

Article

The Influence of Pomace Powder of Musky Squash on the Characteristics of Foamy Confectionery Products during Storage

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Abstract: This paper analyzes the possibility of using pomace powder of musky squash (PPMS, 10–30% of the formulation) for the manufacture of foamy confectionery products based on Jerusalem artichoke syrup, which is a natural substitute for sugar syrup used in the food industry. The content of biologically active compounds (polyphenols, carotenoids) as well as the antimicrobial and antioxidant properties of pumpkin powder were evaluated. Sensory analysis was applied to measure the degree of product acceptance and the analysis revealed that the optimal amount of PPMS accepted by the tasters was 15%. The addition of PPMS increased pH and free water retention, color, and lightness intensification. During the storage period (40 days), the hardness and gumminess showed an essential increase and the cohesion of the samples gradually decreased. The addition of PPMS led to the improvement of textural parameters, thus contributing to the extension of the shelf life of products by 10 days, compared to the control sample. Mutual information analysis was applied to determine the influence of PPMS concentration and storage time of foamy confectionery products on mean total score, mean sensory profile score, moisture content, water activity, antioxidant activity, hardness, cohesiveness, and gumminess. The results of this research indicate that the use of pumpkin pulp in the manufacture of foamy confectionery products can significantly increase their biological value and sensory characteristics and ensure an extension of the products’ shelf life.

Keywords: pumpkin pomace powder; foamy confectionery product; biologically active compounds; color analysis; quality; textural parameters; microbiological stability



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1. Introduction

Color is a key commodity indicator that influences consumer evaluation of a product. Nowadays, the problem of using synthetic food colorants in production is of significant concern, as frequent consumption of these additives can negatively impact consumer health. One possible solution to this problem is the use of natural pigments extracted from plant products, such as carotenoids, anthocyanins, chlorophylls, and betalains [1]. These pigments have powerful antioxidant activity and numerous health benefits, such as slowing down aging, nervous system restoration, and anti-atherogenicity, anti-cancer, and anti-inflammatory properties [2].

More than 1100 carotenoid pigments are known today; they give yellow, orange, and red colors in plants, fruits, and vegetables [3]. Carotenoids from plant sources are important phytonutrients for animal organisms, having multiple effects, including provitamin A activity [4]. Carotenoids are effective active oxygen scavengers and can reduce oxidative stress in the human body. They have an outstanding effect on chronic diseases, preventing cardiovascular and cerebrovascular diseases, eye diseases, osteoporosis, and cancer [5].

In plant sources, carotenoids are always accompanied by other biologically active compounds (BACs) with antioxidant properties, including polyphenols. Research by Milner and Duthie confirms the role of polyphenols as antioxidants in the prevention of degenerative diseases, especially cancer and cardiovascular diseases. Polyphenols are powerful antioxidants that complement and enhance the functions of antioxidant vitamins and enzymes, protecting against oxidative stress caused by excess reactive oxygen species [6,7].

Among the vegetable sources of BACs, especially carotenoids, we can list the pumpkin (family *Curcubitaceae*), consumed widespread in the Republic of Moldova. The carotene content of pumpkin fruits is 16–17 mg/100 g of raw product, but in some forms, it reaches 35–38 mg/100 g. The brighter the color of the yellow-orange pumpkin flesh, the more carotenoids it contains [4].

When a pumpkin is processed correctly, its beneficial substances are also preserved in the powder. Pumpkin pomace powder can be used as a β -carotene supplement in food products. The potential of pumpkin pomace powder in confectionery products has been demonstrated; it can be used as a color and flavor additive [8]. Its ability to retain water allows for extending the shelf life and freshness of the product [9].

The manufacture of food products based on local raw materials is today considered a priority area for the development of the food industry. Fortifying foods with functional ingredients from pumpkin pomace powder increases their nutritional value by providing antioxidants, dietary fibers, minerals, proteins, essential fatty acids, vitamins, and phytochemicals, which positively affect the body. At the same time, the use of pumpkin pulp pomace in the manufacture of foamy confectionery products can significantly increase their biological value as well as sensory characteristics.

Foamy confectionery products have a foam-like structure, made from whipped mass based on sugar syrup and a gelling agent, with or without the addition of other raw materials, food additives, and flavors [10]. The relevance of foam foamy confectionery products lies in the fact that their recipe and preparation technology are quite flexible. These products allow for the introduction of fruit or vegetable pomace powder as well as other functional ingredients, which will greatly increase its biological value without changing its basic properties.

This study aimed to develop a foamy confectionery product with pomace powder of musky squash (PPMS) and artichoke syrup to evaluate the effect of different concentrations of PPMS on the sensory characteristics, physico-chemical, and textural properties of the foamy confectionery products, including monitoring of the main parameters of the product during storage.

2. Materials and Methods

2.1. Chemical Materials

Folin–Ciocalteu phenol reagent (2.1 N) was purchased from Chem-Lab NV (Zedelgem, Belgium); 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) (purity $\geq 97\%$), 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid), diammonium salt (ABTS) ($\geq 98\%$), and 2,2-diphenyl-1-picrylhydrazyl-hydrate (DPPH) ($\geq 95\%$) were provided by Alpha Aesar (Haverhill, MA, USA). Gallic acid (GA) ($\geq 97\%$), quercetin ($>95\%$), and lutein ($>90\%$) β -carotene ($>93\%$) were purchased from Extrasynthese (Lyon, France). Methanol, ethanol, tert-butyl methyl ether, hydrochloric acid, ethyl acetate, petroleum ether, sodium hydroxide, phenolphthalein, sodium nitrite, sodium citrate, trisodium citrate, silver nitrate, hexane, boric acid, hydrochloric acid, Kjeldahl catalyst tablets (KjTabs) VST, sulfuric acid, potassium hydroxide, n-octanol, and acetone were purchased from Chemapol (Prague, Czech Republic). Buffered peptone water and potato dextrose agar with chloramphenicol were obtained from HiMedia Laboratories Private Limited (Maharashtra, India). All reagents were of analytical or chromatographic grade. Spectrophotometric determinations were performed using the spectrophotometer UV-1900 (Shimadzu, Tokyo, Japan).

2.2. Raw Material

The musky squash pumpkin (*Cucurbita moschata* L.) was purchased from the distributor “Aliment-Ulei” LTD in the village Parata, district Dubasari, Republic of Moldova (47.1008338928222660 latitude, 29.1191673278808600 longitude and 17 m altitude). The dry matter content was 9.9 ± 0.02 g/100 g and pH = 6.0 ± 0.4 .

2.3. Characterization of the Pomace Powder of Musky Squash (PPMS)

PPMS was obtained by drying and grinding musky squash pulp pomace. The musky squash pulp pomace was dried in a thermostat (Pol-Eko Aparatura ST 2, Wodzisław Śląski, Poland) with forced air circulation at a constant temperature of 60 ± 2 °C and a relative moisture content of 60–65%. Drying occurred for 20 h until the moisture content reached no more than 7%. Next, the dried mass was crushed using a grinder (Zimmer ZM-625, Rheinau, Germany) and sifted through a sieve with no more than 0.8 mm mesh size. The resulting PPMS was a homogeneous orange powder, which was stored in a dark, airtight container without access to light.

Physico-Chemical Analysis of PPMS

Moisture content (MC) was determined by the AOAC Standard (2005) gravitational method, by drying in an oven (Pol-Eko Aparatura ST 2, Wodzisław Śląski, Poland). For this purpose, $4 \text{ g} \pm 0.001 \text{ g}$ of PPMS was weighed and then dried at 105 ± 1 °C to constant weight (so that the sample mass between measurements did not differ by more than 0.004 g). Each sample was analyzed in triplicate [11,12].

Ash content (AC) was determined by the AOAC Standard (2005) method. Previously dried in the hot-air oven, samples were weighed in a crucible and heated at 600 ± 10 °C in a muffle furnace (Snol, Narkūnai, Lithuania) for 5 h until resulting in a gray ash, which was cooled in the desiccator and weighed [12,13].

