beverages

Review

Exploring the Potential of Rice, Tiger Nut and Carob for the Development of Fermented Beverages in Spain: A Comprehensive Review on the Production Methodologies Worldwide

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Abstract: Rice, tiger nut and carob are Mediterranean products suitable for developing new foods, such as fermented beverages, due to their nutritional properties. These crops have a high carbohydrate content, are gluten and lactose-free and have a low allergenicity index. The development of fermented beverages from these crops can contribute to the Sustainable Development Goals by promoting human health and sustainable production and consumption. A narrative review of the nutritional value and potential functional activity of fermented beverages made from these crops was carried out. This literature review of existing studies on fermented and non-fermented beverages highlights their composition, production methodology, and health benefits. Fermented beverages made from these crops are high in fiber, essential fatty acids, vitamins (group B), and minerals. Fermentation increases the bioaccessibility of these nutrients while decreasing possible anti-nutritional factors. These fermented beverages offer several health benefits due to their antioxidant effects, modulating the intestinal microbiota and reducing the incidence of chronic degenerative diseases such as metabolic syndrome. Therefore, fermented rice, tiger nut and carob beverages can improve the Spanish diet by offering improved nutritional value and beneficial health effects. Additionally, these local crops promote sustainability, making them an appropriate choice for developing new fermented beverages.

Keywords: fermented beverage; carob; tiger nut; rice; antioxidants; microbiota; lactic acid bacteria; yeast; sustainability

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1. Introduction

The increasingly dangerous impact of climate change on food production is jeopardizing food supply and sovereignty, ultimately making it difficult to achieve the 2030 Sustainable Development Goals (SDG) of the United Nations [1]. Climate causes affecting the agri-food system range from droughts, floods, pest propagation, ocean acidification, etc. [2]. Spain might be among the countries most affected by climate change. According to the latest government report (ACCE Project), rainfall levels in Spain have decreased significantly in the last century and the average temperature of the country has risen. Spain is facing serious water availability issues and the generalized increase in temperatures is causing an increased rate of desertification, particularly in the south of the peninsula. It is estimated that, in the best-case scenario, the average temperature of the peninsula could increase by 0.6 degrees per decade. Therefore, Spain is one of the countries that suffers the most from the adverse effects of climate change [3].

In order to face these changes, different measures will have to be taken, and among these, those related to the food system will be necessary to ensure food sovereignty and reduce the agricultural impact on the peninsula's ecosystem. Thus, some new irrigation techniques, the use of resistant species, the reduction of waste, the development of new foods and the reuse of food industry by-products can be effective measures [4]. In this holistic framework between the SDG and the agronomic systems, SDGs 9 and 12 ("Industry, Innovation and Infrastructure" and "Responsible Production and Consumption", respectively) are particularly useful for innovating in new food businesses, agronomic systems, or new foods, as well as reducing food waste [5].

The development of new functional foods not only contributes to the food supply, but also contributes to consumer health and can be effective in helping to achieve more than one SDG, such as SDG3, "Good Health and Well-being" [6]. The Functional Food Center defines "functional foods" as "natural or processed foods that contain biologically-active compounds; which, in defined, effective, non-toxic amounts, provide a clinically proven and documented health benefit utilizing specific biomarkers, to promote optimal health and reduce the risk of chronic/viral diseases and manage their symptoms [7].

Despite the crisis caused by the COVID-19 pandemic, the size of the global functional food market was valued at USD 258,800 million in 2020 [8]. Among the most sold products were those aimed to enhance immunity, functional foods for athletes, foods aimed at improving digestion, foods rich in plant proteins, etc. From all the functional products, beverages play a fundamental role, probably due to their easy-to-ingest nature. Among the main functional beverages, milk beverages rank first, followed by those enriched with phytocompounds, omega-3 or fermented drinks such as kombucha; the latter registered a market figure in 2019 of USD 1.84 billion [9].

Fermentation may contribute to the development of new beverages as it has been found to aid in food digestibility, provide vitamins and minerals, reduce the amount of anti-nutritional compounds, and modify the organoleptic characteristics to make it more appealing to consumers; thus, the incorporation of this type of food into a diverse diet can contribute to improving the nutrition and health status of the population [10,11]. Several studies have found associations between fermented beverage consumption and health status [12–14]. Excluding alcoholic fermented beverages such as wine and beer, there is no other consumption of fermented beverages recorded in Spain, despite its extensive history of fermented foods such as yogurt, bread, fermented meat products and olives. These two latter types of food, although present in the Spanish diet, may not be a functional or healthy alternative for the population. In the first case, fermented meat products have high levels of salt, saturated fat, as well as the presence of nitrite or nitrate used as a preservative [15,16]. In the case of olives, they may have a high content of monosodium glutamate [17], since in case of an excessive intake, higher than the Acceptable Daily Intake (ADI) of 30 mg/kg of body weight per day indicated by the EFSA, certain susceptible population groups may suffer certain side effects such as headache, arterial hypertension and increased insulin levels [18].

When developing a fermented beverage that provides health benefits and meets SDG standards, proximity food categories should be chosen that are organoleptically accepted and suitable for fermentation. In this review, three typical Spanish crops (carob, rice, and tiger nut) belonging to three different food categories (legumes, cereals, and tubers) are taken into consideration to point out the current state of the art on the production of both fermented and non-fermented beverages. These products have been chosen for the following reasons: (i) their high content of carbohydrates (>40%), adequate for fermentation; (ii) their gluten and lactose free-nature; and (iii) their low index of food allergies.

The main reason for choosing this review topic is the limited history of consumption of healthy fermented beverages in Spain, despite being a major agricultural producer of the raw materials. While Spain has a rich tradition in food and beverage production, healthy fermented beverages have not been widely consumed or valued in the country. The implementation of these healthy fermented beverages has the potential to open new markets in Spain. Diversifying beverage options and promoting local and sustainable products can generate economic opportunities for local producers, small and medium-sized enterprises. Furthermore, it is worth noting that the incorporation of healthy fermented beverages into the Spanish population's consumption can have significant benefits for health and nutrition. These beverages often contain bioactive compounds and beneficial micronutrients for the body.

The choice of plant-based beverages is justified by the fact that they are generally a highly consumed food category. The production of plant-based beverages is more environmentally sustainable compared to those of animal origin, such as milk [19,20]. In addition, the development and marketing of these beverages do not present major obstacles since the raw materials have formed part of the gastronomic culture of the peninsula. The production process, which involves fermentation, only requires the implementation of quality and hygiene systems, and the microorganisms are generally recognized as safe (GRAS) by the FDA, while the sales process mainly requires a cold chain [21]

These beverages also have the potential to be considered novel foods. According to EU Regulation 2015/2283, a novel food is defined as one that was not consumed in significant quantities within the EU before May 1997. It can refer to an innovative food that has been recently developed, a food produced using new technologies and production processes, as well as a food traditionally consumed outside the EU. There is a positive list of new authorized foods, which includes foods traditionally consumed in non-EU countries, such as chia seeds (rich in omega-3 fatty acids), and foods made with the latest technological innovations, such as certain dairy products that are heat-treated or fermented, for example, with *Bacteroides xylanisolvens* (DSM 23964) [22]. The list also includes other fermented products, such as fermented apricot kernel drink, fermented wheat germ extract, and concentrates of various mushroom-fermented plant proteins. Therefore, since there is no record of consumption of fermented rice, tiger nut and carob beverages in the EU before May 1997, they could be considered novel foods.

