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LOW-SUGAR APPLES JAM WITH HIBISCUS EXTRACT: TEXTURAL, PHYTOCHEMICAL AND NUTRITIONAL ASPECTS

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Abstract

Nowadays, there is an increase in consumer demands for healthy products, whereas the low-calorie products are gaining increasing popularity. Apples are the most consumed fruits worldwide, especially due to the compositional diversity of health-promoting bioactive compounds, such as phenolics, organic acids, dietary fiber, vitamin C and B, minerals, fibers, etc. In this study, four types of apple jams were obtained, by exploring the potential of *Hibiscus* aqueous extract to inhibit the color changes, that negatively affected the acceptability of the products. Four jam variants were obtained, by varying the type and quantity of sugar, in order to align to the new trends regarding the development and analysis of low-sugar jams. Significant differences ($p<0.5$) were observed in color, phytochemical profile, texture, nutritional parameters and products acceptability. Firmness varied between 0.61±0.01 N and 0.82±0.01 N, for control samples, and 0.85±0.02 N and 0.99±0.02 N for the samples treated with hibiscus infusion. The type and sugar concentration did not significantly influence the firmness. No significant differences were observed for the samples with sugar or xylitol addition in terms of adhesiveness, cohesiveness, springiness and chewiness. Moreover, the hibiscus infusion showed beneficial effects on texture parameters. The phytochemical parameters results showed an increased content in polyphenols, flavonoids and anthocyanins in *Hibiscus* infused samples, whereas no significant impact on antioxidant activity was observed. The overall impression of the products highlighted the consumer preferences for the jam with xylitol, followed by low sugar jam.

Keywords: apple, Hibiscus calyxes, bioactive compounds, low-sugar jam

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Introduction

Due to high sensory quality and nutritional value, apple (*Malus domestica* varieties) is one of the most popular fruits in the world (Harker *et al*., 2003). With a global production of more than 86.4 million tons in 2022, apple is consumed as a fresh fruit or in different processed products, such as juice, dried, alcoholic beverages, jam, marmalades or candies and desserts (Shahbandeh, 2022). It has been suggested that in Europe, apples are one of the most popular fruits with an annual consumption of about 13 kg/person (AMI, 2021). Different classes of compounds are involved in specific sensory characteristics, such as sugars and organic acids involved in the sweetness and sourness, volatile compounds and their mixtures in aroma (Espino-Díaz *et al*., 2016).

Apple consumption is associated with significant health benefits, due to the high content in phenolic compounds, organic acids, dietary fibers, and vitamin C (ascorbic acid). Apple contains more than 84% water, with significant amounts of minerals, such as K, Mg, Ca and Na and trace elements such as Zn, Mn, Cu, Fe, B, F, Se and Mo (Feliciano *et al*., 2010). The main vitamin present in apple belongs to the complex B, whereas the fiber content as pectin's, celluloses, hemicelluloses and lignin's is higher when compared to other fruits (Aprifel, 2009). The major phenolics found in apple belong to the hydroxycinnamic acid, flavan-3-ols/procyanidin, anthocyanin, flavonol and dihydrochalcone classes (Feliciano *et al*., 2010), whereas the individual components are represented by chlorogenic acid, quercetin glycosides, procyanidins and phloridzin (Kahle *et al*., 2005).

Due to the complex nutritional and phytochemical profile, the consumption of apple is associated with health-promoting functions like antioxidants, antiaging, antidiabetics, anti-inflammatory, etc. (Islam *et al*., 2021), cardiovascular diseases, lung dysfunctions, and various cancers, particularly prostate, liver, colon, and lung (Tsao *et al.,* 2003), diverticular and coronary heart diseases (Gorinstein *et al*., 2001), lipid metabolism and decreasing the cholesterol level, weight regulation, etc.