The pH was measured using a pH meter (TESTO 206-pH2, Pruszkow, Poland) calibrated with buffer solutions pH 4.0 and 7.0, directly immersing the electrode in the beaker containing the sample macerated with distilled water, according to the AOAC (2012) method [14].

The titratable acidity (TA) was estimated by titrating a known volume of the sample against the standard, 0.1 N NaOH, using phenolphthalein as an indicator. The results were expressed in % malic acid [13,15].

2.4. Extract Characterization

The hydroethanolic extracts from PPMS and foamy confectionery products were obtained as follows: 0.5 g of the sample was mixed with 25 mL of 70% ethyl alcohol (1:50, *m/v*) and left in a dark place for 24 h. The mixture was further extracted by the ultrasound-assisted method (ISOLAB 621.06.006, Eschau, Germany) at 60 ± 1 °C for 30 min and a frequency of 37 Hz. The conditions used in ultrasound extraction were optimized to achieve a high yield of bioactive compounds, including polyphenols and flavonoids, which are responsible for the antioxidant effects. These conditions were selected based on the findings from our previous research [16,17].

After that, it was centrifuged (MPW-380R, Warsaw, Poland) at 5000 rpm for 10 min at room temperature. The supernatants were analyzed by spectrophotometric methods, which are indicated below.

2.4.1. Total Polyphenol Content (TPC)

TPC in hydroethanolic extracts was determined using the Folin–Ciocalteu reagent, following the procedure as outlined by Paulpriya et al. and Waterman et al. [18,19]. The analysis involved the use of a calibration curve of gallic acid standard (0–500 mg/L, $R^2 = 0.9977$). The findings were expressed in gallic acid equivalent per 100 g dry weight of pumpkin pomace powder (mg GAE/100 g DW).

2.4.2. Total Carotenoid Content (TCC)

TCC was assessed using a modified approach as outlined by Ghendov-Mosanul et al. [20]: 3 g of the material was subjected to extraction using a mixture of methanol/ethyl acetate/petroleum ether (1:1:1, *v/v/v*). After filtration of the extract, the residue underwent two additional extraction cycles using the same solvent mixture. The TCC was then determined by the spectrophotometric method. After plotting the absorption spectrum, the TCC was measured at the wavelength of maximum absorbance (450 nm).

2.4.3. Scavenging Activity of the Free Cation-Radical ABTS (2,2-Azinobis-(3-Ethylbenzothiazoline-6-Sulfonates))

The antioxidant activity (AA) of the hydroethanolic extracts was determined by the method described in the literature [21]. ABTS solution was produced by reacting 7 mM ABTS stock solution with 2.45 mM potassium persulfate (final concentration) for 16 h in the dark at room temperature. ABTS stock solution was diluted with ethyl alcohol to an absorbance of 0.70 ± 0.02 at 734 nm. To 3.9 mL of diluted ABTS solution, 100 μ L of sample or trolox standard was added and the absorbance was measured at 734 nm after 6 min of incubation at 30 °C. ABTS inhibition capacity was expressed in mg trolox equivalent per 100 g dry weight (mg TE/100 g DW) from the calibration curve constructed in the concentration range 0–500 μ mol/L (curve equation $R^2 = 0.9992$) for trolox, the water-soluble analog of vitamin E (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) [22].

2.4.4. DPPH (2,2-Diphenyl-1-Picrylhydrazyl-Hydrate) Free Radical Scavenging Activity

The scavenging activity of the DPPH free radical was determined in the hydroalcoholic extracts from PPMS obtained above (2.4.) by the spectrophotometric method, according to the method described by Paulpriya et al. [18]. Results were expressed in μ mol TE/g DW from the calibration curve (0–500 μ mol/L, $R^2 = 0.9992$) with trolox [22].

2.5. Preparation and Characterization of the Foamy Confectionery Products

2.5.1. Preparation of the Foamy Confectionery Products

PPMS in different concentrations (10% PPMS, 15% PPMS, 20% PPMS, 25% PPMS, and 30% PPMS) was used for the foamy confectionery products' preparation. Jerusalem artichoke syrup (carbohydrates: 69.5 g), finely chopped white gelatin (protein content: 87.2 g, carbohydrates: 0.7 g), and water were also used. The control sample (CS) was prepared without the addition of PPMS. The formula of the foamy confectionery products is presented in Table 1.

Table 1. Formulation of the foamy confectionery products.

Ingredients	CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
Gelatine	2.5	2.5	2.5	2.5	2.5	2.5
Water	15	15	15	15	15	15
Jerusalem artichoke syrup	50	50	50	50	50	50
PPMS	-	7	10.5	14	17.5	21

CS—control sample without pomace powder of musky squash; PPMS—pomace powder of musky squash.

Gelatin for swelling was soaked in water at a temperature of 20 ± 1 °C for 20 min. Jerusalem artichoke syrup was heated to a temperature of 120 ± 2 °C and swollen gelatin was immediately added, stirred to homogeneity, and whipped with a mixer (Vitek, Shenzhen, China) for 5 min. To the cooled mass, sifted (through a sieve with a mesh size not more than 0.8 mm) pumpkin powder was added and whipped for another 10 ± 1 min until a white foamy mass was obtained. The obtained mass was molded and kept at a temperature of 5 ± 1 °C for 5 h. After that, the product was cut into 4 cm sized cubes and dipped in sugar powder. The samples were hermetically sealed using vacuum packaging

and stored at a temperature of 4 ± 1 °C. The products were analyzed immediately after production and after 10, 20, 30, and 40 days of refrigerated storage (4 ± 1 °C).

2.5.2. Sensory Analysis of the Foamy Confectionery Products

To carry out the sensory analysis of the developed product, degustation according to ISO 6658:2017 was organized [23]. The product was evaluated according to the following criteria: consistency, smell, taste, structure, surface, and shape. A group of 9 people was formed for the tasting, which was carried out in degustation booths at room temperature using white light. Each sample was tested in duplicate in sensory analysis laboratories meeting the requirements of ISO 8589:2007 [24]. During the degustation, each participant was offered a sample of all subtypes of the developed product; each sample type was coded. Tasters rated each criterion in points from 0 to 5: 5—exceptional, ideal qualities; 4—appropriate quality; 3—with slight defects; 2—with obvious flaws; 1—with strongly pronounced defects; 0—altered, with big changes.

Each evaluation criterion was assigned an importance factor f_i , which was determined according to the degree of importance of the criterion with the overall evaluation: smell, taste, and color were the most important criteria ($f_i = 0.25$); for appearance and consistency, $f_i = 0.2$; for shape, $f_i = 0.1$ [25].

Calculations for this method included calculating the mean score P_m for each criterion, as well as calculating the mean fractional values P_{mp} and the overall mean score P_{mt} . Each criterion was subjected to the eigenvalue of the factor f_p , depending on the degree of importance of this criterion. The fractional values P_{mp} were calculated using the following formula:

$$P_{mp} = P_m \cdot f_i \cdot f_t \quad (1)$$

where P_m —the arithmetic means of the scores; f_i —importance factor; f_t —transformation coefficient, whereby the 5-point scale used is transformed into a 20-point scale to determine product quality and $f_t = 4$.

The overall average P_{mt} score was calculated by summing the P_{mp} values of all evaluation criteria. Based on this value, the final result of the analysis was determined and the product was given a score according to Table 2.

Table 2. The grade given to the product according to the overall average score.

Overall Average P_{mt}	Note
18.1–20.0	Very good
15.1–18.0	Good
11.1–15.0	Satisfactory
7.1–11.0	Unsatisfactory
0–7.0	Inadequate

2.5.3. Physico-Chemical Analysis of the Foamy Confectionery Products

AC of the foamy confectionery products was determined according to the AOAC method [12]. MC was determined according to Sudarmaji et al. by drying samples to constant mass using a Pol-Eko Aparatura ST 2, Wodzisław Śląski, Poland [11,26].

The pH was assessed utilizing a pH meter (TESTO 206-pH2, Pruszkow, Poland), according to the AOAC (2012) method [14].