One could also speculate on the sale price of these products, which could be in line with other fermented products already on the market, such as kombucha or kefir (5–10€ per liter). Since these kinds of products are perceived as healthy by some groups of the population, they will be willing to pay this extra price [23]. Furthermore, the development and commercialization of these beverages can be focused on both general and specific population groups. Examples of the latter are intolerant to lactose, celiacs, vegetarians or vegans.

2. Literature Search

For this narrative review, scientific articles for the narrative review were obtained from PubMed and Scopus.

For the bibliographic search, the following keywords were employed: "rice", "carob", and "tiger nut", combined with "drink", "fermented", and "beverage", using Boolean operators such as "AND" and "OR". Duplicate articles, as well as those not intended to study beverages or juices for food use, were first excluded. Scientific articles in languages other than English or Spanish, studies of other fermented beverages, and articles that did not grant access to the complete article were then eliminated. Finally, articles that did not consider the use of raw materials as one of the main ingredients or those that did not include information on the fermentation process were excluded. There was no time limit for the search in order to ensure the collection of the greatest number of articles possible due to the few publications found, especially in the case of carob and tiger nut. In the case of rice, due to a large number of studies, only the "ferment* rice beverage OR drink" combination was used. For a thorough review, studies, laws, and market information were added to better understand the context in which this work is developed.

In addition, information from sources such as government websites, associations, books, press articles, and official documents was used to provide additional data beyond review detailing the database searches, the number of reports screened, and the studies used.

3. Vegetable Beverages from Carob, Tiger Nut and Rice

Carob, tiger nut and rice beverages are produced from different cultures and come from different regions around the world. They are rich in nutrients and have contributed to feeding millions of people.

The production of plant-based beverages involves several stages, starting from the collection of raw materials and culminating in the production of final beverages. Generally, the production process begins with the cleaning and selection of the raw material, followed by grinding and filtration to obtain plant-based milk. However, the specific method used at each stage of the process can vary significantly depending on the raw material employed.

Figure 1 provides an overview of the main production methods for beverages made from tiger nuts, carob, and rice. In the case of tiger nuts, a prolonged soaking process is required to soften the tubers, while to produce carob-based beverages, a roasting stage of the beans before grinding is advised. In the case of rice-based beverages, the raw material undergoes a soaking and cooking process before grinding.

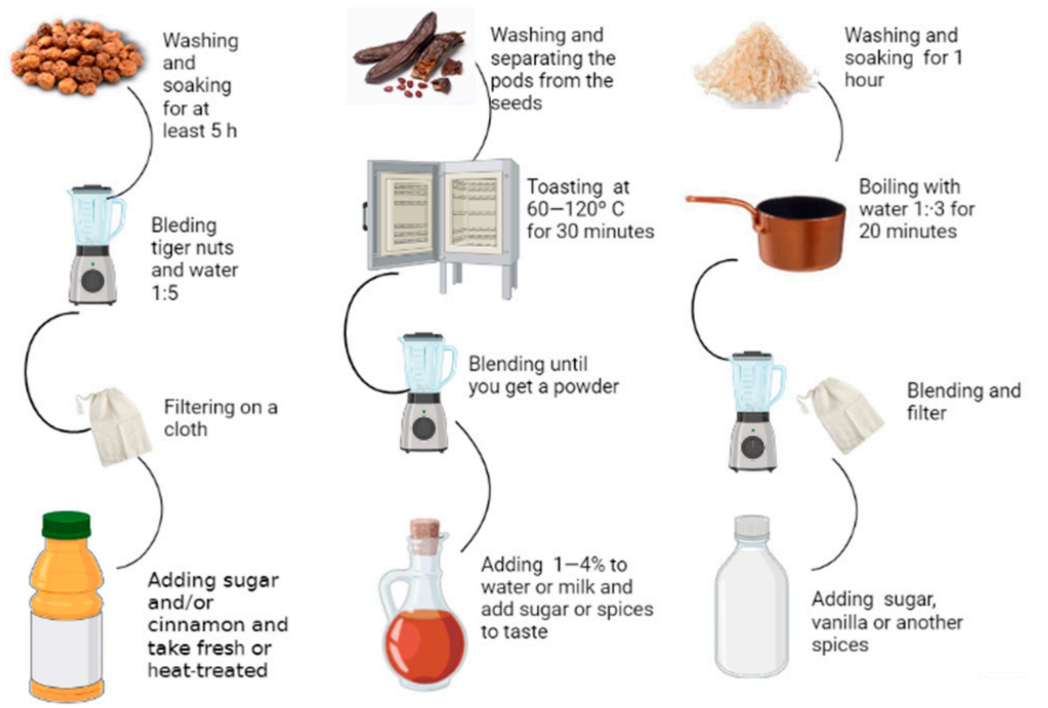

Figure 1. Different production stages for the plant-based beverages obtained from tiger nut, carob and rice, respectively (Image created using BioRender.com, version 2023).

In summary, the production of plant-based beverages consists of a multistep process specific to each raw material. The adequate selection of methods for each production stage is essential to achieve a high-quality and pleasant-tasting beverage.

3.1. Carob Beverages

The carob tree (*Ceratonia siliqua* L.) is a perennial plant belonging to the Fabaceae family, widely spread throughout the Mediterranean basin. It is an extremely drought-tolerant plant, requiring minimal care. Spain has a long-standing history of producing and consuming carob. Previously relegated to being a second-class plant, mainly used for animal feed or human food in case of food scarcity, carob cultivation is now experiencing exponential growth in modern markets due to its primary uses as a source for the extraction of carob bean gum, widely used as stabilizer and thickener (E410) in the food industry or as antidiarrheal in the pharmaceutical industry [24]. Carob is also used as a cocoa substitute, as it has a similar color and taste, making it a valuable raw material in the Spanish economy.

The nutritional value of carobs stands out since they are rich in fiber and minerals. Table 1 shows the nutritional value per 100 g of carob flour. The composition may vary depending on whether it is a pod, germ, or a mixture of both with/without other ingredients. The nutritional value of the flour (ground pods) is shown in Table 1, as they constitute the main raw material for the development of new foods [25].

Table 1. Energy and nutritional value of carob flour per 100 g.

