related to health, sustainability, and animal welfare. In terms of conventional production of dairy, there are three major areas of concern: environment impact (emissions of greenhouse gases, pollution of soil and water, and land use), human health (exposure to zoonotic diseases and increased antibiotic resistance), and animal welfare (treatment of farmed animals, including disease, injury, and mental/emotional well-being) [1]. Therefore, plant-based products offer a more sustainable and ethical option to consumers that are rapidly increasing in popularity among consumers. As a testament to this, U.S. retail sales of plant-based substitutes that directly replace animal products grew 29% between 2017 and 2019 to reach a USD 5 billion market. In the dairy category plant-based cheese substitutes (PBCS) saw the most growth in a year-over-year retail sales comparison by increasing 95% in 2020 [2,3]. Within the plant-based product market, PBCS is an emerging segment that has yet to gain traction or interest from a diverse consumer base [4]. Although PBCS sales continue to grow, the category remains in its infancy compared to other plant-based analog categories (i.e., dairy and meat) [5,6] as PBCS only accounts for less than 1% of all total dollar sales of retail cheese [3]. In order to increase acceptance of these products, sensory methods can be employed to better understand sensory and quality attributes and whether they provide the desirable qualities of a conventional dairy-based product.

Consumer liking is arguably the biggest challenge for any plant-based substitute. From a US consumer standpoint, only 32% agree that PBCS taste as good as regular cheese, while 34% disagree, and another third of cheese consumers remain indifferent [4]. If the PBCS express quality attributes that meet consumers' expectations, then these substitutes can be a satisfactory replacement for a dairy counterpart [4]. The Food and Health Survey consistently shows that taste is the number one driver behind purchase intention [7], more important than price, convenience, and health. Therefore, it is important to develop a product that provides desirable sensory characteristics (i.e., taste, flavor, and mouthfeel properties). In summary, the low sales margins indicate that the consumer market is left unsatisfied and there is substantial room for improvement and growth within this product category.

For PBCS, there are two general approaches to the flavor profile: (1) those which intend to mimic the sensory attributes of conventional dairy cheese and (2) those that embrace the unique flavors and characteristics derived from the plant. The challenge with the former is that plant-based ingredients do not precisely mimic the sensory (i.e., flavor, taste, and aroma) and physical (i.e., mouthfeel and meltability) characteristics of dairy-based cheese which limits consumer acceptability. Yet, the latter expresses novel characteristics in products that may not be desirable to the majority of consumers which has resulted in a specific and narrow niche market. Regardless, if the goal is to mimic or embrace the sensory characteristics, the end product should have physical, functional, and sensory properties that consumers find desirable [8]. To achieve this, sensory evaluation, specifically hedonic evaluation, must be employed to assess the product performance.

Among the accessible published literature of PBCS, the focus has been on soy-based "spreadable" products. This work is not representative of the diverse ingredients used in PBCS products displayed on grocery store shelves. Between 2015 and 2020 coconut oil was the top ingredient in new PBCS, with other common ingredients dominating the retail market include modified and native starches and nut milks [9,10], while available research tends to focus on soft "spreadable" soy-based products. Soymilk's functional and nutritionally complete proteins [11] are comparable to cow's milk and the availability and affordability of soy [6] are some reasons why researchers tend to focus more on this dairy alternative. One potential limitation of soybeans are the concerns with high estrogen levels [12] and being a common food allergen. Relying on plant-based ingredients to simulate the processed nuance of dairy cheese, including the physical, chemical, and functionality properties, is no easy task and sensory challenges are inevitable. Like any plant-based ingredient, soybeans in particular exhibit flavor and mouthfeel challenges, specifically, beany flavor and gritty mouthfeel [6].

To the authors' knowledge, there has not been a review of the sensory attributes of PBCS. This systematic review focuses on the studies that have conducted sensory evaluation of PBCS. After performing the search, (see Methods below), it became clear that all but one of the studies focused on soy-based products and applied different processing techniques, approaches, or methods to improve consumer liking. As a result, the goal of this review is to summarize the literature aimed at improving consumer liking of soy-based PBCS. This review is organized by first summarizing the breadth of work published that aims to improve the sensory attributes and describe the results of the consumer sensory evaluation. We then summarize the current limitations within the existing literature in terms of the sensory evaluation methodology and suggest several areas of needed exploration that have yet to be examined (i.e., consumer segmentation and alternative plant-based proteins). There is an opportunity to improve the PBCS market by decreasing undesirable sensory characteristics and improving overall liking. In order to achieve this, sensory science should complement ongoing scientific research regarding PBCS in order to directly improve the quality and sensory attributes and lead to more efficient development processes.