The water activity (a_w) of the foamy confectionery products was measured at room temperature (25 ± 1 °C) using an electronic dew-point water activity meter, the LabMaster (Novasina AG, CH-8853 Lachen, Switzerland) [27]. Measurement of a_w was carried out until the value was concurrent.

TPC and AA were determined by the ABTS method for foamy confectionery samples (Sections 2.4.1 and 2.4.3) immediately after production. The AA of the samples was monitored at 10, 20, 30, and 40 days of storage. The physico-chemical properties, except for MC, a_w , and AA, were determined only on the first day of storage.

2.5.4. Texture Analysis

Texture indices of the finished product were measured using a TA.HDplusC texture meter (Stable Micro Systems, Godalming, UK) with a P/40 nozzle. Two samples of each sample in the form of $2 \times 2 \times 2$ cm cubes were placed in the work area of the slide and subjected to pressure from the nozzle of the device. The samples underwent two successive cycles under pressure, each equivalent to 50% of the sample height. There was a 15 s interval between the two cycles, and the testing speed was set at 1 mm/s. The quantitative parameters determined were hardness (maximum peak force in the first cycle), cohesiveness (the ratio of the positive area under the curve during the second compression and the first compression), and gumminess (multiplication of hardness by cohesiveness) [28].

2.5.5. Color Analysis

The color analysis was performed by determination of CIELab parameters using a Chroma Meter CR-400 (Konica Minolta, Tokyo, Japan) according to the method in [29]. The L^* , a^* , and b^* values of the samples were determined, where the L^* value indicates the lightness, a^* represents the green ($-a^*$)–red ($+a^*$) values, and b^* is from blue ($-b^*$) to yellow ($+b^*$). The overall differences in color ΔE^* were calculated according to the following formula:

$$\Delta E^* = \sqrt{(L_i^* - L_0^*)^2 + (a_i^* - a_0^*)^2 + (b_i^* - b_0^*)^2} \quad (2)$$

where L_0^* , a_0^* and b_0^* —the values of the control sample; L_i^* , a_i^* and b_i^* —the values of the samples with pumpkin powder.

The color intensity, or chromaticity (C^*), represents the vividness or saturation of a color [30] and was calculated according to the following formula:

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (3)$$

The yellowing index (YI) was calculated according to the following formula:

$$YI = 142.86 \times \frac{b^*}{L^*} \quad (4)$$

The browning index (BI) is defined as brown color purity and is one of the most common indicators of browning in food products containing sugar [31]. The BI was calculated using the following expression [32]:

$$BI = \frac{(a^* + 1.75 \times L^*)}{0.17 \times (5.645 \times L^* + a^* - 3.012 \times b^*)} \times 100 \quad (5)$$

2.5.6. Microbiological Analysis

The microbial analysis of the foamy confectionery products was carried out according to ISO standard methods. The stock solution was prepared by aseptically taking 10 g of each sample and placing it in a 100 mL flask containing 90 mL of sterile 0.1% buffered peptone water, then stirring and homogenizing for two minutes [33]. The suspensions were then diluted and serial dilutions of 10^1 to 10^3 were obtained in triplicates and used for the specific medium. Aliquots of 0.1 mL and 1 mL of each dilution were used for pour plating and spread plating, respectively, into the various media. Spread plating using potato dextrose agar with chloramphenicol (2%) was used to determine yeast and molds; the plates were incubated for 7 days at 25 °C, while the total viable count was at 37 °C for 48 h [34,35]. Acceptable levels of microorganisms were based on sanitary and epidemiological rules and standards [36].

2.6. Mathematical Modeling

The MATLAB R2016a program (MathWorks, Inc., Natick, MA, USA) was applied to determine the influence of the PPMS concentration and the storage time of the foamy confectionery products on the total average score, the average score of the sensory profile, MC, a_w , AA, hardness, cohesiveness, and gumminess. The mutual information values are measured in bits. The closer the bit value is to 1, the more pronounced the influence of the pumpkin powder concentration and storage time of the foamy samples [37].

2.7. Statistical Analysis

The findings are displayed in this paper as the mean values $\pm$ standard error of the mean based on three repeated measurements. Statistical analysis was conducted using Microsoft Office Excel 2007 (Microsoft, Redmond, WA, USA). One-way analysis of variance (ANOVA) was employed along with the Tukey test at a significance level of $p \leq 0.05$. Additionally, Statgraphics software Centurion XVI 16.1.17 (Statgraphics Technologies, Inc., The Plains, VA, USA) was utilized.

3. Results and Discussion

3.1. Physico-Chemical Indications and Phytochemical Proprieties of PPMS

The physico-chemical indicators and phytochemical proprieties of PPMS are presented in Table 3.

Table 3. Physico-chemical indicators and phytochemical properties of PPMS.

Indicators	The Value of the Indicator
MC, g/100 g	6.21 $\pm$ 0.05
AC, g/100 g DW	6.27 $\pm$ 0.06
pH	7.45 $\pm$ 0.05
TA, % expressed in malic acid	1.16 $\pm$ 0.07
TCC, mg/100 g DW	27.76 $\pm$ 5.01
TPC, mg GAE/100 g DW	237.15 $\pm$ 16.8
AA (ABTS), mg TE/100 g DW	681.01 $\pm$ 21.6
AA (DPPH), mg TE/100 g DW	300.03 $\pm$ 14.4

Antioxidant activity of ABTS and DPPH was determined for hydroethanolic extracts of pomace powder of musky squash (PPMS). MC—moisture content; AC—ash content; TA—titratable acidity; TCC—total carotenoid content; TPC—total polyphenol content; AA—antioxidant activity. ABTS—2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonates); DPPH—2,2-diphenyl-1-picrylhydrazyl-hydrate; GAE—gallic acid equivalent; TE—trolox equivalent; DW—dry weight. Results are presented as mean $\pm$ standard deviation.

In the result of the analysis of the physico-chemical properties and phytochemical proprieties of the raw material (Table 3), it was found that PPMS has a moisture content of 6.21% and is a rich source of ash (6.27%). The approximate PPMS compositions were more or less similar to the results of See et al., who observed lower AC (5.37%) but slightly higher MC (10.96%) in pumpkin powder [9]. On the other hand, an AC of 3.8% in PPMS was reported by Ptichkina et al. [38]. The same MC was within the safe limit, as Bothast et al. [39] noted that pumpkin powder with an MC greater than 14% was susceptible to fungal and mold growth. In PPMS, the TA was 1.16%, expressed as malic acid, close to the values recorded by Dhiman et al. of 1.03% [40]. In the research of this study, high TCC (27.76 mg/100 g DW) and TPC (237.15 mg/100 g DW) were found in PPMS, providing high AA. These values correlate with data from Bochnak et al. [41]. Hussain et al. [42] recorded lower values for TPC (134.59 mg GAE/100 g DW). Asif et al. [43] noted that the TPC determined in hot-air-dried samples was 67.6 mg/100 g DW, and that in freeze-dried samples was 63.7 mg/100 g DW.

Our study has shown excellent antioxidant potential (mg TE/100 g DW) in both assays of 681.01 (ABTS) and 300.03 (DPPH), respectively, for pumpkin powder used in foamy confectionery products (Table 3). Other studies have shown the AA of the powder pumpkin

pulp to be 0.53 mmol of AAE (ascorbic acid equivalent)/100 g, as well as a TPC of 192 mg GAE/100 g and a β -carotene content of 32.87 mg/100 g DW [44].

3.2. The Sensory Properties of the Foamy Confectionery Products

The influence of terms of storage on the quality of new types of foamy confectionery products was determined by changes in sensory and physico-chemical parameters within 40 days from the date of manufacture. Foamy confectionery products with PPMS were stored at a temperature of 4 ± 2 °C and a relative humidity of no more than 75%. The samples were packaged following current requirements in polyethylene or polyethylene film and a corrugated cardboard box for confectionery products weighing 150 g. The images of foamy confectionery products with PPMS are presented in Figure 1.