Used from ancient times, jam preparation is a suitable technique for preservation of perishable, seasonal fruits. In general, jam is a fruit solid gel, obtained from fruits pulp, in a single or mixed combination, by cooking with sugar, pectin, acid and other ingredients, such as preservative, coloring agents, limited amount of fruit peals and flavoring materials (Bekele *et al*., 2020). As quality important attributes, jams are characterized by a reasonable thick consistency, whereas a minimum fruit content of 40% and a total soluble solid content no less than 68% should be respected (Featherstone, 2016). Depending on fruit varieties, jams are a rich source of sugar, energy, fiber, vitamins, minerals and amino acids, characterized by lack of any fat and cholesterol, thus decreasing the risk of cardiovascular diseases (Levaj *et al*., 2010). However, when considering consumption of jam, the high sugar intake is usually associated with a greater risk of metabolic diseases, such as obesity and diabetes (Belović *et al*., 2017). Therefore, the production and consumption of low-sugar jam products are becoming popular in healthy diets. This trend implies the replacement of sugar with other substances in order to preserve the sweet and specific taste of the product, thus minimizing the related health problems of the population. Different substitutes for sugar in jam and jellified products are reported, such as the coconut and brown sugar (Curi *et al*., 2017), natural non caloric sweeteners, such as stevia (Gasmalla *et al*., 2014) or fructose, due to its very low glycemic index (Belović *et al.*, 2017). These substitutes are used especially for diabetic products. However, the use of sweeteners in the European Union is regulated by a framework directives 89/107/EEC and 94/35/EC, and amended by Directives 96/83/EC and 2003/115/EC.

However, when considering the processing of apple, enzymatic browning mediated by polyphenol oxidase is still challenging. Browning is initiated by the enzymatic oxidation of phenolic compounds, resulting in the formation of brown colored substances (Jiang *et al*., 2016). Enzymatic browning negatively impacts the quality of the products, in terms of nutritional and biological properties, and color, reducing significantly the consumer acceptability, with important economic impact at the industrial level.

Given the abovementioned key elements, the main objective of this study was to use natural anti-browning belonging to polyphenolic classes to improve the quality and nutritional parameters of apple jam. Therefore, *Hibiscus sabdariffa* L. calyx aqueous extract was used for apple infusion prior processing into jam. The jam formulas involved the use of sugar and sugar substituents in order to produce low-sugar products. In the jam formulas, pectin was not added, considering the high content in pectin of the apples. Four experimental variants were obtained by varying the concentration and the type of sweetener and four corresponding variants, used as a control. The jam samples were analyzed for phytochemical content, color, textural parameters and nutritional composition. Sensorial analysis was performed in order to evaluate the acceptability of the products.

Materials and methods

Raw materials

Apples (*Frumos de Voinești* variety), *Hibiscus satiffa* tea and lemons were purchased from specialized market in Galați, Romania, in September 2022. Refined sugar from sugarcane (Coronita, Agrana, Tandarei, Romania) and xylitol (Top Ingredients, Ilfov, Romania) were used as sweeteners. Apples were sorted and washed, then stalks and cores were removed.

Chemicals

The reagents used in phytochemical evaluations were gallic acid, catechin, Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid), Folin-Ciocalteu's reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), ethanol, purchased from Sigma Aldrich Steinheim (Darmstadt, Germany). All the other chemicals and reagents used in the experiments were of analytical grade.

Jam preparation

The hibiscus infusion was obtained by using 10 g of calyx in 1000 mL of hot distilled water, at temperature of 100°C. The mixture was allowed to extract for 15 min at room temperature (21°C±2°C). About 1 kg of fruits were cut into pieces of uniform size (about 5 mm) and immersed in the *Hibiscus* aqueous extract at 70°C and maintained for infusion for half an hour, followed by homogenized for 5 min, using a blender (Philips HR2100/40). The control samples were obtained by immersion in distilled water at temperature of 70°C. The mixtures (experimental and control formulas) were divided in equal portions and prior cooking, sugar and xylitol were added and mixed. The experimental formulas of apple jams preparation are showed in Table 1. The samples were cooked in a non-stick electric pot (Multicooker Philips HD3037/70, Hamburg, Germany) at 98-99°C for 15 min. Just before the end of cooking, 15 mL of fresh lemon juice was added and the mixtures were further cooked until the appropriate consistency was obtained, by the cold test. Hot jams were packed into glass jars and stored at room temperature (21°C±1°C).

Phytochemical extraction

The extraction of phytochemicals was performed by using 1 g of jam samples and 7 mL of ethanol (70%) and HCl 1 N (ratio 9:1, v/v) in an ultrasound water bath (MRC Scientific Instruments) at 30°C for 1 h. The samples were centrifuged at 7000×*g* for 10 min at 4°C and the supernatants were used to measure the total polyphenolic content (TPC), total flavonoids (TFC), total monomeric anthocyanins (TAC) and antioxidant activity.