Energy	220 kcal
Carbohydrates	89 g
Lipids	3 g
Proteins	4.7 g
Fiber	40 g
Calcium	380 mg
Iron	2.4 mg
Potassium	820 mg
Choline	11 mg

Source: USDA [25].

The high presence of simple carbohydrates makes it an optimal substrate for fermentation by microorganisms. In fact, in the scientific literature, it is possible to find a vast amount of studies on industrial fermentations of carob to produce a wide variety of compounds of interest, ranging from the production and purification of substances such as lactic acid or succinic acid to the production of biohydrogen [26–28].

The most common way of using carob in the production of beverages is by adding it as an ingredient in small amounts, especially in dairy drinks, to sweeten and flavor them as a substitute for cocoa [29]. Carob does not contain caffeine or theobromine, so it can be consumed by a larger population, such as the elderly, children or hypertensive people. The use of carob as the main substrate for the production of both fermented and non-fermented beverages is traditional in some cultures. Table 2 shows the main characteristics of both traditional carob-based drinks and drinks tested by laboratory experiments.

Table 2. Main characteristics of carob-containing beverages are traditional and elaborated specifically for experimental assays.

Name	Origin	Composition	Microorganism	Production Method	References
Jallab	Syria/Palestine/Lebanon	Carob, dates, grape molasses, rose water.	Not present, unfermented	Bring a mixture of the ingredients to a boil, filter and drink with ice.	[30]
Khar-rub	Morocco	Carob and water.	Not present, unfermented	Chopping the pulp, immersion in water at 80 °C with stirring for 45 min. Filtration and cooling.	[31,32]
Aloja (carob beer)	Argentina/Chile	Water, carob pods, sugar (optional).	Spontaneous fermentation (LAB and *Saccharomyces cerevisiae*)	The pods are crushed with a pestle and left to soak in the dark for more than 48 h.	[33,34]
Fermented carob-based alcoholic drink	Laboratory	Water, carob, sugar, enofer (potassium bisulfite meta, biphasic ammonium phosphate, ammonium sulfate) and levital®.	*S. cerevisiae*	Mix sugar with water. Add yeast to ferment the first broth, and add chopped carob and additives. Fermentation.	[35]
Carob-based dairy drink	Laboratory	Water, free fat milk powder, carob powder 4% (unroasted or roasted), no caloric sweeteners, soy lecithin, vanilla extract, carrageenan gum.	Not present, unfermented	Toast the pods for 60 min at 150 °C and crush. Mix the ingredients and bring to 75 °C for two minutes. Filter the mixture and store at 4 °C.	[36]
Fermented carob-based milk drink	Laboratory	Water, carob powder, powdered milk and cultures.	*Lactococcus lactis*	Add 4% (w/v) of carob powder to a reconstituted skimmed milk drink inoculated with *Lactobacillus* and incubate at 30 °C for 16 h.	[37]
Carob-based kefir-like beverage with whey permeate and oat flour	Laboratory	Carob pods. Kefir grains, whey permeate and oat flour.	Not present, unfermented	Bring a mixture of the ingredients to a boil, filter and drink with ice.	[38]

LAB—lactic acid bacteria.

Most carob-based preparations are artisanal mixtures that follow traditional recipes. Aloja is the only traditional fermented beverage made from carob, and it is typical in Argentina. After being soaked in water for over 48 h, fermentation is firstly driven by lactic acid bacteria (LAB) responsible for lowering the pH, followed by fermentation by yeast. Carob is a rich source of fiber, inositols (D-pinitol), and phenolic compounds (gallic acid, caffeic acid, catechin, myricetin, epigallocatechin and epicatechin). Its phenolic content may vary greatly depending on several factors (ripening time, genetic, environmental factors, etc.), but it can reach amounts of 500 mg gallic acid equivalent (GAE)/100 g [39]. The phenolic content of carob-based beverages is usually high, probably due to their dispersion in the liquid medium [31]. Although its bioavailability decreases in the intestinal phase during digestion simulation, the bioavailability of the phenolic compounds appears to increase slightly when the size of the carob flour particles is reduced [40]. During lactic acid fermentations, polyphenolic compounds are reduced, likely due to LAB metabolism and conjugation to lacteal casein [37]. However, in the case of alcoholic fermentations, these compounds slightly increase, likely due to the presence of ethanol as a yeast metabolite [34].

Regarding biological activity, studies associate carob with health benefits at different levels. The first and most well-known benefit of carob is its capacity to improve gastrointestinal disorders, especially acute diarrhea [41]. In these initial studies on carob and acute diarrhea in children, Akşit and colleagues [42] demonstrated that the concomitant administration of an oral rehydration solution and carob juice reduced the frequency of diarrhea by 45% in children. Carob also seems to be able to act by protecting the stomach from ethanol-induced toxicity, modulating the microbiota and antioxidant status, and exhibiting antihelminthic and antibacterial activity [43–47]. Carob could also be implemented to treat metabolic alterations related to both the lipid and the glycemic profile. Many in vivo and clinical studies have shown that carob pulp and fiber can reduce plasma insulin levels, lowering LDL- and increasing HDL-cholesterol levels in both healthy and hypercholesterolemic subjects by consuming 10–15 g daily. These benefits could be due not only to the possible cholesterol clearance in the intestinal lumen by the fiber but also to the phenolic compounds, which seem to act in the inhibition of inflammation by increasing the expression of *SIRT1* and activating the peroxisome proliferator-1- alpha receptor [48–53].

The phenolic compounds of the carob could also be responsible for its possible anticancer activity, although further research is needed in this regard [54,55]. Lastly, carob is also gaining the attention of researchers as a food against infertility, particularly male infertility, as various studies have shown that carob extract can improve fertility parameters. In mice, the administration of carob extract is able to restore testicular function and testicular regeneration after the administration of doxorubicin, and in mice, it prevents sperm DNA fragmentation after the administration of cyclophosphamide [56,57]. In three clinical trials, the administration of carob capsules (1500 mg) or carob syrup in infertile men improved the count, morphology, and motility of spermatozoa [58–60].

Based on the current articles, no carob-based fermented vegetable beverages without alcohol, yeast or animal products have been developed, so it would be interesting to consider the development of a fermented beverage free of animal products and low in alcohol beverages. Despite the fact that the consumption of alcoholic beverages is present in many gastronomic cultures, ethanol is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC), and therefore, there is no safe minimum level that is not 0 [61]. The consumption of non-alcoholic beverages is also suitable for children, elderly and pregnant women. Moreover, no studies have been conducted regarding the health benefits of carob fermented beverages. Carob-based beverages are well-received and organoleptically accepted, especially if the carob has undergone a previous toasting phase [36]. Carob is a widely used medium for industrial fermentation and as a thickener, yet its presence as food in the food industry remains low; thus, carob can be considered to innovate new food.