2. Methods and Search Criteria

A systematic search was carried out using the Web of Science and Google Scholar on studies published in English through March 2021. The search used keywords pertaining to plant-based and imitation cheeses and included sensory evaluation. The following keywords included: "cheese analog(ue)s", "cheese substitutes", "imitation cheese", "cheese replacement", "alternative cheese", "non-dairy cheese", "cheese-like" and "plant-based cheese." Consumer studies coupled with other sensory evaluation analytical methods were selected using "consumer liking", "consumer acceptance", "consumer perception", "sensory quality", "sensory characteristics", "sensory properties", "sensory evaluation". The initial search identified 33 articles. We excluded online focus groups, surveys, and questionnaires, where data was collected based on verbal or visual information and not through sampling products (n = 8 articles). Following an initial search and secondary screening of the above criteria, the search resulted in the selection of 25 articles.

Within the plant-based literature, the term "analogue" is reserved for plant-based products that simulate properties of the conventional animal-based product [13]. While this established term indicates no animal-derived ingredients, within PBCS literature "analogue" is interchangeable for both 100% plant-based and products made with partial dairy ingredients [14,15]. This dual use of the term "analogue" in regard to PBCS has led to confusion within the scientific community. This review focuses on cheese analogs made without any dairy ingredients and studies involving 100% plant-based ingredients. Of the 25 articles found within our defined search query, we excluded 13 papers that evaluated cheese analogs made partially with dairy. Of the remaining 12 articles which evaluated 100% plant-based cheese: 10 PBCS were soft, spreadable products while 2 focused on hard or semi-hard cheeses; 5 were made with only soy and 6 evaluated blended ratios of soy and nut milks; 1 evaluated commercially available coconut-based cheese (Table 1). Only one study purchased commercially purchased products, all other studies created the product for the purpose of the study. Three studies included a conventional dairy-based product as a control [10,16,17]. All studies included a measure of acceptance or liking while four studies [10,16,18,19]. performed a combination of descriptive and hedonic evaluations (Table 1). It was also noted that several studies had limitations in their methodology for sensory testing, which are common errors, such as small participant pools, choice of control, and usage of trained panelists (described below in Section 4).

Table 1. Overview of PBCS articles employing sensory analysis.

Strategy	Ingredient	Sensory Method	Described Sample Size	Solution	Reference
Modified Fermentation	soy	H/D	10 panelists	Ferm/SB	Li, Q. et al., 2013 [16]
	soy	H/D	10 panelists	Ferm/SB	Li, Y. et al., 2020 [18]
	soy	H/D	14 participants	Ferm	Chumchuere et al., 2020 [19]
Blending Milks	soy/coconut	Hedonic	10 participants	Ferm/BM	Adejuyitan et al., 2014 [20]
	soy/groundnut	Hedonic	10 panelists	Ferm/BM	Khodke et al., 2014 [21]
	soy/tigernut	Hedonic	20 participants	Ferm/BM	Balogun et al., 2005 [22]
	soy	Hedonic	20 panelists	B*	Butool et al., 2015 [17]
Modified Processing	soy/coconut	Hedonic	not reported	Blanching/BM/SB	Kadbhane et al., 2019 [23]
	soy	Hedonic	20 participants	Acidification	James et al., 2016 [24]
	soy/cashew	Hedonic	30 participants	Blanching/BM	Oyeyinka et al., 2019 [25]
	soy/almond	Hedonic	50 participants	Ferm/BM	Arise et al., 2020 [26]
Commercial Products[A]	coconut	H/D	4 panelists	N/A	Saraco et al., 2020 [10]

H/D: hedonic and descriptive sensory methods; Ferm: fermentation; BM: blending milks; B*: blended carrot puree; SB: sodium bicarbonate; N/A: Compared commercially available products, Commercial Products[A]: One study compared attributes across commercially available products.

