Physicochemical and textural properties of reduced sugar jellies from *Physalis peruviana* L. fruit

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Abstract

Introduction. *Physalis peruviana* L. fruit contain various functional compounds with health promoting effects. The aim of this study was to investigate the possibility of obtaining reduced sugar jellies from physalis juice with different sugars and sugar substitues.

Materials and methods. Jellies containing physalis juice and sucrose (sample S), fructose (sample F) or maltitol and maltitol syrup (sample M), respectively, were prepared and studied.

Results and discussion. There were no significant differences between the samples in terms of dry matter content, titratable acidity and pH. The highest total sugar content was found in sample S (72.68%), and the lowest – in sample M (7.12%). Sample M had about 90% lower total sugar content than sample S and about 83% lower than sample F. Therefore, according to EU Regulation No 1924/2006, the jelly with maltitol/maltitol syrup can be classified with a nutrition claim "Food with no added sugars". Due to its composition, the same nutrition claim can be ascribed to sample F. Sample F had the biggest sorption capacity, in which an absorption process was observed, and the moisture content of the jelly increased from 28.23% to 32.65% after 120 h. Samples S and M revealed a desorption process (decrease by about 2-3%, 120 h), thus being more stable in terms of storage. The texture profile of sample M was more favorable with regard to jelly's further use, as it had the highest hardness and adhesiveness values (10.12 N and 0.42 N.mm, respectively), compared to samples S and F. Additionally, sample M had about 40% lower energy value than sample S (680 kJ/100 g vs. 1142 kJ/100 g), thus allowing for the nutrition claim "Energy-reduced food" under the terms of Regulation No 1924/2006. The calculated glycemic indicator values were 39.2 (sample S), 23.5 (sample M) and 14.6 (sample F), respectively. These results suggest that physalis juice can be successfully processed into functional sweet jellies.

Conclusions. The jellies with physalis juice and maltitol/maltitol syrup can be classified with the nutrition claims "Energy-reduced food" and "Food with no added sugars".

Introduction

Foods with sweet taste, respectively confectionery, are suitable for the technological realization of certain functional concepts and as carriers of ingredients with functional properties, because they are easily portable, convenient for consumption and are preferred by all age groups [1]. According to the same authors, these types of food can be obtained by adding functional ingredients to the composition of traditional sweet foods or by substituting certain ingredients in their existing composition. An individual segment of the confectionery group of foods is represented by jellies, which are distinguished by their taste, shape and elasticity [2]. The main ingredients used in the production of jellies are water, sugar, glucose syrup and a gelling agent that forms the characteristic consistency of the product [3].

Variants of jelly formulations with sweeteners or various sugars are proposed in order to limit the consumption of sugar (sucrose), which is a major cause of noncommunicable diseases such as obesity, diabetes, etc. [4, 5]. There is an opportunity to replace the water, as well, in the formulation of the jelly, with fruit puree or fruit juice. Usually, those obtained from oranges, apples, grapes, strawberries and some other fruits are used for this purpose [6].

Like other berries, *Physalis peruviana* L. fruit (also known as Cape gooseberry, Inca berry, Peruvian groundcherry, goldenberry, physalis) contain a variety of highly functional phytochemical and nutritive compounds with health promoting effects (vitamins, minerals, fibers, protein, polyphenols, phytosterols, carotenoids, etc.), and physalis popularity worldwide is constantly growing during the last two decades [7-10]. Fresh physalis fruit are excellent for direct consumption, but considering their limited shelf-life (about one month, without removing the protective calyx), it is a much better option if they are processed into commercially stable products. The latter include various categories of fruit derivatives and functional foods, preferred by the consumers, such as juices, yogurts, ice-creams, jellies, raisins, etc. [11-15]. According to Sheikha et al. [16], physalis juice contained (on a wet weight basis) 89.34% water, 0.13% lipids, 1.02% protein, 6.95% total sugars, and 0.14% pectin. The basic chemical indices of physalis fruit in the study by Yıldız et al. [17] were: dry matter 18.68%, water soluble dry matter 14.17%, ash 2.98%, protein 1.66%, oil 0.18%, carbohydrates 13.86%, total sugar 63.9 g/kg, and reducing sugar 31.99 g/kg. Similar data were reported by Sharoba and Ramadan [18], dry matter 21.00%, water soluble dry matter 16.40%, ash 1.08%, protein 0.84%, and oil 0.32%. Besides, the attractive bright yellow-to-orange color, the tender juicy texture and the exotic flavor (sweet and sour, with a hint of strawberry, citrus and vanilla) of physalis fruit make an excellent contribution to the organoleptic properties of various foods. Physalis fruit and fruit juice are associated with pronounced hypercholesterolemic and anti-diabetic effects [8, 12, 15, 19, 20], thus being a suitable means for reducing the glycemic load of modern human diet.