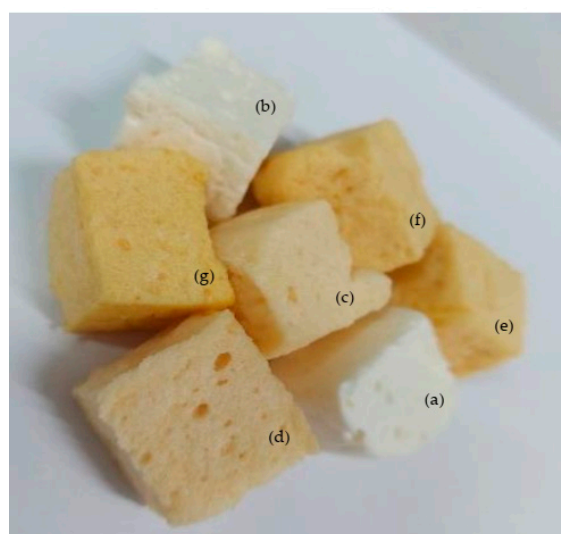


Figure 1. Image of foamy confectionery products: (a) classic commercial marshmallow, (b) control sample (CS)—foamy confectionery product without PPMS, (c) foamy confectionery product with 10% PPMS, (d) foamy confectionery product with 15% PPMS, (e) foamy confectionery product with 20% PPMS, (f) foamy confectionery product with 25% PPMS, and (g) foamy confectionery product with 30% PPMS.

Sensory analysis is important both for the general assessment of food characteristics and for assessing the quality and safety of products based on taste, smell, texture, and appearance. This analysis is necessary to determine consumer attitudes toward food products by measuring the degree of acceptance of a new product or improvement of an existing product [45,46]. The results of the sensory analysis are presented in Table 4.

The flavor of food is a manifestation of the complex interactions between aroma, taste, and oral sensations. Aroma, in particular, is associated with volatile compounds, while taste is linked with non-volatile, high-molecular-weight components [47]. The products exhibited a pronounced pumpkin flavor profile. Slices of the foamy confectionery products showed different shades of orange color, from light to more intense depending on the concentration range of PPMS, and the CS had a milky color typical of the product without dye. The added 10% and 15% PPMS showed more consistency in the foamy confectionery products, while lower values were found in the 25% and 30% PPMS products. The taste, odor, and intensity of the appearance of the pumpkin flavoring were highly evaluated in all samples.

According to the data obtained, the CS and the sample with a PPMS content of 15% were rated “Very good”, but the other processed product samples were rated “Good” and “Satisfactory”.

The optimal amount of PPMS from the tasters’ point of view was 15%; a higher amount of flour reduces the grade and sensory qualities of the product.

Table 4. Sensory characteristics of the foamy confectionery products with PPMS (results are presented as mean $\pm$ standard deviation).

Sensory Characteristics	CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
Total average score, taking into account factors of importance	18.96 $\pm$ 0.04 ^b	19.89 $\pm$ 0.05 ^c	20.00 $\pm$ 0.0 ^c	19.91 $\pm$ 0.06 ^c	19.56 $\pm$ 0.03 ^c	17.44 $\pm$ 0.05 ^a
The average score of the sensory profile	4.78 $\pm$ 0.05 ^b	4.98 $\pm$ 0.02 ^d	5.00 $\pm$ 0.0 ^d	4.98 $\pm$ 0.02 ^d	4.87 $\pm$ 0.04 ^c	4.31 $\pm$ 0.01 ^a
Taste and odor	4.56 $\pm$ 0.01 ^a	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	4.56 $\pm$ 0.01 ^a
Appearance	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	5.00 $\pm$ 0.0 ^b	4.56 $\pm$ 0.01 ^a
Consistency	5.00 $\pm$ 0.0 ^d	5.00 $\pm$ 0.0 ^d	5.00 $\pm$ 0.0 ^d	4.89 $\pm$ 0.04 ^c	4.56 $\pm$ 0.05 ^b	4.00 $\pm$ 0.03 ^a
Shape	4.89 $\pm$ 0.05 ^c	5.00 $\pm$ 0.0 ^d	5.00 $\pm$ 0.0 ^d	5.00 $\pm$ 0.0 ^d	4.78 $\pm$ 0.03 ^{b,c}	4.00 $\pm$ 0.02 ^a
Color	4.44 $\pm$ 0.03 ^a	4.89 $\pm$ 0.02 ^{b,c}	5.00 $\pm$ 0.0 ^c	5.00 $\pm$ 0.0 ^c	5.00 $\pm$ 0.0 ^c	4.44 $\pm$ 0.04 ^a

PPMS—pomace powder of musky squash. Different letters (^{a–d}) designate statistically different results ($p \leq 0.05$).

The results of changes in the average score of the sensory profile of the foamy confectionery products with PPMS during storage with consideration of importance factors are presented in Table 5.

Table 5. Changes in the average score of the sensory profile of the foamy confectionery products with PPMS during storage with consideration of important factors (results are presented as mean $\pm$ standard deviation).

Sensory Indicators/ Storage Date	CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
Total average score, taking into account factors of importance						
- first day	18.96 $\pm$ 0.08 ^g	19.89 $\pm$ 0.07 ^{h,i}	20.00 $\pm$ 0.0 ⁱ	19.91 $\pm$ 0.05 ⁱ	19.56 $\pm$ 0.04 ^h	17.44 $\pm$ 0.04 ^d
- 10th day	18.87 $\pm$ 0.06 ^g	19.84 $\pm$ 0.06 ^{h,i}	20.00 $\pm$ 0.0 ⁱ	19.91 $\pm$ 0.03 ⁱ	19.51 $\pm$ 0.05 ^h	17.36 $\pm$ 0.05 ^d
- 20th day	18.64 $\pm$ 0.09 ^f	19.76 $\pm$ 0.09 ^h	19.96 $\pm$ 0.03 ⁱ	19.78 $\pm$ 0.04 ^h	19.38 $\pm$ 0.07 ^{g,h}	17.24 $\pm$ 0.03 ^d
- 30th day	18.33 $\pm$ 0.04 ^f	19.56 $\pm$ 0.05 ^h	19.87 $\pm$ 0.05 ^{h,i}	19.60 $\pm$ 0.05 ^h	19.16 $\pm$ 0.05 ^g	16.93 $\pm$ 0.06 ^c
- 40th day	16.71 $\pm$ 0.07 ^{b,c}	18.11 $\pm$ 0.06 ^e	18.96 $\pm$ 0.07 ^{f,g}	17.09 $\pm$ 0.08 ^c	16.22 $\pm$ 0.03 ^b	15.18 $\pm$ 0.04 ^a
The average score of the sensory profile						
- first day	4.78 $\pm$ 0.02 ^{ij}	4.98 $\pm$ 0.02 ^k	5.00 $\pm$ 0.0 ^k	4.98 $\pm$ 0.01 ^k	4.87 $\pm$ 0.03 ^{j,k}	4.31 $\pm$ 0.03 ^{d,e}
- 10th day	4.76 $\pm$ 0.01 ⁱ	4.96 $\pm$ 0.02 ^k	5.00 $\pm$ 0.0 ^k	4.98 $\pm$ 0.01 ^k	4.84 $\pm$ 0.01 ^j	4.29 $\pm$ 0.01 ^{d,e}
- 20th day	4.67 $\pm$ 0.03 ^{h,i}	4.91 $\pm$ 0.03 ^{j,k}	4.98 $\pm$ 0.1 ^k	4.93 $\pm$ 0.02 ^k	4.80 $\pm$ 0.02 ^{ij}	4.27 $\pm$ 0.02 ^d
- 30th day	4.58 $\pm$ 0.01 ^f	4.87 $\pm$ 0.02 ^j	4.96 $\pm$ 0.03 ^k	4.89 $\pm$ 0.03 ^{j,k}	4.20 $\pm$ 0.01 ^{c,d}	4.20 $\pm$ 0.02 ^{c,d}
- 40th day	4.16 $\pm$ 0.02 ^c	4.47 $\pm$ 0.01 ^f	4.71 $\pm$ 0.02 ^{h,i}	4.24 $\pm$ 0.02 ^d	4.04 $\pm$ 0.01 ^b	3.80 $\pm$ 0.0 ^a

PPMS—pomace powder of musky squash. Different letters (^{a–k}) designate statistically different results ($p \leq 0.05$).