3. Literature Review

The sensory challenges for developing soy-based PBCS products have been most often attributed to undesirable beany flavor and gritty mouthfeel [6,16,27]. The beany flavor from soybeans occurs as a result of lipoxygenase activity [27], which does not occur in undamaged raw soybeans; however, in the presence of water and oxygen, an enzymatic process takes place and emphasizes off-flavors [28]. The gritty mouthfeel is a result of the larger, rough particulates, made up of proteinaceous, carbohydrate, and cellulosic components [29]. These attributes are often considered to be "off characteristics" which diminish the overall quality and acceptance of the soy-PBCS while their dairy counterparts remain smooth and uniform [16]. Adapting various soybean processing methods (i.e., posed solutions of fermenting, blending milks, blanching, and/or adding sodium bicarbonate) report a refinement in sensory characteristics which is necessary in order to increase overall liking.

One study completed a sensory profile of commercially available plant-based cheese and compared their acceptance to a conventional dairy-based cheese product. The remaining literature (n = 11) focuses on evaluating processing strategies to improve the liking and sensory qualities of PBCS (refer to Table 1). These strategies can be divided into three categories (1) modified fermentation (n = 3), (2) blending milks (n = 4), and (3) modified processing (n = 4) of soybeans. Here, we summarize the results of these strategies in terms of improving their liking using sensory evaluation methods, all of which suggest an improvement in sensory profile resulting in increased liking of PBCS.

3.1. Strategies to Improve Consumer Liking

3.1.1. Modified Fermentation

In order to prevent a gritty mouthfeel (sedimentation of large particles) and ultimately obtain a soy-PBCS with a smooth texture, alternate methods include the adoption of fermentation techniques. Specifically, the incorporation of lactic acid bacteria (LAB) softens the rough particulates in order to achieve a smoother texture when blended [30]. The role of soymilk fermentation is suggested to aid in removing the undesirable beany flavor while inadvertently improving the nutritional composition [16]. An additional method of incorporating sodium bicarbonate increases the pH which affects the protein structures of the soybean seed coats and allows for the reduction of the gritty mouthfeel [31]. The following studies incorporated combination approaches of sodium bicarbonate and various fermentation techniques were suggested to improve the beany and gritty characteristics expressed by soybeans, although no study specifically measured these characteristics.

Two studies Li, Q. et al. [16] and Li, Y. et al. [18] coupled both hedonic and descriptive testing methods to evaluate whether modified fermentation improved the sensory attributes and acceptance PBCS. Li, Y. et al. [18] initially soaked the soybeans in a 0.5% (wt/vol) sodium carbonate solution for 20 min before creating the soymilk. The milk was then inoculated with 3% of the LAB starter culture and/or *Geotrichum candidum* at 10^4 CFU/mL before undergoing fermentation. The control PBCS sample prepared with the LAB starter culture (which was not inoculated with *G. candidum*) was stored at 4 °C and used to compare maturation differences between the samples prepared with the combination of LAB and *G. candidum*. The samples were ripened in a variety of temperatures (4 °C, 10 °C, and 15 °C) and assessed at three different aging durations (21, 28 and 35 days). In the hedonic test, 10 trained panelists rated liking using a 5-point scale (0 = inconsumable, 1 = unacceptable, 2 = acceptable, 3 = satisfactory, and 4 = excellent). The panelists indicated that the highest-rated PBCS in terms of color, flavor, appearance, and overall liking was the sample which combined the LAB and *G. candidum* approaches (ripened at 10 °C for 28 days). Panelist ratings fell within the "excellent" category, which was higher compared to the traditional LAB PBCS product, which ranked "satisfactory" in terms of color, flavor, appearance, and overall acceptability. Following the hedonic analysis, a descriptive test was performed with the same panelists using a 5-point intensity scale (1 = little to 5 = very much). Ratings were collected for hardness, springiness, and chewiness. In terms of textural profile, the authors described the textural attributes to be improved in the combination approach describing the product to change from "brittle and hard" to "soft and sticky". The authors concluded that the combined approach exhibited a more stable, homogeneous structure, and presumably reduced the undesirable beany and gritty sensory properties, which ultimately increased the consumer likeability. It should be noted that the study did not ask panelists to rate the samples in terms of beany or gritty sensory attributes in order to determine whether this affected consumer acceptance. For this study, no formal statistics were reported for collected liking and intensity ratings. This study also performed objective measures of textural properties using a texture profile analyzer and measured the hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. While it can be advantageous to pair instrumental and sensory methodologies, in this case, no formal comparison was performed between instrumental and sensory data.