Phytochemical profile

TPC was determined by the Folin-Ciocalteu method. Briefly, 0.2 mL of ethanolic extract solutions were mixed with 1 mL of Folin-Ciocalteu reagent and 3 mL of 10% sodium carbonate. The samples were allowed to react at 25°C for 1 h, in the dark, for the development of a blue color. The absorbances of the mixtures were measured at 765 nm with a UV-VIS Spectrophotometer (Biochrom Libra S22 UV/Vis). TPC analysis was performed by triplicate in each sample and the results were expressed as g of gallic acid equivalents (GAE) per g of jam on a dry weight (DW) basis (mg GAE/g DW).

TFC was determined by the aluminum chloride method. In brief, 0.250 mL of ethanolic extract solutions were mixed with 0.075 mL of sodium nitrite solution (5% $NaNO_2$ in distilled water). The mixtures were left for 5 min at room temperature, followed by addition of 150 μL of 10% of $AlCl_3$. The test tubes were vortexed and incubated for 6 min at room temperature. Then, 0.5 mL of sodium hydroxide (1 N NaOH) was added, and the volume of the mixture was diluted with 0.775 mL of distilled water. The tubes were mixed and then incubated for 15 min. After incubation, the absorbance of the pink color formed by the reaction of flavonoids with aluminum chloride was measured by a spectrophotometer at 510 nm. Catechin was used for the preparation of the standard curve. Flavonoid content was expressed as catechin equivalents (mg CE/ g DW).

TAC was measured by the *p*H-differential method, following the protocol of Giusti and Wrolstad (2001).

Texture analysis

Texture analysis was achieved by the Texture Profile Analysis method, using a CT3 Texture Analyzer (Brookfield Ametek, USA). Immediately after processing the samples were packed into cylindric plastic containers (30 mm diameter, 43 mm height), covered with aluminum foil and let for 24 hours in order to be sure that the gelling process was completed. Two compression cycles were applied until the target distance of 10 mm was reached. The testing probe was an acrylic cylinder (25.4 mm diameter, 35 mm height) and the testing speed was 1 mm/s. The results were collected and processed using the TexturePro CT V1.5 software, which delivered the texture parameters: firmness (N), adhesiveness (mJ), cohesiveness (dimensionless), springiness (mm), chewiness (mJ). Five determinations for each sample were made and the results are presented as the mean ± standard deviation.

Color parameters

Instrumental color measurements of the apple jams were conducted with a NR110 3nh colorimeter (Shenzhen 3nh Technology, China). The chromaticity coordinates mainly lightness factor *L**, red-green axis *a**, yellow-blue axis *b**, the common distinction between colors - Hue and the intensity or the saturation of the color - Chroma were measured to evaluate the color.

Nutritional characterization

The AOAC standard (1990) official methods were used to evaluate the moisture (AOAC Official Method 934.06), ash (AOAC Official Method 942.05), salt (AOAC Official Method 990.23), protein (AOAC Official Method 984.13), carbohydrates, total sugars and energy in the samples, Carbohydrates were calculated by subtracting moisture, protein, salt and ash. The results are expressed per 100 g of sample.

Sensorial analysis

Sensory evaluation of the apple jams was performed as described by Teodorescu *et al.* (2023), by using the scoring method with different levels of perception for each attribute on a scale ranging from 1 (very low) to 9 (very high). Nine panelists with ages between 24 and 55 years were trained on the jams sensory-relevant characteristics. Before analysis, the jams were held at 25 ± 1°C for four hours. The samples were displayed in clear, coded glass jars. Prior to each analysis and between analysis the samples, the panelists were asked to cleanse their palate with water. After getting the panelists' informed consent, they evaluated the following sensorial characteristics: general appearance, homogeneity of the paste, specific taste of apple jam, the intensity of the sweet taste, the specific color of the apple variety, specific aroma of apples, specific aroma of hibiscus, consistency, adhesion, spreadability and general impression. The acceptability index (AI) was calculated based on Equation 1:

$$\text{Acceptability index (\%)} = \frac{A}{B} x100 \qquad (1)$$

where: *A* is the average of the hedonic values obtained for an individual attribute and *B* is the maximum hedonic value attributed to the same attribute.