3.2. Tiger Nut Beverages

Tiger nut (*Cyperus esculentus* L.), "chufa" in Spanish, is a tuber that has been grown in the Iberian Peninsula for over 5000 years, and it has adapted to the local ecosystem. As the world's leading producer, Spain is spearheaded by the Valencian Community. Remarkable for its high oil content, tiger nut is mainly composed of monounsaturated fatty acids, which are far superior to other tubers and cereals, although its carbohydrate content, mainly starch, is still quite high (40%). The protein fraction, higher than other tubers, is mainly composed of albumins. Detailed studies have been conducted to evaluate the tiger nut's nutritional composition [62,63], being the main nutrients depicted in Table 3.

Table 3. Energy and nutritional value of tiger nut per 100 g.

Energy	409 kcal
Carbohydrates	42.5 g
Lipids	23.7 g
Proteins	6.1 g
Fiber	17.4 g
Calcium	69.5 mg
Iron	3.4 mg
Potassium	519.2 mg
Zinc	4.19 mg

Source: BEDCA [64].

Tiger nut is an underutilized crop that could be used to develop various food products, being of special interest in less developed countries due to its ease of growth and the possibility of storing throughout the year. Tiger nuts can be consumed raw or cooked, but its primary use is in the traditional Valencian beverage called "horchata" according to Royal Decree 1338/1988 [65]. "Horchata de chufa" is a nutritive product of milky appearance obtained mechanically from healthy, mature, selected, and clean *Cyperus sculentus* L. tubers. It is rehydrated, milled and extracted with potable water, with or without the addition of sugar, sugars or their mixtures, to give it a typical color, aroma and flavor. The minimum content of starch, fat and sugars must be specified for each type of "horchata de chufa" [65]. If the product contains added sugars, it is called "horchata" or natural "horchata". If it does not contain them, it is called "chufa" beverage, although the legislation also contemplates the term sugar-free "horchata".

Tiger nut has scarce research in evaluating fermentation as an alternative method for the development of new foods or as a substrate for the production of industrially interesting compounds. One of the earliest studies exploring tiger nut fermentation was to produce a 50% tiger nut yogurt [66]. The results showed that the 50% milk and 50% tiger nut yogurt had rheological and sensory characteristics similar to conventional yogurt, and it was the most accepted by the tasting panel, followed by cow's yogurt and, lastly, the one containing only tiger nut beverages.

Furthermore, when Bukola and colleagues [67] subjected the tiger nut to different fermentation methods (solid or liquid with spontaneous fermentation or inoculated with starter), the results showed that the microbial count during fermentation was in accordance with other fermented foods. Although the current objective of this study was not the development of a fermented tiger nut beverage, the results showed that the previously ground and fermented tiger nut in liquid medium contained the highest number of microbial counts and at a pH lower than 4, which could be taken into account when developing fermented drinks based on tiger nut. In 2021, Madsen and colleagues [68] conducted a similar study to develop a dessert similar to a "cold milk soup" made with tiger nut drink. To make the product more similar to commercial milk soup, vanilla, lemon juice, xanthan gum, sucrose, lecithin, and potato proteinated from various vegetable sources were added, as well as a commercial yogurt inoculum (containing *Lactobacillus delbrueckii* sp. *bulgaricus* and *Streptococcus thermophilus*). The commercial inoculum caused the least drop in pH compared to other strains previously isolated in the laboratory from different plant sources, indicating a worse fermentation performance. The authors hypothesized that commercial strains selected and developed from cow's milk sources might have greater difficulty in metabolizing sugars in a vegetable matrix. Similarly, the lower pH drop resulted in a sweeter taste than the sample fermented with isolated bacteria from vegetable, since the latter increased the acetic acid content, which was unpleasant. The use of thickeners such as xanthan gum helped the product to approach the rheological characteristics of commercial products, but without forming the typical gel structure of dairy derivatives, as found in earlier studies [68]. Few studies have been conducted attempting to explore the development of new drinks based on fermented tiger nuts, which are summarized in Table 4, excluding commercially known beverages such as "horchata" or sugar-free "horchata" among the others previously mentioned.

Table 4. Main characteristics of traditional tiger nut-containing beverages elaborated specifically for experimental assays.

Name	Origin	Composition	Microorganism	Production Method	References
Lactose-free fermented product from horchata	Spain	UHT tiger nut drink and various bacterial inoculum.	*S. thermophilus* BS5b and *L. acidophilus* BL228	Inoculate the culture in milk and ferment for 3 h and 45 min.	[69]
Fermented tiger nut drink milk	Nigeria	Tiger nut drink + inoculums isolated from tiger nuts.	*S. cerevisiae* and *Candida kefyr*, *L. plantarum*, *Lactococcus lactis*, *L. brevis*, *Lactococcus cremoris*, *L. bulgaricus* and *Lactococcus thermophilus*	Preparation of tiger nut milk, pasteurization at 90 °C for 15 min, fermentation at 45 °C for 18 h.	[70]
Fermented tiger nut beverage with different proteins	Germany	Tiger nuts, whey protein, sodium caseinate, goma xantana and tiger nut protein.	*L. delbrueckii* ssp. *bulgaricus* and *S. thermophilus*	Wash tiger nuts, grind, separation of the porridge by rotary evaporator, addition of 1/10 in water, add 0.1 g of xanthan gum and between 1–3 g of protein. Add 0.1 g of starter culture and let ferment for 16.5 h at 38 °C.	[71]
Kunun-Aya	Nigeria	Tiger nuts, palm date, coconut water and spices.	Without fermentation or spontaneous fermentation	Washing of the tiger nuts, soaking for more than 5 h, crushed together with the other ingredients and filtering through meshes.	[72]
Milk drink with tiger nuts	Pakistan	Milk permeate (60%), tiger nut drink (30%), sugar (5%).	*L. plantarum*, *L. acidophilus*; *L. brevis*	Mixing of ingredients heating to 90 °C for 5 min and then cooled to 40 °C.	[73]
Tiger nut beer	Nigeria	Tiger nuts, barley, water, commercial enzyme and yeast.	*S. cerevisiae*	Tiger nut flour, heat to 70 °C to get gelling, add enzymes to convert starch into sugars, add barley, water and yeast.	[74]
Tiger nut wine	Nigeria	Tiger nut drink, zobo flower, sugar, yeast extract, ammonium phosphate and potassium phosphate.	*S. cerevisiae*	Mix of ingredients and alcoholic fermentation for 7 days.	[75]
Tiger nut kefir	Turkey	Yellow or brown tiger nut drink together with kefir granules.	*Lactobacillus paracasei*, *L. casei*, *L. hilgardii*, *L. nagelii* and *S. cerevisiae*	Inoculation of 2% kefir grains in tiger nut drink and fermentation until pH 4.6 and cooling to 4 °C.	[76]

One of the earliest studies on tiger nut fermentation was conducted by Wakil and colleagues [70], where tiger nut drink was subjected to spontaneous fermentation and fermentative strains were isolated. LAB strains (*Lactobacillus plantarum*, *L. brevis*, *L. cremoris*, *L. bulgaricus* and *Lactococcus thermophilus*) were isolated, as well as *S. cerevisiae* and *Candida kefyr* yeasts. Subsequently, the isolated strains were re-inoculated into another tiger nut beverage to evaluate fermentation kinetics, microbial growth, and consumer acceptability. Results showed an adequate growth of the starter cultures for proper fermentation, a low bacterial count of coliforms and a high acceptability of the panelists when the beverage was fermented with a mixed culture of LAB [70]. Similar results have been found in Patent ES2335783T3, where different LAB strains were tested for "horchata" fermentation, evaluating fermentation time, bacterial count, viscosity and flavor. The best results were obtained with the combination of the strains *S. thermophilus BS5* and *L. acidophilus BL228*, producing a creamy beverage with an excellent taste, according to panelists [69].