The effect of the storage period on the sensory attributes of the foamy confectionery products with PPMS was studied at predetermined intervals, as delineated above, to assess the acceptability of the product. The results (Table 5) indicated that the fresh product prepared with 15% added PPMS elicited a higher flavor score (20.00) than the CS without added PPMS (18.96). At 25 and 30% levels of added PPMS, the scores were somewhat lower (19.56 and 17.44).

With the advancement in the storage period, the flavor score declined consistently. On the 20th day, although the score diminished, it remained in good condition. Again, the foamy confectionery products prepared with 15% added PPMS obtained better scores than other samples. On the 30th day, the average score had decreased slightly to 4.96, indicating the acceptability of the product. On the 40th day, the products prepared with 25% and 30% levels of added PPMS were not acceptable based on flavor, as the score had declined to

above 4.0. In determining the mean interaction effect between x (PPMS concentration) and y (shelf life) on the consistency and shape of foam confectionery, it was observed that the maximum score was noted for samples prepared using 15% PPMS on the 1st (fresh) and 10th days of the storage period ($x_2 y_1$, and $x_2 y_2$). The scores for consistency and shape decreased consistently as the period of storage elapsed. The product remained acceptable for up to 30 days as far as consistency and shape were concerned. On the 40th day, the consistency and shape of the foamy confectionery products were unacceptable. The mean interaction effects between x and y on the taste, odor, color, and appearance of the score of the foamy confectionery products revealed that the maximum average score (5.0) was noted in samples made using 15% PPMS on the 1st and 10th days of the storage period ($x_2 y_2$). As the period of storage elapsed, the scores for the appearance of the product declined, but the trend remained almost the same. The 25% and 30% PPMS products elicited lower scores for appearance irrespective of the storage period. The product remained acceptable for up to 30 days.

The total average score based on taste, odor, appearance, consistency, shape, and color, recorded in Table 5, suggested that the maximum total average score, taking into account factors of importance (20.00) and the average sensory profile score (5.00), was perceived in samples prepared using 15% PPMS on the 1st and 10th days of storage ($x_2 y_2$). A slightly lower total average score (taking into account factors of the importance of the foamy confectionery products) and average score of sensory profiles were observed for samples made with 20% PPMS (19.91 and 4.98, respectively). Other PPMS combinations yielded products with lower scores. The total average score, taking into account factors of the importance of the foamy confectionery products, and the average score of sensory profiles diminished with advancement in the storage period. On the 20th day, the product elicited lower scores but it was in good condition and liked by panelists. On the 30th day, the score further declined but remained in fairly acceptable condition. The product was, however, not acceptable on the 40th day as evidenced by the overall acceptability scores declining to around 4.0. The results suggested that the use of PPMS extended the shelf life of foamy confectionery products and had an additive effect.

3.3. Physico-Chemical Analysis of the Foamy Confectionery Products

The physico-chemical indicators of the foamy confectionery products fortified with PPMS on the first day and during storage are presented in Table 6.

The addition of PPMS has a significant contribution to the physico-chemical properties of the foamed confectionery products. The AC of foamy confectionery products increased significantly ($p < 0.05$) as the proportion of PPMS additive increased. Thus, at a PPMS concentration of 10%, the AC increases by 14.3 times; at a PPMS concentration consisting of 30%, the ash content increases by almost 40 times. This may be because PPMS had a high ash content (Table 3). According to Ivanova et al. and Tamashevich et al. [48–50], the use of plant raw materials in marshmallow production led to an increase in macro- and microelements by 1.1–3 times compared to the control.

The addition of pumpkin powder leads to an increase in the pH value of foamy confectionery product samples from 5.71 to 6.42 depending on the PPMS added. Darwish, A. [51] studied the effect of pumpkin powder on the quality of yogurts in quantities from 1 to 5% and also confirmed that the pH level in pumpkin probiotic yogurts with the addition of pumpkin powder increased (from 4.53 to 4.98). The increase in pH levels in foamy confectionery products with added PPMS may be due to the presence of several protein-powder polysaccharides in the pumpkin [52].

Increasing PPMS concentration in foamy confectionery products led to the retention of free water and, respectively, to an increase in the moisture content of the foamy confectionery samples. Kita et al. [53] noted that the addition of fruit powders into snacks with Jerusalem artichoke also increased the water content of obtained products. During storage, the moisture content was reduced in all analyzed samples.

Table 6. Physico-chemical indicators, a_w and AA of the foamy confectionery products with PPMS (results are presented as mean $\pm$ standard deviation).

Indicators/Storage Date	CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
AC, g/100 g DW	0.04 $\pm$ 0.01 ^a	0.57 $\pm$ 0.01 ^{b,c}	0.79 $\pm$ 0.01 ^c	1.07 $\pm$ 0.02 ^d	1.34 $\pm$ 0.02 ^e	1.61 $\pm$ 0.01 ^f
pH	4.83 $\pm$ 0.01 ^a	5.71 $\pm$ 0.02 ^b	5.84 $\pm$ 0.02 ^{b,c}	5.98 $\pm$ 0.01 ^c	6.15 $\pm$ 0.01 ^d	6.42 $\pm$ 0.01 ^e
MC, g/100 g						
- first day	40.47 $\pm$ 0.03 ^l	36.63 $\pm$ 0.02 ^h	37.02 $\pm$ 0.03 ^h	38.15 $\pm$ 0.05 ⁱ	38.98 $\pm$ 0.03 ^k	40.85 $\pm$ 0.05 ^l
- 10th day	39.57 $\pm$ 0.03 ^k	34.08 $\pm$ 0.04 ^e	34.47 $\pm$ 0.06 ^e	36.96 $\pm$ 0.05 ^h	36.82 $\pm$ 0.07 ^h	39.02 $\pm$ 0.03 ^k
- 20th day	36.37 $\pm$ 0.06 ^{g,h}	32.80 $\pm$ 0.03 ^c	34.15 $\pm$ 0.05 ^e	35.59 $\pm$ 0.08 ^{f,g}	36.50 $\pm$ 0.02 ^h	37.85 $\pm$ 0.07 ⁱ
- 30th day	34.91 $\pm$ 0.07 ^f	32.42 $\pm$ 0.06 ^{b,c}	33.49 $\pm$ 0.05 ^d	35.27 $\pm$ 0.08 ^f	36.08 $\pm$ 0.05 ^g	37.04 $\pm$ 0.04 ^h
- 40th day	31.25 $\pm$ 0.04 ^a	31.40 $\pm$ 0.05 ^a	32.29 $\pm$ 0.06 ^b	34.03 $\pm$ 0.02 ^e	34.91 $\pm$ 0.04 ^f	36.53 $\pm$ 0.05 ^h
a_w , C. U.						
- first day	0.674 $\pm$ 0.0 ^l	0.629 $\pm$ 0.001 ^d	0.631 $\pm$ 0.001 ^{d,e}	0.646 $\pm$ 0.002 ^{g,h}	0.649 $\pm$ 0.001 ^h	0.670 $\pm$ 0.002 ^l
- 10th day	0.672 $\pm$ 0.001 ^l	0.629 $\pm$ 0.002 ^d	0.628 $\pm$ 0.002 ^d	0.640 $\pm$ 0.001 ^f	0.648 $\pm$ 0.002 ^{g,h}	0.665 $\pm$ 0.001 ^k
- 20th day	0.667 $\pm$ 0.002 ^{k,l}	0.617 $\pm$ 0.001 ^b	0.623 $\pm$ 0.002 ^c	0.636 $\pm$ 0.002 ^{e,f}	0.640 $\pm$ 0.003 ^{f,g}	0.664 $\pm$ 0.002 ^{j,k}
- 30th day	0.662 $\pm$ 0.001 ^j	0.615 $\pm$ 0.001 ^{a,b}	0.622 $\pm$ 0.001 ^c	0.635 $\pm$ 0.002 ^{e,f}	0.639 $\pm$ 0.002 ^f	0.664 $\pm$ 0.001 ^{j,k}
- 40th day	0.656 $\pm$ 0.001 ⁱ	0.615 $\pm$ 0.002 ^{a,b}	0.620 $\pm$ 0.002 ^{b,c}	0.634 $\pm$ 0.001 ^e	0.639 $\pm$ 0.001 ^f	0.665 $\pm$ 0.003 ^k
AA (ABTS), mg TE/100 g DW						
- first day	43.49 $\pm$ 0.16 ^a	60.20 $\pm$ 0.15 ^c	102.80 $\pm$ 0.45 ^e	116.20 $\pm$ 0.38 ^f	131.37 $\pm$ 0.46 ^h	133.89 $\pm$ 0.37 ^h
- 10th day	43.26 $\pm$ 0.11 ^a	62.78 $\pm$ 0.18 ^c	103.02 $\pm$ 0.38 ^e	116.44 $\pm$ 0.27 ^f	132.39 $\pm$ 0.39 ^h	133.95 $\pm$ 0.31 ^h
- 20th day	45.79 $\pm$ 0.18 ^a	62.82 $\pm$ 0.22 ^c	108.01 $\pm$ 0.41 ^e	123.42 $\pm$ 0.31 ^g	135.17 $\pm$ 0.41 ^h	134.63 $\pm$ 0.26 ^h
- 30th day	45.12 $\pm$ 0.10 ^a	59.02 $\pm$ 0.17 ^b	107.12 $\pm$ 0.38 ^e	125.42 $\pm$ 0.45 ^g	130.79 $\pm$ 0.26 ^h	133.28 $\pm$ 0.29 ^h
- 40th day	43.12 $\pm$ 0.21 ^a	43.80 $\pm$ 0.15 ^a	98.65 $\pm$ 0.26 ^d	110.13 $\pm$ 0.26 ^{e,f}	106.07 $\pm$ 0.19 ^e	99.63 $\pm$ 0.17 ^d