Statistical analysis

The nutritional analysis of the products was carried out in duplicates within the Laboratory for physical-chemical and microbiological analyzes of food, Dunarea de

Jos University of Galati, using accredited methods. The phytochemicals, color and textural analysis were performed in triplicates and the results were expressed as mean standard deviation (SD). The experimental data for the phytochemical composition were statistically analyzed by using One-Way analysis of variance (ANOVA), by using Minitab 19 software (Minitab LLC, State College, PA, USA). The posthoc analysis was developed by using Tukey test to identify the significant differences.

Results and discussion

Phytochemical profile of the jams

Different formulas were used in this study to process apple in jams, by using an infusion step in hibiscus calyx aqueous extract and by varying the type and sugar concentration (Table 1).

Table 1. Experimental formulas of apple jams preparation (basis: 250 g of apple pulp).

Sample	**Pre-treatment**	**Sugar** (g)	**Xylitol** (g)	**Lemon juice** (mL)
AH_1	**Infusion** in 1000 mL of aqueous extract at 70°C for 30 min	125	0	15
AH_2		25	0	15
AH_3		0	25	15
AH_4		0	0	15
A_1	**Infusion** in 1000 mL of distilled water at 70°C for 30 min	125	0	15
A_2		25	0	15
A_3		0	25	15
A_4		0	0	15

The wide spectrum of beneficial biological properties of apples is also related to polyphenolic content, considered important quality indicators with potential antioxidant effects. Different levels of phytochemicals were found in the apple jams, as it can be observed in Table 2.

From Table 2, it can be observed that all the tested phytochemical vary significantly in a sugar type and concentration dependent manner. An increase in TPC was found in samples with hibiscus infusion, when compared to control, the highest value being found for the samples without sugar addition (68.54±3.49 mg GAE/100 g DW when compared with 68.54±3.49 mg GAE/100 g DW). It can be observed that in infused samples, the TPC was significantly higher, due to probably the hibiscus contribution in total polyphenols content. The same trend was found in case of TFC, the samples with infusion showing a higher level of flavonoids, while the highest TAC content was determined in the jam sample without sugar addition (158.40±5.73 mg C3G/100 g DW) (AH_4). No significant impact of the formulation was found on antioxidant activity values (Table 2). These differences in polyphenols and antioxidant activity may be explained by the disruption of the cell structure, and thus the polyphenols become prone to non-enzymatic oxidation (Patras *et al.*, 2011).

Table 2. Phytochemicals concentration and antioxidant activity of the apple jams.

Product code	**A_1**	**AH_1**	**A_2**	**AH_2**	**A_3**	**AH_3**	**A_4**	**AH_4**
TPC, mg GAE/100 g DW	48.16 ± 1.46^{A}	50.56 ± 3.62^{A}	57.53 ± 1.04^{A}	58.18 ± 4.02^{A}	50.38 ± 1.5^{A}	54.85 ± 1.6^{A}	68.54 ± 3.4^{A}	73.11 ± 1.64^{A}
TFC, mg CE/100 g DW	17.49 ± 0.11^{A}	27.48 ± 1.67^{B}	9.30 ± 0.83^{A}	18.23 ± 1.50^{B}	9.49 ± 0.56^{A}	19.55 ± 1.6^{B}	10.07 ± 1.3^{A}	18.61 ± 3.10^{B}
TAC, mg C3G/100 DW	0^{A}	58.44 ± 7.30^{B}	0^{A}	138.09 ± 9.6^{B}	0^{A}	98.40 ± 3.8^{B}	0^{A}	158.40 ± 5.73^{B}
Antioxidant activity (mMol/g DW)	9.39 ± 0.14^{A}	9.70 ± 0.31^{A}	9.43 ± 0.08^{A}	8.57 ± 0.02^{A}	8.49 ± 0.28^{A}	9.07 ± 0.19^{A}	10.55 ± 0.0^{A}	9.55 ± 0.12^{A}

The presence of A and B superscript indicates significant differences between samples at $p < 0.05$, based on the Tukey test.