Using a similar approach as above, Li, Q. et al. [16] first soaked soybeans overnight in a 0.1% (*w*/*v*) sodium bicarbonate solution before undergoing different fermentation conditions which included LAB, glucono-delta-lactone coagulation, and/or enzymatic hydrolysis. Sensory analysis was used to identify which fermentation approach resulted in an increased consumer liking, and compared intensity ratings of appearance, color, creaminess, firmness, spread-ability, and flavor to a dairy-based control. Sensory characteristics were rated on a 9-point structured scale by 10 trained panelists. The results indicated that the highest-rated PBCS sample for all attributes was prepared using a combination of LAB and glucono-delta-lactone processes. This sample received an overall liking rating of 7.4 which was significantly different compared to other PBCS (only using one fermentation method), with ratings between 6.3 and 6.8. Although the dairy control ranked significantly higher in terms of overall liking, scoring a 7.7, the utilization of the combined fermentation methods made a significant improvement in the overall liking compared to PBCS products. The dairy-based control performed significantly better for every attribute, except for creaminess, which was not significantly different from PBCS prepared with combination of LAB and glucono-delta-lactone processes. Results of this study exemplify how a PBCS ranks in comparison to a conventional dairy cheese product and how incorporating a combined fermentation method can help improve the sensory characteristics of PBCS. Similarly, a texture profile analyzer was used to quantify textural properties (hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience); however, these results were not compared to hedonic performance. Combining instrumental and sensory data can be useful to identify relationships between textural properties and consumer liking. Further, it is suggested that this approach increases liking as a result of reducing the perception of beany or gritty sensory attributes; however, these attributes were not directly measured in this study.

Chumchuere et al. [19] evaluated the physicochemical properties of a (fried vs. unfried) semi-hard soy PBCS which utilized a combined fermentation approach, inoculated with LAB and *Streptococcus thermophilus*, and was ripened at 4 °C for 7 days. A group of 14 participants used a linear scale to rate liking and intensity of sensory attributes in order to identify if frying improved the sensory characteristics and overall liking. Results of the hedonic test indicated that the fried sample received a significantly higher rating for overall liking (average rating 54.1) compared to the unfried sample (average rating 33.5). The participants rated the intensity of taste (acidity, salty, bitterness, and astringency), flavor (strong, cheesy, fermented, beany, rancid), texture (firmness and open texture), and color. There were significant differences between the unfried and fried PBCS for color, firmness, open texture, astringency, and all but one flavor attribute (strong, fermented, beany, and rancid). Sensations that were rated as more intense included color, firmness, open texture, and strong flavor, and reduced intensity ratings for astringency and fermented and beany flavor. This study was able to confirm that frying PBCS increases liking by reducing undesirable sensory attributes (astringency, beany and fermented flavor). Intensity ratings on quality and sensory attributes help to understand the change in characteristics as a result of modified processing, which led to an increased hedonic rating.

3.1.2. Blending Milks

Blending different ratios of plant-based milks with soymilk results in an improved flavor profile compared to 100% soymilk PBCS. While no study specifically evaluated off-flavors or perception of beany flavor in any product, it is suggested that this attribute is reduced as a result of blending soymilk with alternative non-dairy milks. Adejuyitan et al. [20] created soft PBCS prepared using fermented soybeans prior to blending soy and coconut milks at 5 different ratios to combat the naturally beany flavor of soymilk. Using a 9-point hedonic scale, ratings from 10 untrained participants indicated that the highest-rated PBCS sample in terms of flavor, texture, taste, and mouthfeel, and overall acceptability was the 50:50 soy/coconut blend. This sample had an average overall acceptability rating of 7.3 compared to the 100% soy control, which was rated at 5.6, resulting in a significant difference between the two samples. This study shows that the combination of the two methodologies, fermentation and a blended ratio of plant-based milks, resulted in improved flavor, texture, and increased consumer liking.