AC—ash content; MC—moisture content; a_w —water activity; AA—antioxidant activity; ABTS—2,2-azino-bis-(3-ethylbenzothiazoline-6-sulfonates); TE—trolox equivalent; DW—dry weight. Different letters (^{a–l}) designate statistically different results ($p \leq 0.05$).

Important properties characterizing the quality of products during storage are MC and the ratio of free and bound moisture in the product. It has been established that the rate of moisture loss depends on the food's chemical composition and the amount of pectinous substances, proteins, and sugars as well as and the presence of reducing substances (glucose, maltose, fructose, etc.) [54].

Pectin substances of fruit powders, including PPMS, have hydrophilic properties; they can firmly retain moisture in the product [55]. Therefore, the more PPMS in the formulation, the more firmly the molecules of the polysaccharides retain moisture in the sample, and the faster the rate of sample moisture removal decrease during storage. Thus, when the samples were stored for 40 days, the MC loss for CS was 22.8%, that for the sample with 10% PPMS was 14.3%, that with 15% PPMS was 12.8%, that with 20% PPMS was 10.8%, that with 25% PPMS was 10.4%, and that with 30% PPMS was 10.6%. Samples with PPMS can retain MC 1.1–1.3 times better after storage for 40 days, in comparison with the CS.

The a_w indicator does not exceed the norm, which indicates good resistance of the product to damage. The a_w value also decreases slightly during storage, which indicates the beneficial properties of pumpkin flour to slow down the chemical and enzymatic reactions in the product.

In the hydroethanolic extracts of foamy confectionery products, immediately after production, TPC was determined, which had average values between 35.07 and 58.23 mg GAE/100 g DW. The CS, without the addition of PPMS, had an average TPC of 10.68 mg GAE/100 g DW. This suggests that part of the polyphenols of the raw material had passed into the finished product. During storage, the TPC in the samples varied insignificantly.

The ABTS radical-cation scavenging activity of foamy confectionery samples with different concentrations of PPMS was monitored, starting on the day of manufacture and repeating every 10 days until day 40. AA in all samples was well preserved for 30 days, but on the 40th day, a decrease in values was observed. AA reduction is more insignificant during storage for samples with 15–20% PPMS. Our proximate findings were similar to the findings of Artamonova et al. [56]. A slight increase in AA values recorded on the 20th day of storage can be explained by redox reactions between the chemicals of the complete

food matrix. An analysis of literature sources shows that analogous dependencies were obtained for fruit extracts [57].

3.4. Color Evaluation of the Foamy Confectionery Products

The chromatic parameters L^* , a^* , b^* , C^* , YI , and BI of the foamy confectionery products prepared without and with PPMS addition are presented in Table 7.

Table 7. Changes in color indicators of the foamy confectionery products with PPMS (results are presented as mean $\pm$ standard deviation) during storage.

CIELab Chromatic Parameters	Samples of the Foamy Confectionery Products (First Day)					
	CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
L^*	79.03 ± 0.11^f	$76.1 \pm 0.07^{d,e}$	74.06 ± 0.06^d	71.89 ± 0.11^c	69.76 ± 0.08^b	65.34 ± 0.12^a
a^*	-2.07 ± 0.03^a	6.08 ± 0.05^b	8.14 ± 0.07^b	13.56 ± 0.06^c	20.76 ± 0.11^d	35.01 ± 0.09^e
b^*	23.01 ± 0.09^a	30.21 ± 0.12^b	38.02 ± 0.05^c	44.92 ± 0.08^d	52.04 ± 0.05^e	61.14 ± 0.11^f
ΔE^*	-	11.27 ± 0.08^a	18.83 ± 0.06^b	27.85 ± 0.07^c	38.08 ± 0.08^d	54.93 ± 0.10^e
C^*	23.1 ± 0.07^a	30.82 ± 0.08^b	38.88 ± 0.06^c	46.92 ± 0.07^d	56.03 ± 0.08^e	70.45 ± 0.09^f
YI	41.59 ± 0.09^a	56.71 ± 0.10^b	73.34 ± 0.07^b	89.27 ± 0.09^c	106.57 ± 0.09^d	133.68 ± 0.10^e
BI	156.1 ± 0.10^d	155.54 ± 0.09^d	149.85 ± 0.06^c	147.8 ± 0.08^b	147.07 ± 0.07^a	149.41 ± 0.11^c
Samples of the Foamy Confectionery Products (Recommended Day of Storage—30th day)						
L^*	78.58 ± 0.26^f	75.15 ± 0.21^e	73.52 ± 0.18^d	71.35 ± 0.22^c	68.99 ± 0.21^b	65.05 ± 0.19^a
a^*	-1.06 ± 0.02^a	5.03 ± 0.05^b	7.45 ± 0.08^c	13.04 ± 0.05^d	20.12 ± 0.10^e	34.25 ± 0.11^f
b^*	22.04 ± 0.13^a	30.54 ± 0.09^b	37.89 ± 0.11^c	44.18 ± 0.14^d	51.41 ± 0.11^e	60.85 ± 0.17^f
ΔE^*	-	11.00 ± 0.14^a	18.69 ± 0.15^b	27.23 ± 0.17^c	37.46 ± 0.13^d	54.19 ± 0.15^e
C^*	22.07 ± 0.09^a	30.95 ± 0.07^b	38.62 ± 0.10^c	46.06 ± 0.09^d	55.21 ± 0.11^e	69.83 ± 0.16^f
YI	40.07 ± 0.14^a	58.06 ± 0.19^b	73.63 ± 0.17^b	88.46 ± 0.21^c	106.46 ± 0.16^d	133.64 ± 0.17^e
BI	157.73 ± 0.15^d	154.09 ± 0.17^c	149.21 ± 0.16^b	147.79 ± 0.18^b	146.80 ± 0.13^a	148.97 ± 0.12^b

L^* —lightness; a^* —red–green parameter; b^* —yellow–blue parameter; C^* —chromaticity; ΔE^* —overall difference in color; YI —yellowing index; BI —browning index. Different letters (^{a–f}) designate statistically different results ($p \leq 0.05$).