Our results are in contrast with the earlier report (Scibisz and Mitek, 2009), suggesting that, in general, the use of sweetener instead of sugar in jams and marmalades did not lead to a significant difference in the total phenolic content. In our study, the high-sugar jam contains similar total phenolic content compared to low sugar and free sugar jams. This can be explained by the complex gel network formed during heating, obtained at the equilibrium between the pectin, sugar, and citric acid. In our study, pectin was not added to the formulation, considering the pectin content of fresh apples. However, the jam firmness occurred through the gel formation by the high methoxy pectin, in acidic conditions, due to the complex contribution of both hydrogen bonds and hydrophobic forces (Rababah *et al.*, 2015). From the results presented in Table 2, it can be concluded that lowering/replacing the sugar had a protective effect on polyphenols during jam processing. The higher bioactive content in sugar free apples jam may be also explained by the content in soluble solids. Lowering or replacing the sugar led to a decrease in soluble solids, thus protecting anthocyanins from thermal degradation.

Texture analysis

For jellified vegetal products like jam, texture is very important in order to assess the components (pectin, sugar and organic acids) ability to create a stable and specific gel structure. For the obtained apple jam samples texture parameters like firmness, adhesiveness, cohesiveness, springiness and chewiness were analyzed and results were presented in Figure 1.

Firmness, expressed as the maximum force registered in the first compression cycle, varied between 0.61±0.01 N and 0.82±0.01 N, for control samples, and 0.85±0.02 N and 0.99±0.02 N for the samples treated with hibiscus infusion. The control samples showed lower firmness values for all formulation variants, while the type and sugar concentration did not significantly influence the firmness. This could be explained by the xylitol water affinity, which leads to an increase in solids (Zacharis, 2012) and similar gel structure for all formulations. Unexpectedly, the samples with no added sugar or xylitol registered the highest firmness, both for control and hibiscus treated samples. This could be owed to the processing method, which implies consistency appreciation by the cold test. Having no added sugar, these samples suffered a more intense water evaporation which induced an increase in total solids. Similar behavior could be observed for the rest of texture parameters. Adhesiveness showed values ranging between 2.14±0.41 and 3.91±0.44 mJ for control samples and 2.78±0.22 and 4.12±0.39 mJ for hibiscus samples. No significant differences ($p < 0.05$) were observed for the samples with sugar or xylitol addition in terms of adhesiveness, cohesiveness, springiness and chewiness. Moreover, the hibiscus infusion showed beneficial effects on texture parameters.