The use of a microbial consortium as a starter culture can be beneficial to improve fermentation processes in plant matrices, taking advantage of the diversity of microbial metabolism. One study examined the behavior of a tiger nut beverage inoculated with kefir grain (containing a mixture of LAB and yeast) with respect to several parameters [76]. Fermentation reduced anti-nutritional compounds and improved the synthesis of B vitamins, including vitamin B12, although a reduction in vitamin C caused by both pasteurization and fermentation was observed. Furthermore, fermentation increased the antioxidant status of the beverage from 77.8 to 101.8 mg gallic acid (GAE)/L, which highlights the potential of the use of kefir grains in tiger nut-based beverages.

In Nigeria, a traditional beverage made from tiger nuts, known as Kunun-Aya, is consumed. This beverage is generally prepared with tiger nuts, coconut, dates, cinnamon and clove. The production process is similar to that of the Valencian "horchata" and other tiger nut-based drinks: after a soaking period that can go from 5 h to a full day, the tuber is ground with water and additional ingredients and subsequently passed through a mesh. Kunun-Aya is predominantly consumed unfermented, although it can also be found fermented [72]. The main microorganisms isolated are LAB and *S. cerevisiae.* Due to the lack of control of the fermentation process, which is completely artisanal, it is not possible to define a specific consortium of microorganisms for the production of this type of drink due to the variability associated with spontaneous fermentations, and the presence of pathogenic microorganisms can even be detected [77].

Another research work found on lactic acid fermentation of tiger nut-based beverages was carried out by El-Shenawy et al. [73], who evaluated three different probiotic strains in different combinations (*L. plantarum*, *L. brevis*; *L. plantarum*, *L. acidophilus*;) on the probiotic behavior, rheological change and acceptability of a drink composed of 65% milk permeate, 30% tiger nut drink and 5% sugar. No major differences were found between the three samples, except for a lower acceptability of the mixture containing *L. acidophilus* and *L. brevis*, probably due to the higher production of acetaldehyde and diacetyl compared to the other two samples [73]. In another study, it was also shown how the addition of milk protein in fermented tiger nut beverages decreases syneresis and improves the aromatic profile, although the highest rheological characteristics were obtained by adding xanthan gum [71]. Additionally, other studies have evaluated the feasibility of the tiger nut for the elaboration of alcoholic beverages such as wine and beer, showing the viability of the process, although the alcoholic degree reached is lower than that of traditional wine and beer beverages. However, these beverages showed good organoleptic acceptability [74,75].

Tiger nut has been shown to possess various beneficial health properties beyond its optimal nutritional value. These include anticancer, immunomodulatory, cardiovascular, and improvement of intestinal microbiota effects. This is likely due to its macronutrient composition, consisting of soluble and insoluble fiber, monounsaturated and polyunsaturated fatty acids, as well as its high levels of phytocompounds [78–80]. The bioaccessibility of carotenoids, such as lutein, zeaxanthin, β-carotenes, and total polyphenols has been shown to be higher in tiger nut beverages than in flour, oil, and whole grains [81]. Additionally, gastrointestinal digestion has been shown to increase antioxidant activity, likely due to the release of polyphenols from the matrix due to hydrolysis or proteolysis. Further research has pointed out the potential health benefits of the phytochemicals contained in tiger nuts. Several studies have indicated that the polyphenolic compounds found in tiger nuts may be effective in reducing oxidative stress, which can lead to a variety of health issues, including cardiovascular diseases and cancer. In addition, compounds such as lutein and zeaxanthin, which are present in high concentrations in tiger nuts, have been suggested to have a protective effect on the eyes, reducing the risk of age-related macular degeneration. Finally, the high fiber content of tiger nuts has been linked to improvements in digestive health, as well as potential benefits in weight management and blood sugar control [82].

3.3. Rice Beverages

Rice (*Oryzasativa* L.) is one of the most nutritious and consumed foods in the world and has been cultivated and consumed for millennia. Rice is an important source of energy thanks to its high carbohydrate content, and it also contains essential nutrients such as proteins, vitamins, minerals and fiber [83]. This cereal is a versatile food that can be found in many ways, such as white rice, brown rice, red rice, wild rice, etc. Table 5 shows the nutritional value of white rice, which is the most commonly commercialized and consumed type.

Table 5. Energy and nutritional value of white rice per 100 g.

Energy	387 kcal
Carbohydrates	86.0 g
Lipids	0.9 g
Proteins	7.0 g
Fiber	0.2 g
Folate	20.0 µg
Niacine	3.1 mg
Calcium	10.0 mg
Potassium	110.0 mg

Source: BEDCA [64].

In addition to being a valuable source of nutrients, rice is also used as a base for many fermented products. In fact, due to the high consumption of rice in the world, probably it could have the largest number of fermented products, including dozens of fermented beverages [84,85]. Rice is not always an essential ingredient for these drinks, as its production can be made with a wide variety of cereals its production can be applied to a wide variety of cereals, depending on food availability. These fermented rice-based products are rich in probiotics, antioxidants and other beneficial compounds for health. They also have a unique flavor and texture that make them popular in Asian countries such as Japan, China, Korea, Thailand and several Latin American countries such as Panama, Ecuador, Costa Rica or Peru. Fermented rice-based beverages such as sake, mirin, amazake, shochu, huangjiu and "chicha" have been consumed for centuries [86]. These beverages are usually prepared with rice, water and microorganisms such as yeasts and bacteria but can also contain herbs, fruits or other cereals. The fermentation process begins with the washing and soaking of the rice, sometimes followed by cooking. Then, the microbial culture is added and left to ferment for several days or weeks. During this process, microorganisms break down the rice sugars and release aromatic compounds, organic acids and beneficial compounds that contribute to the unique flavor and texture of the drink. Table 6 shows the most documented fermented rice-based beverages in scientific literature.

Table 6. Main characteristics of rice-based beverages are traditional and elaborated specifically for experimental assays.