Khodke et al. [21] created six soft PBCS at varying ratios of soy to groundnut (a legume crop formally known as peanut) milk in order to reduce the naturally occurring beany flavor of soymilk. Results of a hedonic evaluation (9-point hedonic scale) performed by 10 trained participants indicated the 90:10 soy/groundnut ratio received the highest acceptability rating compared to other ratio blends, including PBCS control, in terms of color, flavor, appearance, texture, and taste. When comparing the 90:10 blend to the PBCS control, flavor (7.8 vs. 6.3) and appearance (8.6 vs. 7) attributes saw the greatest improvement in ratings. The 90:10 blend received an average rating of 8.0 for overall acceptability while the control, 100% soy, rated 7.5. Statistical analysis was performed but was not structured in a way to evaluate whether the attributes were significantly different across sample categories. This comparison provides evidence that incorporating groundnut milk with soymilk can improve the flavor and texture which can help to increase overall acceptability.

Balogun et al. [22] created soft PBCS by blending soy and tiger nut milks prepared with six different ratios to combat the naturally beany flavor of soymilk. Using a 9-point hedonic scale, 20 untrained participants screened for PBCS product consumption indicated that the blended product prepared with 95:5 soy to tiger nut ratio received the highest ratings in terms of color, taste, texture, aroma, and overall acceptability. This blended PBCS had an average rating of 7.4 for overall acceptability where the 100% soy control had an average rating of 6.3. Statistical analysis revealed no significant difference between the 5% tiger nut blend and control PBCS. Significant differences were observed for liking of taste ratings between 5% tiger nut blend and control PBCS, with the blended product receiving significantly higher ratings (7.0 vs. 5.7, respectively). Even with a small percentage (5%) of soy milk replaced with nut milk, it is suggested to reduce the beaniness of soy which results in improved flavor, texture, and overall consumer liking. For this study, it was not determined whether beaniness was specifically reduced; however, it was observed to improve taste compared to a 100% soy PBCS. Even though the incorporation of tiger nut milk improved liking of taste, for this study, it did not translate to a significant increase in overall acceptability of PBCS.

Other than blending with nut milks, one study has provided evidence of blending soy with carrot puree to improve the liking of soy-based PBCS compared to a dairy control. Butool et al. [16] incorporated different ratios of carrot puree at 10% and 20% ratios in order to improve the appearance, flavor, texture, color, acceptance, and nutritional value of the soy-PBCS. Although off-flavors were not exclusively acknowledged by the authors, it was understood that soybeans naturally express beany flavors and that incorporating carrot puree within the PBCS may aid in masking these undesirable characteristics. The samples were compared to the customary dairy counterpart, 100% buffalo milk, which acted as the control, and all were prepared in a traditional curry dish. Participants included 5 trained and 15 semi-trained participants and were asked to rate each sample on a 9-point hedonic scale in terms of color, appearance, flavor, and overall liking. The sample with 20% carrot puree received the highest average rating of 8.4, compared to the dairy control sample which had an average rating of 8.5. A full-soy control was also rated by participants, receiving an average overall acceptance rating of 7.1. The greatest increase in ratings was observed for flavor, 6.5 compared to 8.3 for the PBCS control and 20% puree PBCS, respectively. While no formal statistics were performed, the authors concluded that incorporating carrot puree can lead to improvement in sensory characteristics (color, appearance, flavor, mouthfeel, taste, and overall liking). This study provides preliminary evidence that the incorporation of carrot puree into a soy-PBCS is able to produce a product that is not different from a conventional animal cheese product when incorporated in a meal.

3.1.3. Modified Processing of Soybeans

In order to eliminate the beany flavor, blanching and grinding soybeans at or above 80 °C has shown to reduce lipoxygenase activity in order to improve these sensory properties [16]. Additionally, incorporating sodium bicarbonate results in the softening of soybean seed coats [31] in order to reduce the gritty mouthfeel expressed [6]. In the following studies, the methods of sodium bicarbonate, blanching, or blending a variety of plant-based milks at different ratios were utilized in order to improve the sensory characteristics of soy-based PBCS. This section reviews studies that performed modified processing, which often entails blending soybeans with other non-dairy milks.

Kadbhane et al. [23] created a spreadable PBCS with soybeans that were blanched in 0.5% $NaHCO_3$ solution for 10 min prior to blending 5 different ratios of soy to coconut (90:10, 80:20, 70:30, 60:40 and 50:50). All samples were ripened at 4 °C, sampled at day 1, day 3, and day 6 of maturation. For this study, there was no 100% soymilk PBCS control sample, and instead the samples were compared against each other and the maturation days prior. Results of a composite scoring hedonic test, with an unknown amount of participants, indicating the most preferred maturation period fell at day 1. In terms of PBCS samples, the 50:50 sample received the highest ratings in terms of appearance, texture, color, flavor, and overall acceptability. Overall, the 90:10 ratio consistently was rated the lowest while the 50:50 blended ratio was rated the highest in every category and for every maturation day (1, 3, and 6). For this study, no statistical analysis was performed. Nonetheless, this provides preliminary evidence that blending soy and nut milks and sodium bicarbonate could help to improve the likeability of PBCS.