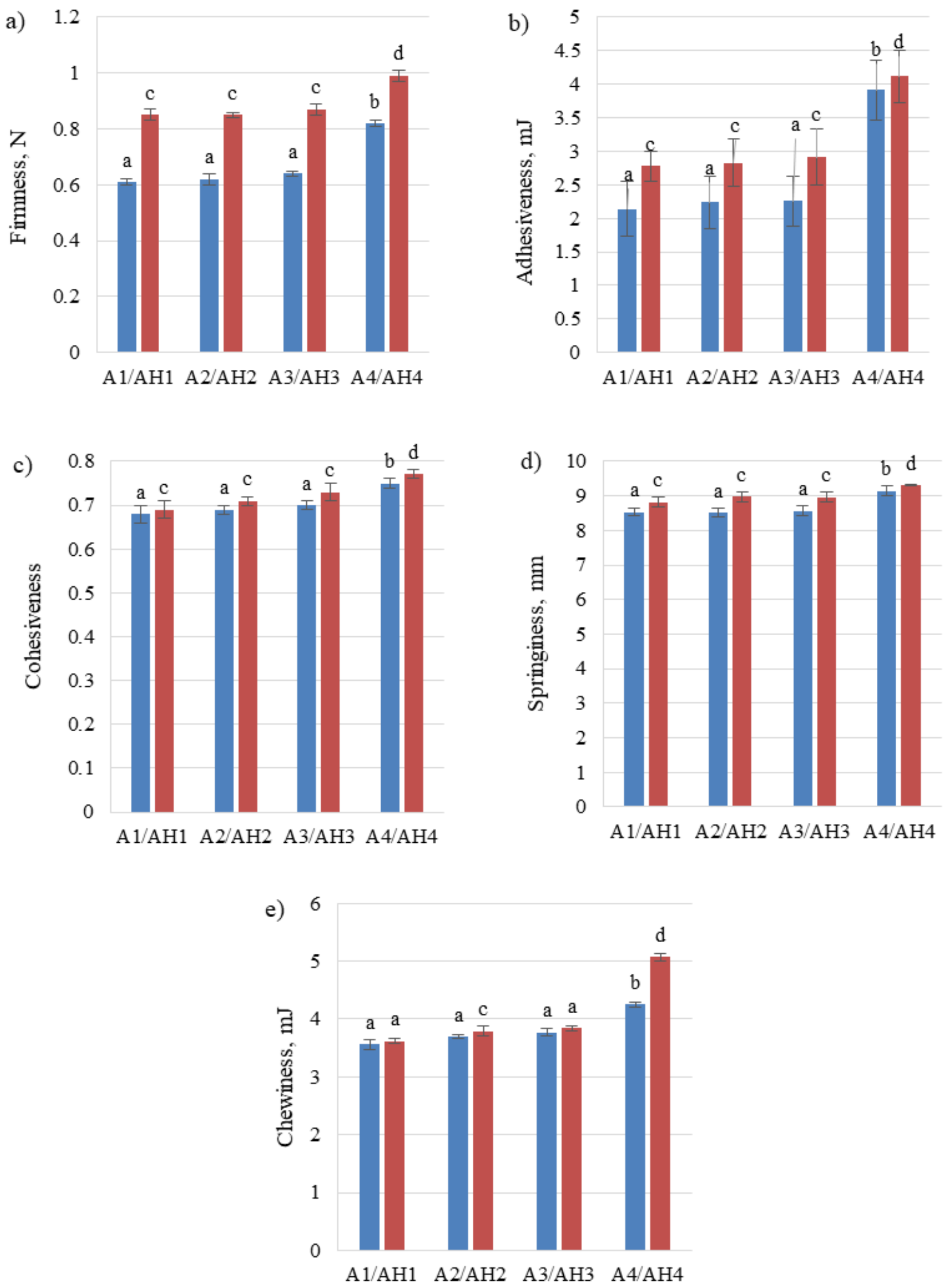

Figure 1. Results of instrumental texture analysis of apple jams produced from apples pulp with and without infusion in hibiscus extract. Values of firmness (a), adhesiveness (b), cohesiveness (c), springiness (d) and chewiness (e) for control samples (blue) and hibiscus samples (red). Same lowercase letters show no significant differences ($p > 0.05$).

Color parameters

The results of the color parameters of the apple jams are presented in Figure 2.

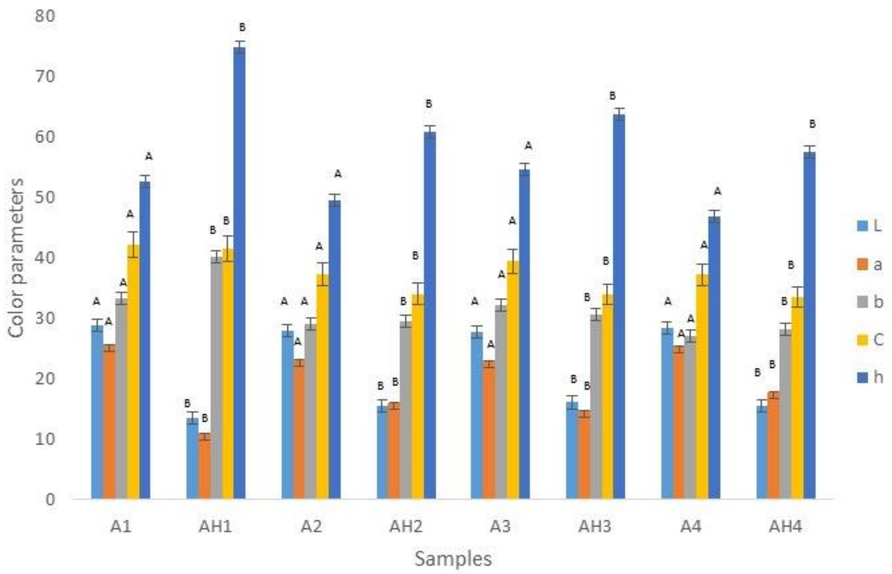

Figure 2. Color parameters of the apple jams produced from apples pulp with and without infusion in hibiscus extract. The presence of A and B superscript of each color parameter indicates significant differences between the samples with $p < 0.05$, based on the Tukey test.