The addition and increasing concentration of PPMS resulted in a color change (darkening) and yellow tint in the foamy confectionery products samples compared to the CS. The value of L^* decreased while the values of a^* and b^* increased. Increasing the concentration of PPMS affected the intensity of the yellow color. The more PPMS was added, the more intense the yellow color of the final product. This can also be seen in the C^* and YI values. An increase in the C^* value indicates an increase in the brightness of the foamy confectionery product color with increasing PPMS concentration; the color of the samples also becomes more intense. A logical relationship is also characteristic of the YI and BI ; a decrease in the BI and a proportional increase in the YI also indicate that the samples acquire a more saturated yellow color with an increase in the concentration of PPMS. The addition of PPMS resulted in a decrease in the lightness of the foamy confectionery products. Storage did not cause a significant change in coordinate L^* values in any of the foamy confectionery products analyzed. The addition of PPMS resulted in a significant increase in a^* values. It was found that for all foamy confectionery product samples, the values of L^* were over 50 and were in the clear zone [58]. It was found that the L^* of the foamy confectionery products showed a decreasing trend with the PPMS addition, which indicates that the experimental samples become darker compared to the CS. The value of L^* decreased, and darkening was increased with an increase in the PPMS concentration from 10% to 30%. This effect was caused by the presence of natural pigments, such as carotenoids, which are naturally found in pumpkin powder [59,60]. The values of the parameters a^* and b^* were positive, demonstrating the predominance of red color over green and a strong predominance of yellow coloration, in disfavor of the blue, respectively. The resulting color of the foamy confectionery products was yellow. It was also found that the values

of parameters a^* and b^* in the samples with PPMS were higher than in the case of the CS. This is probably due to the natural coloring pigments, carotenoids, in the PPMS. ΔE^* represents a dimensionless parameter, resulting from the combination of the L^* , a^* , and b^* values of the pairs of samples, which indicates whether or not there are differences in the colors perceived by the human eye, depending on the specific sensory thresholds [61]. Lo Faro et al. showed the difference between colors: if $\Delta E^* < 0.2$, there is an imperceptible difference; if $0.2 < \Delta E^* < 0.5$, there is a very small difference; if $0.5 < \Delta E^* < 1.5$, there is a small difference; if $2 < \Delta E^* < 3$, there is a barely distinguishable difference; if $3 < \Delta E^* < 6$, there is a very distinguishable difference; if $6 < \Delta E^* < 12$, there is a large color difference; if $\Delta E^* > 12$, they are completely different colors [61]. The values of ΔE^* were found to be $\Delta E^* > 12$, indicating completely different colors [62]. The storage resulted in a slight increase in coordinate a^* values that was the strongest in the case of the CS. The decrease in b^* values was not a significant change.

3.5. Textural Properties of the Foamy Confectionery Products

The results of the changes in the textural indicators of the foamy confectionery products with PPMS are presented in Table 8.

Table 8. Changes in textural indicators of the foamy confectionery products with PPMS (results are presented as mean $\pm$ standard deviation).

Textural Indicators/ Storage Date	CS	10% PPMS	Foamy Confectionery Products		25% PPMS	30% PPMS
			15% PPMS	20% PPMS		
Hardness, g						
- first day	387.2 $\pm$ 15.2 ^a	513.9 $\pm$ 18.4 ^b	587.8 $\pm$ 23.5 ^{b,c}	643.6 $\pm$ 11.8 ^c	695.3 $\pm$ 17.4 ^c	772.3 $\pm$ 21.4 ^d
- 10th day	590.0 $\pm$ 20.4 ^{b,c}	650.7 $\pm$ 26.2 ^c	735.2 $\pm$ 31.4 ^{c,d}	925.7 $\pm$ 22.1 ^e	989.6 $\pm$ 24.8 ^f	1138.8 $\pm$ 28.1 ^g
- 20th day	618.1 $\pm$ 31.5 ^{b,c}	737.8 $\pm$ 16.9 ^d	930.3 $\pm$ 27.1 ^e	934.5 $\pm$ 19.3 ^e	1246.3 $\pm$ 19.6 ^h	1363.1 $\pm$ 31.2 ⁱ
- 30th day	634.5 $\pm$ 29.7 ^c	823.0 $\pm$ 16.0 ^d	1080.0 $\pm$ 35.6 ^{f,g}	1090.8 $\pm$ 30.2 ^{f,g}	1264.3 $\pm$ 23.1 ^h	1586.1 $\pm$ 25.2 ^j
- 40th day	588.2 $\pm$ 31.3 ^c	835.1 $\pm$ 21.4 ^{d,e}	1120.3 $\pm$ 24.7 ^g	1200.3 $\pm$ 28.1 ^{g,h}	1280.1 $\pm$ 30.7 ^h	1602.3 $\pm$ 19.5 ^j
Cohesiveness, %						
- first day	1.38 $\pm$ 0.01 ^d	1.44 $\pm$ 0.00 ^e	1.38 $\pm$ 0.01 ^d	1.59 $\pm$ 0.02 ^{h,i}	1.71 $\pm$ 0.01 ^k	1.65 $\pm$ 0.02 ^{ij}
- 10th day	1.33 $\pm$ 0.02 ^{b,c}	1.38 $\pm$ 0.02 ^{c,d,e}	1.35 $\pm$ 0.01 ^{c,d}	1.51 $\pm$ 0.02 ^{f,g}	1.57 $\pm$ 0.02 ^{g,h}	1.65 $\pm$ 0.01 ^{ij}
- 20th day	1.32 $\pm$ 0.03 ^{a,b,c}	1.34 $\pm$ 0.02 ^{b,c,d}	1.33 $\pm$ 0.03 ^{b,c,d}	1.44 $\pm$ 0.00 ^e	1.55 $\pm$ 0.03 ^{f,g,h}	1.64 $\pm$ 0.02 ^{ij}
- 30th day	1.29 $\pm$ 0.02 ^{a,b}	1.34 $\pm$ 0.01 ^c	1.33 $\pm$ 0.01 ^{b,c}	1.35 $\pm$ 0.01 ^{c,d}	1.52 $\pm$ 0.02 ^{f,g}	1.56 $\pm$ 0.03 ^{g,h}
- 40th day	1.38 $\pm$ 0.02 ^{a,b}	1.33 $\pm$ 0.02 ^{b,c}	1.32 $\pm$ 0.02 ^{b,c}	1.31 $\pm$ 0.02 ^{b,c}	1.50 $\pm$ 0.01 ^f	1.55 $\pm$ 0.02 ^{g,h}
Gumminess, g						
- first day	534.3 $\pm$ 30.2 ^a	740.0 $\pm$ 26.7 ^b	740.0 $\pm$ 26.7 ^b	1023.4 $\pm$ 20.6 ^{c,d}	1188.9 $\pm$ 23.4 ^{d,e}	1274.3 $\pm$ 18.3 ^e
- 10th day	784.8 $\pm$ 28.6 ^b	898.0 $\pm$ 16.7 ^{c,d}	898.0 $\pm$ 16.7 ^{c,d}	1397.8 $\pm$ 38.1 ^{e,f}	1553.6 $\pm$ 28.9 ^f	1879.1 $\pm$ 21.4 ^g
- 20th day	816.0 $\pm$ 34.6 ^{b,c}	988.6 $\pm$ 21.5 ^{c,d}	988.6 $\pm$ 21.5 ^{c,d}	1345.6 $\pm$ 33.5 ^e	1931.8 $\pm$ 38.1 ^g	2235.4 $\pm$ 33.2 ^h
- 30th day	818.5 $\pm$ 29.8 ^{b,c}	1102.8 $\pm$ 36.9 ^d	1102.8 $\pm$ 36.9 ^d	1472.6 $\pm$ 29.3 ^f	1921.7 $\pm$ 30.6 ^g	2474.4 $\pm$ 29.4 ⁱ
- 40th day	819.5 $\pm$ 35.2 ^{b,c}	1110.7 $\pm$ 26.1 ^d	1110.7 $\pm$ 26.1 ^d	1572.4 $\pm$ 27.2 ^f	1920.1 $\pm$ 38.2 ^g	2483.6 $\pm$ 31.5 ⁱ

PPMS—pomace powder of musky squash. Different letters (^{a–k}) designate statistically different results ($p \leq 0.05$).