James and colleagues [24] created 3 soft soy PBCS samples using different coagulants (lime juice, alum, and steep water) to further understand the physicochemical, sensory, and microbial effects of the PBCS. A hedonic test was performed with 20 participants who rated appearance, aroma, taste, mouthfeel, and overall acceptability on a 9-point hedonic scale. The results indicated that only liking of mouthfeel was perceived as significantly different, with lime coagulated PBCS receiving the highest rating and significantly higher than the steep water coagulated PBCS, with no difference between either sample to the alum coagulated PBCS. There was a trend for the lime coagulated PBCS to be rated higher for all other attributes, but this was not significant. It should be noted that off-flavors and gritty mouthfeel were not exclusively acknowledged by the authors. This study suggests that lime could be used as a coagulant in order to improve mouthfeel properties, and future studies may want to specifically evaluate the sensory characteristics to determine if this helps to reduce the undesirable gritty characteristic.

In contrast to the studies described above, the following two articles used the largest sample sizes, $n = 30$ and $n = 50$, respectively [25,26], and sensory remained the focal point of the articles. Oyeyinka et al. [25] created soft PBCS while utilizing techniques of blanching soybeans for 30 min prior to blending soy and cashew milks at six different ratios in order to combat the naturally beany flavor of soymilk. The results of a 9-point hedonic test performed with 30 untrained participants (screened for product usage) indicated that blending soy with cashew milk did not result in any significant differences in any measures of liking, including overall acceptability. For this study, it is suggested that the addition of cashews may provide nutritional benefits while having the same level of acceptance among consumers compared to full soy PBCS.

Arise et al. [26] created a soft spreadable PBCS using a fermentation process that combined different blends of soy and almond milk ratios, which was tested in a sensory experiment prepared as breaded and fried. Although beany flavor was not exclusively acknowledged or described as a challenge, it is understood that all soybeans naturally express a beany flavor, and frying the PBCS coupled with the techniques described above will aid in decreasing these naturally undesirable characteristics. Results of a 9-point hedonic test performed with 50 untrained participants screened for "regular cheese consumption" indicated that the fried 70:30 soy to almond milk PBCS sample received the highest ratings in terms of overall acceptability. The 70:30 blend resulted in a significant improvement in overall acceptability compared to the 100% soy control (7.6 vs. 7.0, respectively). However, when looking at liking ratings for taste, color, texture, and aroma there were no significant differences in ratings between the 70:30 blend and 100% soy PBCS, but there was a trend for the 70:30 blend to have higher ratings for taste, color, and texture. Additional sensory studies are needed to determine if this approach results in masking of beany flavors or reducing grittiness. Overall, this study suggests blending soy with almond milk can improve the overall acceptability of PBCS.