Undoubtedly the use of non-traditional plant-derived ingredients has been gaining popularity in food technology, which in turn stimulates the development of various and novel arrangements for their incorporation in many food systems. In that way, the bioactive and functional assets of *P. peruviana* fruit, as well as the possibility for their extended cultivation in many countries of the tropical, sub-tropical and the temperate zones [8, 9], create prerequisites for exploring the options of physalis use in a wide range of foods.

For these reasons, the aim of this study was to investigate the possibility of obtaining reduced sugar jellies from physalis juice (*Physalis peruviana* L.) with different sugars and sugar substitues, and to determine the influence of these ingredients on the basic physicochemical and structural properties of the jellies.

Materials and methods

Ingredients and jelly processing

To carry out the study physalis juice obtained under laboratory conditions was used. Physalis fruit were purchased from a local supermarket, with Colombia being the producer (Frutas Comerciales S.A., Bogotá) and were kept in a refrigerator (5-8 °C) until processing. The berries were separated from the husk (calyx) and then were subjected to mechanical grinding in a high-speed vacuum blender HR3752/00 for 4 min. Extracted fruit mass was filtered through a sieve with a mesh size below 215 µm to remove seeds and peels. The moisture content of the berries, determined by drying to constant weight at 105 °C, was 83.07±0.27%.

To determine the effect of physalis juice and the ingredients with sweetening properties on the values of the basic physicochemical parameters and properties of the jelly, three samples were developed and further analyzed (Table 1). The final formulation of the jellies presented in Table 1 was obtained as a result of a series of preliminary tests (data not shown), based on modification of jelly composition with regard to gelling agents, sugars and sugar substitutes and physalis juice participation (i.e. ingredient choice and percentage).

Table 1

Formulation of jellies from physalis juice

Ingredients, % (w/w)	Sample*		
	S	F	M
Sucrose	47	-	-
Fructose	-	47	-
Maltitol	-	-	34
Maltitol syrup	-	-	13
Physalis juice	50	50	50
Pectin	1.8	1.8	1.8
Carrageenan	0.6	0.6	0.6
Citric acid	0.6	0.6	0.6
Total	100	100	100

* S – with sugar; F – with fructose; M – with maltitol and maltitol syrup

For convenience the samples in the study were labeled as follows: sample S – containing sucrose; sample F – containing fructose, and sample M – containing maltitol and maltitol syrup. The formulation of sample M (Table 1) was calculated on a dry matter content basis, in order to comply with the other two samples. Crystalline maltitol (food additive code E 965i) with trade name „Maltisorb P90“ (Roquette Freres, France) and maltitol syrup (E 965ii) with trade name „C*Maltidex L 16306“ (Cargill Inc., Minneapolis, MN, USA) were used.

The jellies were obtained under laboratory conditions to a boiling point of around 108 °C, and were further formed by pouring in silicone molds and cooling at 20±2 °C for 24 h.

The described stages of jelly processing in the study are illustrated on Figure 1.