Name	Origin	Composition	Microorganism	Production Method	References
Sake and Mirin	Japan	Rice, water, koji, yeast and water.	Commercial: *Aspergillus oryzae* and *S. cerevisiae* Artisanal: *Lactobacillus* spp., *Acinetobacter* spp., *Staphylococcus* spp., *Bacillus* spp. and *Planococcaceae* spp.	Clean, cook the rice, let it ferment with the koji fungus for 24–48 h and add a solution of water and yeast. Ferment for at least 5 days.	[87,88]
Shochu	Japan	Rice or other cereals, white koji and yeast.	*Aspergillus luchuensis* and *S. cerevisiae*	Similar to sake but adding a distillation stage at the end of the process.	[89]
Amazake	Japan	Rice, water and koji.	*A. oryzae*	Cook the rice, allow to cool until reaching 50 °C, add rice/koji and leave to ferment for at least one day.	[90]
Rice beer/Bhaati jaanr/Makegeolli	Korea/India and other Asian countries	Rice, water, a variety of plants and artisanal inoculum.	Different inoculum and fermentation methods, *Lactobacillus* and *Bifidobacterium* most present together with *S. cerevisiae*	Mix the rice with the plants, water and inoculum and leave to ferment for a minimum of a week.	[85,91]
Chicha	Various countries in South America	Corn or rice, water and inoculum or spontaneous fermentation.	Many varieties of phyla (Formicute, Proteobacteria, Bacteroides and Actinobacteria)	Soak and cook the corn or rice to obtain a thick mixture. Then leave it to ferment and decant.	[92,93]
Isomalto-oligosaccharide (IMO) Organic Rice Syrup Fermentation.	Laboratory	Organic rice, distilled water, blending enzyme (BAN), saccharifying enzyme (FUNGAMYL, PROMOZYME), transglucosidase and reconstituted skimmed milk.	*L. plantarum* KCCM 12116 *L. casei* KCCM 12452 *L. acidophilus* KCCM 32820 *L. fermentum* KCCM 35269 *L. rhamnosus* KCCM 3241	Suspend organic rice in distilled water, heat raw rice to 95 °C for 40 min, inject liquefying enzyme at 0.02%, and inject saccharifying enzymes at 0.05% and 0.01%. Ferment with five starter strains.	[94]
Probiotic beverage using cereal enzymatic hydrolysate	Laboratory	Rice, water, 0.05% α-amylase, 0.05% amyloglucosidase and probiotic culture.	*Limosilactobacillus reuteri*	The cereals were soaked for 10 h, milled, gelatinized, added enzymes, filtered, evaporated, and cooled. Finally, it was inoculated.	[95]
Fermented rice beverage	Laboratory	Rice, water, and microorganisms.	*L. plantarum* L7	100 g of boiled rice was inoculated with L7 strain and incubated for 6 days. Samples stored at −20 °C.	[96]

Table 6. *Cont.*

Name	Origin	Composition	Microorganism	Production Method	References
Probiotic beverage of whole rice	Laboratory	Whole rice, water lipase, alpha-glucosidase, alpha-amylase, yeast extract, isolated soy protein, pyridoxine hydrochloride and inoculum.	GABA-producing lactic acid bacteria (*L. pentosus*)	Brown rice is milled into fine flour, mixed with water in a 1:3 ratio, digested with heat-stable α-amylase and glucoamylase, filtered through a sterilized muslin cloth, and inoculated with probiotics.	[97]
Probiotic beverage enriched with pea and rice protein	Laboratory	Inoculum, organic pea protein concentrate, organic brown rice protein, and water.	*L. acidophilus* CL1285, *L. casei* LBC80R, *L. rhamnosus* CLR2	Preparation of protein drink, 50/50 mix, pasteurization, reduction, inoculation of probiotic bacteria, packaging, incubation.	[98,99]
Fermented beverage obtained from soy and rice incorporated with succinoglycan	Laboratory	Nontransgenic bulk soybean, sugar, polished rice, inulin, succinoglycan, lactic culture, viscozyme and commercial enzyme.	*Streptococcus thermophillus*, *L. delbrueckii* ssp. *bulgaricus* and *L. paracasei*	Mix soybean and rice (70:30), process, filter and cool the product, add lactic culture, homogenize, distribute in containers, add sucrose and succinoglycan, homogenize, pasteurize, cool, add culture, incubate and store.	[100]
Fermented rice beverage with chestnuts	Laboratory	Glutinous rice, Chinese chestnuts, fungus, and three strains of lactic acid bacteria.	*Rhizopus oryzae* *Pediococcus pentosaceus* (DH16, DH20 and DH24)	Glutinous rice is washed and soaked, boiled. Add yeast and lactic acid bacteria. Ferment, add water, homogenize and bottle. Sterilize and add chopped chestnuts to the sticky rice before cooking.	[101]
Production of fermented beverages based on rice flour	Laboratory	Powdered rice (12% by weight), water, red grape must (10% by volume) and starter culture.	*L. plantarum* CCM 7039, *L. brevis* CCM 1815, *L. fermentum* CCM 7192, *Bifidobacterium longum* CCM 4990	Mix rice flour with water and red grape must, homogenize and cool. Then the starter strain was added and fermented at 30 °C for 24 h.	[102]

Sake is a traditional Japanese alcoholic beverage, also known as Japanese wine. To prepare this beverage, rice is cleaned, cooked and ground to obtain a rice puree, which is mixed with a koji starter (*Aspergillus oryzae*), a solid-state culture used as an enzyme source and a raw material for different fermentation processes [103]. This mixture is added to a solution of water and yeast, which is left to ferment for several days. Then, the resulting liquid is filtered and bottled. Sake has an alcoholic content between 15–25% v/v. Varieties of Sake have been documented where there is a greater presence of microbial species depending on the fermentation method of each place, for example, due to the use of uncooked rice [87]. In these varieties of sake, the genera *Lactobacillus, Acinetobacter* and *Staphylococcus* have been detected during the first 24 h, followed by *Bacillus* and secondary populations of *Staphylococcus* and *Planococcaceae*. This type of sake has shown greater acceptability among consumers, but the lack of standardization limits its production to an artisanal level since there is a possibility that undesirable microorganisms will develop [88]. In order to also avoid possible post-preparation contamination of commercial sake, the beverage is pasteurized after the fermentation process. Similarly to sake, mirin is made from rice, water, koji and yeast, but it contains more sugar and less alcohol. Mirin is often used in cooking to add a sweet flavor to different dishes. Although sake and mirin could contain interesting bioactive compounds, the high presence of ethanol restricts its consumption to a moderate intake in certain population groups [104].