3.2. Sensory Profile of Coconut-Based Cheese Products

Saraco and Blaxland [10] aimed to investigate if PBCS products were able to mimic the physical, sensory, and functional properties of their dairy counterparts or if further improvement would be needed. In contrast to the articles reviewed above, the authors did not create a PBCS but rather employed a descriptive sensory evaluation to assess the product performances between commercially available dairy and non-dairy cheeses in the UK. It was found that of the 109 commercially available PBCS, 74% of these products had coconut oil as their primary ingredient, while only 3% were soy-based. The most abundant variety of PBCS was mild cheddar. Based on these findings, the PBCS products that underwent sensory evaluation were all coconut-based and of the mild cheddar and semi-hard Italian varieties. In the descriptive analysis performed by 1 semi-trained and 3 trained panelists, two mild cheddar PBCS and two semi-hard Italian PBCS varieties were compared to their dairy counterparts and assessed based on their appearance, color, odor, mouthfeel, flavor, and aftertaste. Panelists also reported whether the PBCS products were deemed acceptable compared to their conventional dairy cheese. It was noted that not all PBCS sensory attributes were considered simultaneously comparable to their dairy counterparts. Results of the descriptive analysis concluded that neither the texture or flavor expressed in the semi-hard Italian PBCS were regarded as acceptable. The "yeasty" and "unpleasant onion/garlic" flavors, "oily" mouthfeel, and "sour" aftertaste were deemed potentially unacceptable to consumers compared to the dairy counterpart. While one of the mild cheddar PBCS expressed acceptable texture, the "rancid (intense)" odor, and "intense cheese rind" flavor deemed this sample potentially unacceptable to consumers. The other mild cheddar PBCS sample was the only non-dairy sample to have potentially acceptable attributes. Although the mild cheddar PBCS sample did not have a typical texture found in cheese it was deemed acceptable in both flavor and texture and was described as the following: with a "glossy, cheese-like, smooth" appearance, "pale yellow" color (similar to dairy sample), "waxy/mild/parmesan-like" odor, "oily/rubbery" mouthfeel (less resistance compared to dairy sample), "intense/typical processed cheese-like" flavor, and a "salty" aftertaste. This study demonstrates the wide variety in sensations that are perceived from two types of PBCS. The combination of rating specific sensory and quality attributes along with liking ratings can provide a greater understanding of the product profile and the relationship each attribute to the overall sensory experience, either leading to acceptance or rejection.

4. Review of the Sensory Methods

Sensory preferences are like a fingerprint, unique to each individual and influenced by many factors but the pulse is fueled by the same source, where consumers' purchase intention is ultimately driven by taste [32]. Regardless of whether the PBCS, either embraces the natural sensory characteristics of plant-based ingredients or closely mimics conventional dairy products, the finished product should have physical, functional, and sensory properties that consumers find desirable. However, as an instrumental technique, following proper standard protocols helps to increase rigor and minimize bias. While there is established work in PBCS using sensory approaches, common errors in sensory methodology and limitations of the current literature still exist. Below, we highlight some of these errors and limitations and also highlight areas that describe additional considerations when performing sensory evaluation for PBCS.

4.1. Limitations and Considerations for Current Literature

In the reviewed literature, there were differences in methodologies used, including data collection measures, number of participants, and whether participants received training. Many of the studies reported using trained panels which are known to induce bias when collecting hedonic ratings and may not be representative of the consumer population. While the incorporation of sensory analysis is helpful and suggests that it is a beneficial tool, there is an opportunity to improve upon the sensory methods utilized. There are limitations within the current literature that are notable, suggesting additional work is needed to validate findings. As noted above, the literature repeatedly describes beany flavor and gritty mouthfeel to be "off characteristics" and undesirable in soy products. These studies suggest that modifying fermentation, processing, or blending other plant-based milks approaches improves these sensory characteristics [16–31]. It is described that beany and gritty sensory attributes are reduced; however, no study directly measured these attributes during sensory analysis. To better understand the impact of blending milks and modifying processing steps of PBCS, sensory methods that quantify attributes, such as descriptive sensory analysis, could be performed to determine how these strategies impact sensory attributes such as beany and gritty. Other sensory qualities, such as mouthfeel characteristics, were understudied among these articles and provides an opportunity for future investigation of PBCS. Furthermore, out of the 12 studies reviewed, four did not undergo statistical analysis, and they were, therefore, unable to determine whether a significant improvement was achieved.

It should be noted that a combination of sensory methods can provide a more in-depth understanding between the perception of sensory attributes and their impact on liking/disliking. Integrating hedonic, discrimination, and/or descriptive testing can reveal important relationships between the sensory profile and consumer liking [33]. Another advantage is the combination of instrumental analysis with consumer liking. This approach can help to identify the connections between physical attributes with improved liking. For example, several studies reviewed here measured the textural profile which can help to link attributes like hardness and chewiness with consumer ratings of mouthfeel attributes; however, no formal analysis was conducted to better determine how textural attributes affected liking. Future studies can benefit from combining both sensory methods with instrumental analysis to provide a greater understanding of the physical attributes that drive liking and disliking of PBCS.

4.2. Consumers and Future Considerations for Segmentation

It is important to recruit a large and diverse group of participants screened based on consumption of PBCS or dairy-based cheese. Although smaller pools (n~20) are sufficient enough for trial hedonic testing, much larger groups (n = 75–150 [33] and even larger n = 200–500 [34,35] are crucial for more accurately predicting consumer acceptance in the market. While this process seems straightforward, recruitment for large sampling can be challenging due to screening parameters (i.e., allergies, availability, and product usage) and additional incurred costs, yet, provide a more rigorous/confident response rate. However, screening can provide a better understanding and deeper connection to types of PBCS consumers.