It was revealed that the hardness of samples with the addition of PPMS increases in direct proportion to the amount of pumpkin flour. However, samples containing 25% and 30% PPMS showed a too-high value of hardness (695.3 g and 772.3 g, respectively). These values are outside the normal range reported by other studies such as Mardani et al. According to the authors, the hardness of classic foamy confectionery products was 637.68 g [63].

During the 40-day storage period, the hardness and gumminess of the analyzed foamy confectionery products registered an essential increase, and the cohesiveness of the samples gradually decreased, except the CS, which, on the 40th day of storage, registered a deterioration in the parameters of texture. The improvement in the texture parameters of the fortified foamy confectionery product samples was probably due to the better water-holding capacity of the foamy confectionery products fortified with PPMS compared to the foamy confectionery products without additions. The texture parameters were influenced by increasing the PPMS concentration in the samples. During the 40-day storage period, in

the case of the 15% PPMS sample, the hardness and gumminess increased from 587.8 g to 1120.3 g and from 811.2% to 1478.8%, respectively. However, the cohesiveness decreased from 1.38% to 1.32%. In general, the texture parameters of the foamy confectionery product samples with the addition of PPMS correlated with their sensory indicators (Table 4) and their MC (Table 6). The addition of 10–30% PPMS to the foamy confectionery products determined the improvement in their degree of water retention and the textural parameters of the foamy confectionery products, thus contributing to the extension of the shelf life of the foamy confectionery products by 10 days compared to the CS.

3.6. Microbiological Results

The microbiological parameters of fresh samples of foam confectionery products (on the first day of preparation) and during 40 days of storage at 4 ± 1 °C were investigated (Table 9).

Table 9. Changes in microbiological indicators of the foamy confectionery products with PPMS during storage.

Microbiological Indicators/ Storage Date	Admitted Level [36]	Foamy Confectionery Products					
		CS	10% PPMS	15% PPMS	20% PPMS	25% PPMS	30% PPMS
QMAFAnM, CFU, max.							
- first day	5×10^3	2×10^2	3×10^2	2×10^2	2×10^2	3×10^2	4×10^2
- 10th day		5×10^2	3×10^2	6×10^2	5×10^2	4×10^2	5×10^2
- 20th day		5×10^2	2×10^2	2×10^1	3×10^1	8×10^1	2×10^2
- 30th day		6×10^2	3×10^1	2×10^1	3×10^1	4×10^1	8×10^1
- 40th day		7×10^2	7×10^1	1×10^1	2×10^1	3×10^1	7×10^1
Mold, CFU, max.	100	Were not found during storage					
Yeast, CFU, max.							
- first day	50	<5	<5	<5	<5	<5	<5
- 10th day		<10	<4	<3	<4	<4	<5
- 20th day		<20	<2	<2	<3	<5	<4
- 30th day		<20	<2	<2	<2	<3	<3
- 40th day		<50	<7	<2	<2	<3	<3

PPMS—pomace powder of musky squash; QMAFAnM—quantity of mesophilic aerobic and facultative anaerobic microorganisms; CFU—colony forming unit.

The results of the microbiological examination of the samples showed that the product under study does not contain coliform bacteria and pathogenic microorganisms; QMAFAnM, molds, and yeasts are contained in smaller quantities than the permissible level. Most of the studied samples contain bacteria of the genus *Micrococcus*. The antimicrobial and antioxidant properties of pumpkin powder allow for maintaining the microbiological stability of foamy confectionery products during storage [64].

3.7. Mathematical Modeling

Mutual information analysis was applied to demonstrate the influence of the PPMS concentration (10, 15, 20, 25, and 30%) and the storage time (10th, 20th, 30th, and 40th day) of the foamy confectionery products on the total average score, average score of sensory profile, MC, a_w , AA, hardness, cohesiveness, and gumminess (Table 10).

It was shown that the greatest influence of the PPMS concentration was on the AA (mutual information, 0.999 bits), followed by the a_w (0.895 bits), the total average score (0.717 bits), and the gumminess (0.708 bits). A satisfactory influence was found on the cohesiveness (0.488 bits), the average score of the sensory profile (0.452 bits), and the hardness (0.428 bits), and the lowest mutual information value was for the MC (0.141 bits).

In the case of the storage time, its influence on the analyzed parameters was much lower than that of the PPMS concentration. It can be seen that the greatest influence of storage time was on MC (0.179 bits). The influence on other parameters was as follows: hardness: 0.023 bits; total average score: 0.021 bits; average score of sensory profile:

0.015 bits; and AA: 0.011 bits. For a_w , cohesiveness, and gumminess, the mutual information values were insignificant (0.001 bits).

Table 10. The values of mutual analysis of the influence of PPMS concentration (10, 15, 20, 25, and 30%) and the storage time (10th, 20th, 30th, and 40th day) of the foamy confectionery products on the sensory and physico-chemical quality, AA, and texture parameters.

Parameter	Foamy Confectionery Products	
	PPMS Concentration, Bits	Storage Time, Bits
Total average score	0.717	0.021
Average score of sensory profile	0.452	0.015
MC	0.141	0.179
a_w	0.895	0.001
AA (ABTS)	0.999	0.011
Hardness	0.428	0.023
Cohesiveness	0.488	0.001
Gumminess	0.708	0.001

PPMS—pomace powder of musky squash; MC—moisture content; a_w —water activity; AA—antioxidant activity; ABTS—2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonates).

The informational analysis was applied regarding the research on the influence of different amounts of sea buckthorn flour and rose hip powder on the quality of wheat bread and gingerbread [20]. It was also used to investigate the influence of storage time and different amounts of apple pomace [16], microencapsulated extracts of summer savory, rosemary [65], and basil [66] on the quality of dairy products.

4. Conclusions

This study aimed to develop foamy confectionery products with PPMS and artichoke syrup. PPMS used in foamy confectionery products showed excellent antioxidant potential (mg TE/100 g DW: 681 (ABTS) and 300 (DPPH)). The antimicrobial and antioxidant properties of pumpkin powder allow for maintaining the microbiological stability of the foamy confectionery products during storage.

The effect of different concentrations of PPMS on the sensory characteristics, physico-chemical, and textural properties of foamy confectionery products was evaluated. Sensory analysis was applied to measure the degree of product acceptance (taste and odor, appearance, consistency, shape, color). The optimal amount of PPMS, accepted by the tasters, was 15%. The main parameters of the product were monitored during storage. The mean total score and the mean sensory profile score gradually decreased. On the 30th day, the score was acceptable, clearly superior to the CS. The use of PPMS extended the shelf life of foamy confectionery products.

The addition of PPMS significantly influenced the physico-chemical properties of foamy confectionery products. There was an increase in the pH value, as well as the retention of free water in foamy confectionery products, caused by the presence of reducing substances and pectin substances with hydrophilic properties, which can firmly retain the ratio between free and bound water.

The increase in the concentration of PPMS led to an intensification of the color and lightness with the increase in the concentration of PPMS, and the storage (40 days) did not cause significant changes in the color and lightness of the products. During the 40-day storage period, the hardness and gumminess of the foamed confectionery products showed an essential increase, and the cohesiveness of the samples gradually decreased. The texture parameters of the foamy confectionery products were improved due to the better water-holding capacity of the products with PPMS compared to the CS. The addition of 10–30% PPMS to foamy confectionery products led to the improvement of textural parameters, thus contributing to the extension of the shelf life of foamy confectionery products by 10 days compared to the CS.

Mutual information analysis was applied to determine the influence of PPMS concentration and storage time of foamed confectionery products on the mean total score, mean sensory profile score, MC, a_w , AA, hardness, cohesiveness, and gumminess. The greatest influence of PPMS concentration was on AA, a_w , and gumminess.

The results of the conducted research indicate that the use of pumpkin pulp in the manufacture of foamy confectionery products can significantly increase their biological value and sensory characteristics and ensure a significant shelf life of the products.

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