Color remains one of the important parameters that influences the consumers acceptance of products. In Figure 2, the apple jam samples without infusion in hibiscus extract are brighter, with values between 27.75±0.1 and 28.76±0.2 for *L** parameter, similar to Şirin (2019), who evaluated the influence of sugar types addition in apple marmalade. It seems that the type and quantity of sugar addition does not influence the lightness of the samples. This phenomenon could be related to the color of hibiscus extract, who imprinted specific changes due to the color compounds transferred to the apples. Unexpectedly, due to the influence of the color of the hibiscus extract, the samples which were infused measured lower values for *a** parameter, but this fact could be attributed to other interactions between sugars and hibiscus phytochemicals. However, positive values of *a** and *b** parameters highlighted the presence of a combination of red and yellow colors. Similar to the findings of Geicu *et al*. (2009) for apple puree treated by electric pulsed field, the yellow component is prevailing in all the samples.

The samples with the highest intensity of the color are A1 and AH1 with a Chroma value of 42.17±0.1, respectively 41.55±0.3, while the lowest value was attributed to AH4 with 33.58±0.4. According to the color wheel, which is the base of color parameters calculation, the Hue values places the jam samples with or without infusion in the yellowish-light brownish side, which is specific to the apple jams.

Nutritional characterization

Table 3 shows the physicochemical properties of the apple jams produced from apples pulp with and without infusion in hibiscus extract.

Table 3. Physicochemical properties of jams produced from apples pulp with and without infusion in hibiscus extract.*

Properties	A1	AH1	A2	AH2	A3	AH 3	A4	AH4
Ash (%)	0.11±0.01	0.10±0.01	0.13±0.09	0.17±0.01	0.16±0.01	0.13±0.09	0.16±0.01	0.20±0.01
Moisture (%)	34.50±1.23	37.50±1.02	37.30±2.34	41.90±2.03	36.70±2.11	42.60±1.22	30.60±1.11	35.90±1.34
Carbohydrates,	61.90±1.24	61.80±2.07	32.15±1.02	32.89±1.09	23.60±0.89	23.60±1.01	15.60±1.01	15.21±1.99
of which sugars (%)	39.30±1.09	38.80±1.99	14.87±1.01	14.97±0.99	43.06±1.15	16.20±1.09	15.89±0.98	14.73±1.11
Energy value (%)								
kcal	249.20±5.67	249.28±6.78	130.20±2.33	133.84±4.56	96.00±2.36	96.68±3.45	64.00±1.22	63.12±2.39
kJ	1042.65±9.11	1042.98±8.11	544.75±8.90	559.98±7.89	401.66±7.68	404.50±9.07	267.77±3.48	264.09±3.11

* The experiments were performed in duplicates and the results are expressed as average ± SD. The protein and fat were not detectable. The carbohydrate content was determined by subtracting the summed-up percentage composition of moisture, protein, lipid, and ash content from 100.

The moisture content varied from 30.6% in A4 to 42.6% in AH3. The jams without sugar addition (A4 and AH_4) showed the lowest moisture content values, maybe due to the lack of sugar addition which contributed to the gel structure formation and to reducing the evaporation process effect. The moisture content significantly influences the gelling capacity of the jams, thus with the decrease of the moisture content the firmness of the gel increases. The gel strength has a significant impact on the jam spreadability, thus influencing the sensory property of the product.

The ash content was higher for the sugar free samples and lower than those reported by Awolu *et al.* (2018) for jam produced from banana, watermelon and pineapple, who reported values ranging from 0.27% to 0.32%, due to the differences in mineral content of the raw materials. The carbohydrates content varied as a function of the quantity and type of the added sugar or as a result of the concentration phenomenon which occurs due to the thermal treatment.

Sensorial analysis

The samples were subjected to sensorial analysis, in order to evaluate the acceptability degree of the jams. A hedonic nine-points scale was used. As shown in the radar plot (Figure 3), all processed jams tasted different, with the highest score (8.22) for the sample with lower concentration of sugar (A_2), followed by samples A_1, A_3 and A_4, with the same score.