Dairy alternatives were once geared primarily toward consumers who actively avoided dairy due to allergy, intolerance, or a vegan diet. However, this is quickly changing due to emerging plant-based proteins and sensory quality advancements, coupled with concerns over environmental impacts, sustainability, health, and animal welfare, where more adults across dietary spectrums are choosing dairy substitutes [10]. In terms of PBCS and the current market, there are consumers who want to enjoy the nuance and embrace the uniqueness of the plant sensory in PBCS. Jeske et al. [5] explains that a noteworthy approach from manufacturers and consumers would be to appreciate the flavor of plant ingredients [5]. After all, why would a sunflower seed PBCS product not have a flavor profile of sunflower seeds [5]? Yet, there are consumers who expect PBCS to resemble their dairy counterparts in terms of traditional chemical (flavor, taste, and aroma) and physical (meltability and mouthfeel) properties. If the flavor, mouthfeel, or other sensory qualities of the end product are not what the consumer expects, it may result in rejection of that product [36]. With the potential for such a strong consumer segmentation, in the future, it may be worthwhile to further understand the diverse consumer segments of plant-based products. Consumers may also differ in whether the nutritional value of PBCS will influence acceptance, considering the differences in protein quality and calcium content, among other nutritional components, compared to conventional cheese products. If we better understand these consumer categories, it can be used to optimize plant-based materials specifically in PBCS to best cater to these different consumers.

Identifying an appropriate control is paramount for managing expectations and the performance of PBCS. Ultimately, the choice of the control hinges upon the goal of the PBCS, whether it is to embrace the uniqueness of the plant-based milk or to mimic sensory attributes of a dairy counterpart coupled with an all-encompassing consideration of sensory attributes, style, and functionality. Although the underlying goal of the PBCS was not explicitly expressed to the reader in the studies mentioned, it was gathered that there is a link between the goal and the choice of the control used in each study. While most studies used a 100% plant-based milk substitute as a control, three studies used a dairy counterpart [10,16,17]. If the intention is to embrace the natural PBCS attributes, comparing different kinds of PBCS will indicate if further refinement is needed or if the current product can be marketed. On the other hand, if the goal is to create a PBCS that fully mimics the chemical and physical attributes of conventional cheese then a dairy control should be used. Results will determine how the PBCS sensory properties compare to the dairy-based cheese product and depict whether further refinement is necessary or if there was an improvement in the development.

5. Conclusions

A human's sensory perception is indispensable and the investment in sensory evaluation is imperative. Sensory science is an important part of a product's development in its pre-commercial production life as it acts as the link in the chain which connects producers to consumers. Not only do consumers sometimes have the ability to detect odorants, among other sensory attributes, at lower levels than those of an instrument, but instruments cannot gauge pleasure, or predict liking as humans do [37]. Through the use of sensory evaluation, these studies demonstrate several promising processing techniques that can improve the overall quality (taste and textural) properties leading to increased liking of soy-based PBCS. These studies suggest that modifications in processing and addition of alternative milk products can improve consumer liking.

Emerging plant proteins may help to enhance the quality of PBCS. This can only be determined with the integration of sensory science. In terms of sensory evaluation, the only PBCS to be formally evaluated is limited to products either partially or fully prepared with soy and limited to spreadable products. Although some approaches reviewed here include blending nut milks with soy there are other plant-based ingredients that are used to produce PBCS without the use of soy. Few available studies explore other ingredients (i.e., corn [38], or zein [39] but do not incorporate sensory evaluation. Future research will help to uncover additional strategies along with more diverse plant-based ingredients to increase consumer acceptance of PBCS.

Sensory science can complement ongoing scientific research regarding PBCS in order to directly improve the quality attributes which can lead to more efficient development processes. Through the integration of sensory evaluation, product developers can gain a better understanding of ways to increase liking and acceptance by refining the sensory characteristics (i.e., flavor, meltability, mouthfeel, and aroma). Regardless of whether the PBCS intends to mimic the sensory experience of dairy-based cheese or embrace the naturally occurring flavors of plant-derived PBCS, expanding the product selection will better accommodate a broader audience of consumers which will therefore increase consumer sales.

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