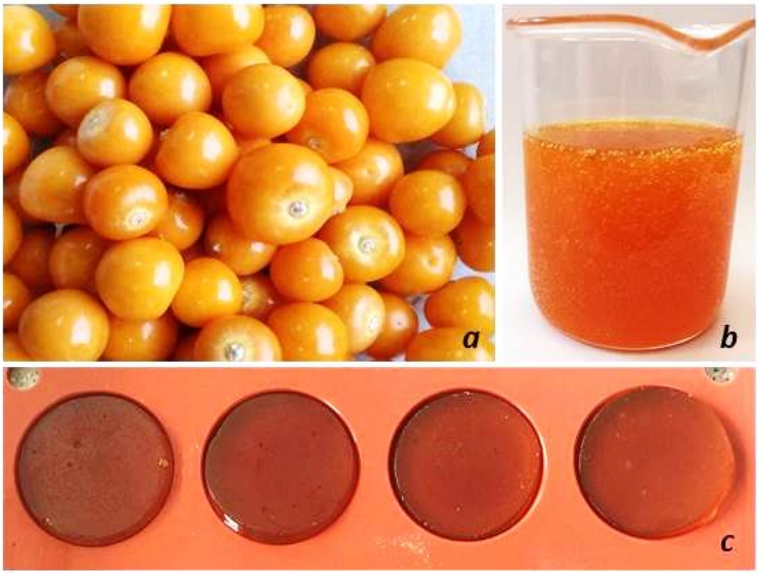

Figure 1. Stages of obtaining jellies from physalis juice:
a – physalis berries; b – juice after filtration; c – jelly after cooling (sample M)

Jelly analysis

The values of the basic physicochemical parameters of the jellies, such as dry matter content, total sugar content, reducing substances, pH and titratable acidity, were analyzed according to Lurie et al. [21]. The color of the jellies was determined spectrophotometrically on 10% sample solutions at λ = 450nm.

The sorption properties of the samples were analyzed by the equilibrium moisture determination method described in [21], at a relative air humidity of 75%, maintained over a saturated solution of NaCl.

The texture parameters of the samples were analyzed after 24 h of their formation with a texture meter LS1 (Lloyd Instruments Ltd., UK). The analysis was performed with a cone-shaped probe with a tip angle of 90°, speed 0.2 mm/s and immersion depth of 10 mm. The values of texture parameters like hardness and adhesiveness were reported directly and cohesiveness was calculated according to Seyed et al. [22].

The energy value of the samples was calculated according to the content of macronutrients in their composition and using the conversion factors defined in Regulation (EU) No 1169/2011 [23].

The glycemic indicator was defined and calculated according to the methodology developed by Dorohovich et al. [24].

Statistical analysis

All data were expressed as mean ± standard deviation (n=3). ANOVA and Tukey′s multiple comparison test ($p<0.05$) were applied for the determination of significant differences.

Results and discussion

Physicochemical characteristics of the jellies

The values of the main physicochemical parameters of the analyzed samples are shown in Table 2. Data revealed that, in terms of parameters dry matter content, titratable acidity and pH, no significant differences were observed between the values of the three samples. Significant differences were observed in the total sugar and reducing substances contents between the samples.

Table 2

Main physicochemical parameters of jellies from physalis juice

Parameters	Sample[1]		
	S	F	M
Dry matter, %	70.23±0.29[2,a]	71.77±0.23[a]	69.43±0.41[a]
Total sugar content (as invert sugar), % dry matter	72.68±0.10[a]	67.32±0.10[b]	7.12±0.10[c]
Reducing substances (as invert sugar), % dry matter	10.72±0.10[a]	58.94±0.10[b]	4.27±0.10[c]
Titratable acidity (as citric acid), %	1.81±0.01[a]	1.86±0.01[a]	1.82±0.01[a]
pH (10% solution)	3.52±0.01[a]	3.41±0.02[a]	3.43±0.02[a]
Color, E (10% solution; λ=450 nm)	0.28±0.01[a]	0.48±0.01[b]	0.29±0.01[a]

[1] S – with sugar; F – with fructose; M – with maltitol and maltitol syrup;
[2] data expressed as mean ± standard deviation (n = 3);
[a–c] means with different superscripts in a row differed significantly ($p < 0.05$).

It can be seen (Table 2) that the highest total sugar content was found in sample S, followed by sample F. The lowest value of this parameter was associated with sample M, obtained with sweeteners. The relative content of total sugar for samples F and M, compared to sample S (accepted as 100%) is shown in Figure 2.