Shochu is another typical Japanese beverage produced by a fermentation process similar to sake, but white koji (*Aspergillus luchuensis*) is used, and after fermentation, the drink is subjected to a distillation phase that greatly increases its alcohol content, up to 40% v/v [89,105]. In contrast, Amazake is a traditional Japanese non-alcoholic beverage made from a mixture of rice, water, and koji. This drink is naturally sweet, although some varieties include the addition of sugars. It is usually served cold and contains a great variety of digestible and indigestible sugars such as trehalose, maltose and raffinose. It also contains 20 amino acids, B complex vitamins, lipids and glycosphingolipids, as well as substances with antioxidant activity. Because it does not contain alcohol, it is suitable to be consumed at all ages, including children [90]. Amazake appears to have anti-fatigue activity, gut microbiota modulatory effect and the ability to improve intestinal motility and lipid metabolism, as well as to increase collagen synthesis. Unfortunately, the number of clinical trials on the benefits of Amazake for human health is limited, and current available studies have not yet been reproduced [106–109].

In addition to the typical Japanese rice beverages, there are other fermented beverages based on rice that are prepared using unique processes. Makgeolli, Bhaati Jaanr and rice beer are popular in Japan, China, Bhutan, Nepal, India and Korea. These drinks are prepared with rice malt and yeasts, as well as a variety of plant and vegetable ingredients, such as flowers and fruit peel ash, which act as fermentative bases for microbial growth. Studies have shown that LAB and yeasts are the main microbial components of these drinks. *Lactobacillus* and *Bifidobacterium* were the most usually found genera, with *Pediococcus acidilactici*, the main representative species, followed by yeasts of the species *S. cerevisiae* [85,91]. Some of the mentioned bacteria have been shown to maintain their viability intact during a gastrointestinal simulation, suggesting possible probiotic potential. However, no studies of the bioavailability or bioactivity of compounds of interest in these beverages are available. In addition to the described products, it is possible to find more fermented rice beverages in the Asian continent, but their production processes are similar to those described above or have not been well characterized, so they are not included in this review.

Fermented drinks based on rice are also found in South America, known as rice "chicha". This drink is typical of countries such as Ecuador, Brazil, Costa Rica, Peru and Venezuela. "Chicha" can be prepared with different cereals, depending on their availability at the time of production, although the most frequent ones are corn and rice. The preparation of traditional "chicha" is carried out in two stages. Firstly, the corn or rice is cut and soaked for one night. Secondly, a cooking process is applied until the cereal softens, and it is mixed with water at room temperature to obtain a thick mixture. The mixture is strained to separate the liquid and any solid particles. The liquid is poured into a container where it is left to ferment for one or two days. Finally, the "chicha" is decanted to separate the yeast and the sediment. In a recent study, 27 samples of whole "chicha" produced in different regions of Peru were analyzed, showing that *Firmicutes* and *Proteobacteria* were the dominant phyla in most samples, followed by *Bacteroidetes* and *Actinobacteria*. At the family level, *Lactobacillaceae* and *Acetobateraceae* were the most representative families detected in most samples. At the genus level, *Lactobacillus* was the most representative genus in all samples, followed by *Weissella*, *Leuconostoc*, *Lactococcus* and *Streptococcus* [91]. These results provide information on the bacterial composition of this typical Andean fermented drink, revealing its diversity. "Chicha" is a type of beverage that undergoes fermentation; this results in a drink that contains varying levels of alcohol, typically ranging from 2–12% *v*/*v*, depending on the duration of the fermentation process. As a result, "chicha" is considered an alcoholic beverage [93].

Since most fermented rice drinks presented so far come from artisan recipes and present discrete amounts of ethanol, it is interesting to focus on the development of probiotic LAB beverages through well-established processes and without, if possible, the presence of ethanol. Upon reviewing the scientific literature, different studies were found that try to explore lactic acid fermentation for the production of rice-based drinks. In one of these first studies, carried out by Kim et al. [94], low-purity isomalto-oligosaccharide (IMO) syrup was produced from gelatinized organic rice through treatment with commercial amylolytic enzymes such as BAN, FUNGAMYL, PROMOZYME and transglucosidase. Afterward, the syrup was inoculated with five different strains of *Lactobacillus*, and primary fermentation was carried out in reconstituted skimmed milk broth. The highest number of viable cells was obtained for *L. plantarum*, with 7.2×10^8 CFU/mL, and the highest dry cell weight was also that of *L. plantarum* (13 mg/mL). Lactic acid was quantified in the highest amount of 8125.78 mg/kg. These results indicate that *L. plantarum* is a good strain for fermenting IMO syrup preparations. However, no further evaluation studies of this drink were carried out to support these findings.

The use of glycolytic enzymes before rice fermentation is common in other experiments. A more recent study by Yang et al. [95] added α-amylase and amyloglucosidase at 0.05% to beverages formulated with different cereals, subsequently inoculated with *Limosilactobacillus reuteri*. The rice drink presented pH values of 3.53 after 24 h of fermentation. Regarding the volatile compounds analysis of the drinks, 3-furaldehyde and benzaldehyde were detected in the coix seed substrate but not in whole rice. The 2-pentyl furan content was higher in coix seed than in whole rice [95]. 2-acetylthiazole and benzothiazole were detected in whole rice, while they were not detected in quinoa. These differences in the content of aromatic compounds depend on the substrates used. In addition, the results of this study showed that fermentation of the four cereal substrates produced significant differences in the flavor of the food products obtained. Fermented rice showed a more obvious sweet taste, which may be due to the carbohydrates fermented by the bacteria during the fermentation process. Moreover, fermented rice had a slightly lower flavor intensity than the other three substrates. These results suggest that fermented rice is a good option for those looking for a sweet and mild flavor in their food products.

In another study, the probiotic effects of nine isolates of LAB from the traditional drink Bhaati Jaanr were evaluated and subsequently inoculated into a rice drink prepared in the laboratory. Among them, the *L. plantarum* L7 isolate was the most promising, as it had desirable properties such as variable pH tolerance, hydrophobicity of the cell surface, autoaggregation, susceptibility to antibiotics, and antibacterial activities [96]. When used as a starter for fermentation, this strain increased functional components and mineral bioavailability, improved acidification and the generation of organic acids, reduced starches and increased its antioxidant potential. These characteristics make rice drinks a functional beverage, as both rice and fermentation products can contribute to the better nutritional status of the population.

The functional potential of fermented rice beverages was evidenced through another study in which a probiotic beverage was developed using the probiotic *L. pentosus* 9D3 strain isolated from Thai pickled herbs and whole rice as key raw material. This beverage contained high levels of gamma-aminobutyric acid (GABA), probiotic cells, inhibitory activities against oxidative stress and enzymes associated with obesity and diabetes [97]. The product also presented good sensory and nutritional qualities and remained stable at low temperatures for long periods. This drink could be an alternative for those with lactose intolerance or vegan/vegetarian diets.