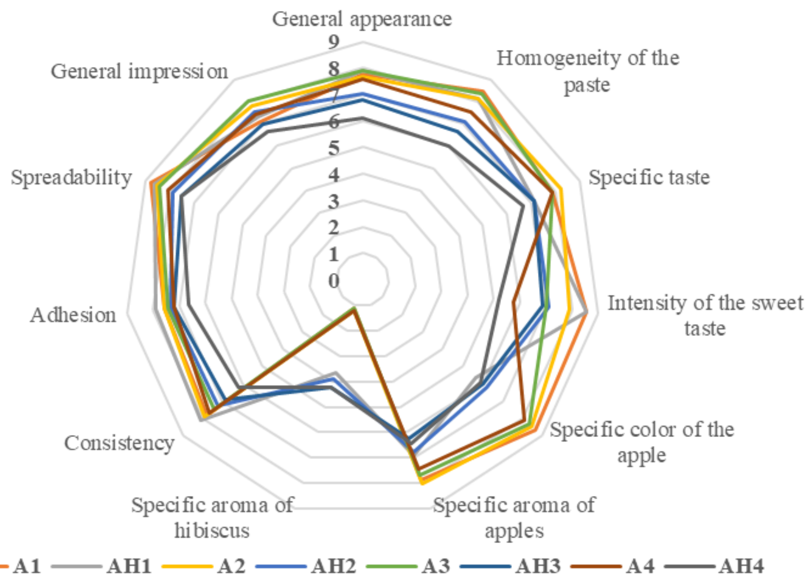

Figure 3. Sensory attributes of apple jams produced from apples pulp with and without infusion in hibiscus extract.

The lower taste characteristic was found for the sample with hibiscus infusion and no added sugar (AH_4) (6.66). From Figure 3, it can be observed that for general impression, the samples without hibiscus infusion obtained higher scores. Therefore,

A_3 got the highest score value of 8.00 when it came to the general impression, whereas the lowest was attributed to AH_4. For the overall impression, the points awarded classify the products, according to the preferences of the panelists as follows: $A_3>A_2>AH_2>A_4>AH_1>A_1>AH_3>AH_4$. Therefore, it can be appreciated that the infused apples jams were located in the “like moderately’’ region of the hedonic scale.

The acceptability index (AI, %) values are showed in Table 4. In general, an AI higher than 70% is considered satisfactory (Dutcosky, 2007). Thus, from the data presented in Table 4, it can be seen that higher acceptability values were obtained for samples without hibiscus infusion, whereas different sensorial characteristics should be improved for the infused samples, such as sweetness.

The calculation of the AI for the general impression characteristic allowed the classification of the products as follows: $A_3>A_2>AH_2>A_4>AH_1>A_1>AH_3>AH_4$.

Table 4. The acceptability index (AI, %) for the apple jams produced from apples pulp with and without infusion in hibiscus extract.

Sensorial attributes	**A_1**	**AH_1**	**A_2**	**AH_2**	**A_3**	**AH_3**	**A_4**	**AH_4**
General appearance	86.42	87.65	85.19	87.50	87.65	75.31	83.95	76.39
Homogeneity of the paste	93.83	90.12	90.12	79.01	92.59	83.33	83.95	75.00
Specific taste	87.65	88.89	91.36	79.01	87.65	88.89	87.65	74.07
Intensity of the sweet taste	95.06	95.06	98.61	88.89	87.50	76.54	72.22	65.28
Specific color of the apple	96.30	70.83	93.83	77.78	92.59	75.00	90.12	84.13
Specific aroma of apples	87.65	86.11	88.89	75.31	85.19	77.78	82.72	71.60
Consistency	86.42	90.12	87.65	90.28	93.06	98.41	85.19	88.89
Adhesion	94.44	87.65	94.44	91.67	93.06	90.28	80.25	83.33
Spreadability	97.53	96.30	95.06	87.65	93.83	83.95	90.12	83.95
General impression	79.01	81.48	86.42	83.95	88.89	75.31	82.72	74.07

Conclusions

In this study, apples were used to produce jams, using hibiscus aqueous extract to improve the color and antioxidant activity. In order to lower the sugar addition, sugars of different types and quantity were added, and the resulting nutritional, phytochemical, color, textural and sensory characteristics were analyzed. In general, addition of hibiscus extract enhanced the polyphenolic content, but no significant impact on antioxidant activity was observed. The nutritional values were dependent on sugar addition, whereas the textural analysis showed that the type and sugar concentration did not significantly influence the firmness. The samples with no added sugar or xylitol registered the highest firmness, whereas no significant differences were observed for the samples with sugar or xylitol addition in terms of adhesiveness, cohesiveness, springiness and chewiness. Moreover, the hibiscus infusion showed beneficial effects on texture parameters. The sensorial analysis highlighted the preference of panelist for low-sugar jams.

Informed Consent Statement: Written informed consent was obtained from all subjects (patients) in this study, according to the decision of the Dunarea de Jos University Ethics Commission no. 28/19.10.2022.

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