Fermented rice beverages can also be enriched with other ingredients to increase their nutritional value and their possible functional effects, such as adding other protein sources to the beverage. Manus et al. [98] evaluated the effect of fermenting a probiotic beverage enriched with pea and rice proteins on its protein quality. It was demonstrated that fermentation increased the quality of the probiotic pea and rice proteins (PRF), as well as the level of live probiotics present in the feces. In another study, the same research group evaluated the physicochemical stability, sensory properties and microbiological quality of a fermented beverage (with the same bacterial strains) enriched with PRF during storage at 4 °C. The results showed that protein enrichment induced an increase in the pH, titratable acidity, and viscosity of the PRF products, while fermentation led to a decrease in pH and viscosity. In addition, the PRF products preserved a high level of viable probiotics throughout the storage, which improved their nutritional and nutraceutical value [99].

In another study, the effect of the incorporation of inulin and succinoglycan oligosaccharides on the physicochemical properties, rheology, syneresis and probiotic viability of soy and rice fermented beverages with *Lactobacillus paracasei* was evaluated. It was found that these formulations improved the digestibility of the protein, reduced syneresis and maintained probiotic viability after being exposed to intestinal resistance tests [100]. In another recent assay, the taste-related metabolites, volatile compounds, and amino acids were examined in a traditional glutinous rice fermented beverage supplemented with chestnuts as a fermentation substrate for LAB. It was found that the beverage with chestnuts had higher sensory scores, a greater diversity of volatile and taste-related metabolites, a higher antioxidant activity against free radicals in vitro, and protection against oxidative damage in Caco-2 cells induced by hydrogen peroxide (H_2O_2), compared to the control [101].

On the other hand, in a more recent development, a probiotic rice beverage enriched with grape must was obtained. The fermented rice beverages with *Lactobacillus plantarum* CCM 7039 or a mixture of *Lactobacillus plantarum* CCM 7039 and *Bifidobacterium longum* CCM 4990 showed the highest counts of LAB, highest lactic growth rates, and lowest viscosities. In addition, these samples also had the highest values of taste, flavor, and texture, as well as the most acceptable acidity. The general sensory evaluation showed that these fermented rice beverages were the most acceptable to consumers. Therefore, these enriched fermented beverages have become an interesting alternative for the food industry [102].

4. Future Trends and Needs for Carob, Tiger Nut and Rice Beverages in Spain

Carob, tiger nut and rice are very common crops in Spain. This country represents the world's largest producer of carob, the Valencian Community, the main producer with an estimated 11,000 tons in 2019 (no more recent data has been found) [110]. Regarding tiger nuts, Spain is also the main producer in Europe, with a production of 5.3 million kilograms per year, with practically all of its production concentrated in the Valencian Community [111]. Finally, Spain is the second largest rice producer in Europe, with an annual production of over 700,000 tons. In Spain, the region of Andalusia leads the production of rice, followed by Extremadura as the second, Catalonia as the third, and the Valencian Community as the fourth largest producer of rice. It's worth noting that the "Arroz de Valencia" from the Valencian Community is the only rice variety among these four regions that has a Protected Designation of Origin. This means that the rice grown in this region meets specific quality and production requirements, making it a unique and highly valued product. Italy remains the top rice producer in Europe, with the

Piedmont region leading the production [112]. The abundant presence of these foods in the Spanish diet makes them an ideal option for the preparation of fermented beverages. These beverages contain a variety of micronutrients, such as group B vitamins, folic acid and minerals such as calcium, magnesium, potassium and phosphorus (Tables 1, 3 and 5). In addition, they contain a variety of bioactive compounds such as soluble and insoluble fiber and a high presence of phenolic compounds, mainly highlighting phenolic acids and flavonoids that can have a positive effect on health, such as possibly reducing inflammation and increasing antioxidant activity [113–115]. However, it is important to note that most of the beverages reviewed contain alcohol, which is not good for health [61–104]. Therefore, the consumption of fermented beverages with no alcohol content is recommended. Additionally, these beverages can also be considered symbiotic due to the presence of microorganisms and fermentable fibers, which can improve the nutritional profile through the synthesis of bioactive compounds such as vitamins and the reduction of anti-nutritional factors [116–118]. However, the results of the reviewed studies have also indicated a greater need for the characterization of microbial strains, as well as the evaluation of the interaction between different microbial species.

Moreover, there is an urgent need for more research to standardize production processes. The use of enzymes can be useful to facilitate the manufacturing process, as well as to improve quality control and final results [119]. Given that most of the found articles are based on microbiological studies, more extensive and in-depth research is needed to address the effects of these beverages on health markers such as blood pressure, cholesterol and blood glucose, as well as clinical trials to better understand the safety and efficacy of these drinks. Furthermore, it is necessary to evaluate the impact of additional ingredients such as sugar and additives to ensure the safety and quality of these drinks for human consumption.

The production of these beverages in Spain can offer an environmentally sustainable alternative as it is a local product, which reduces the carbon footprint associated with international transport. Scientific reviews and statistical centers around the world have shown that plant-based milk has little to no environmental impact compared to cow's milk. According to the available data, beverages of animal origin, particularly cow's milk, cause around three times more greenhouse gas emissions and use ten times more land and between 2 and 20 times more fresh water. Among the plant-based drinks analyzed in other reviews, rice milk has the lowest environmental impact. However, there are no data available for carob or tiger nut milk due to their low production [19,20].

5. Conclusions

The findings of this review highlight the potential of fermented rice, tiger nut, and carob beverages as healthy alternatives to promote the consumption of new fermented drinks. These beverages have a rich culinary heritage in various cultures worldwide, with each culture having its traditional recipes. However, this diversity impedes the standardization of these products in the market.

One limitation observed in most of the reviewed beverages is their high ethanol content, rendering them unsuitable for general consumption. Regarding carob, it is predominantly consumed in its unfermented form, and while there are extensive studies exploring industrial fermentation, there is a lack of research investigating the fermentation of this raw material. Tiger nut fermentation, on the other hand, is mainly studied in laboratory settings, lacking homogeneity among the studies, which makes it challenging to define optimal production conditions. In contrast, rice emerges as an ideal substrate for the development of these beverages, and the use of enzymes shows promise in enhancing microbial metabolism during fermentation.

The limited articles in this area suggest that these beverages can offer numerous health benefits, such as antioxidant and anticancer activities, as well as modulation of the intestinal microbiota. The implementation of consuming fermented beverages based on rice, tiger nuts, and carob can be a healthy and beneficial option for the Spanish population, particularly in communities where these ingredients hold significant importance in the local economy, such as the Valencian Community. This approach can promote sustainable and local production practices. However, it is crucial to consider the production of low-alcohol beverages to avoid potential deleterious effects. This can be achieved by avoiding the use of yeast and instead focusing on the utilization of lactic acid bacteria (LAB). Lactic acid fermentation has demonstrated its ability to increase the phenolic content and nutritional value of these beverages. Further research is necessary to standardize production processes, evaluate the effects of these beverages on health markers, and gain a better understanding of their safety and quality for human consumption. By addressing these aspects, it can be favored the widespread adoption of fermented beverages and harness their potential to promote health and well-being.

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