From the graphically related dependence (Figure 2) it can be seen that sample M has a total sugar content of about 90% lower than sample S and about 83% lower than sample F. Therefore, according to the terms and provisions of Regulation (EC) No 1924/2006 [25], the jelly from physalis juice with maltitol and maltitol syrup as sweeteners (sample M) can be classified with a nutrition claim “Foods with no added sugars”. Although the total sugar content of sample F was relatively close to that of sample S, the jelly with fructose can also be classified with the same nutrition claim, due to its composition.

In regard to reducing substances, the highest content was found in sample F. This finding can be explained by the participation of fructose in the composition of the sample, which refers to reducing monosaccharides. Respectively, the lowest content of reducing substances is observed in sample M.

The color of the obtained jellies was defined by both the color of the added physalis juice (Figure 1), which has high content of carotenoids [16, 26] and by processes occurring under the influence of temperature during sample boiling. The results obtained (Table 2) show that sample F was the most colored, compared to samples S and M.

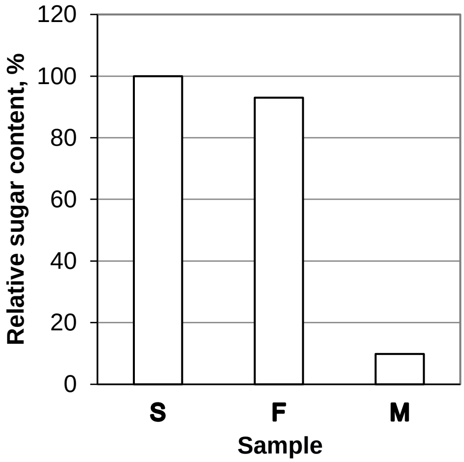

Figure 2. Relative content of total sugar (%) in jellies from physalis juice: S – with sugar; F – with fructose; M – with maltitol/maltitol syrup

Sorption characteristics of the jellies

The sorption properties of the jellies were analyzed during 5 consecutive days, at room temperature and at a constant relative humidity of 75%. The obtained results are shown in Figure 3.

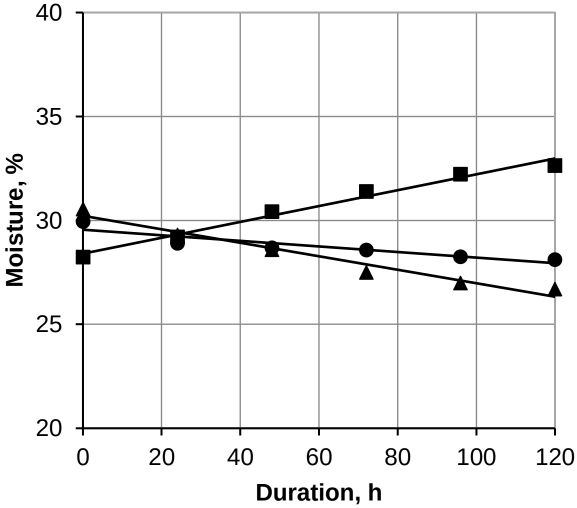

Figure 3. Sorption properties of jellies from physalis juice:
● – with sugar (S); ■ – with fructose (F); ▲ – with maltitol/maltitol syrup (M)

It is evident from the graphically expressed dependencies that sample F possessed the most pronounced sorption properties, in which an absorption process was observed. For example, after 120 h (5 days) the moisture content of this sample increased by about 4% compared to its original one (from 28.23% to 32.65%). The other two samples (S and M) revealed a desorption process, and their moisture decreased with time (by about 2-3%). These results suggested that samples S and M would be more stable for a longer period of storage, with regard to the occurrence of microbiological, oxidative and other transformations, which could deteriorate the quality of the final products.

Texture profiles of the jellies

The texture profiles of the jellies are shown in Figure 4, and the values of the determined texture parameters – in Table 3.

Table 3

Values of the basic texture parameters of jellies from physalis juice

Sample[1]	**Parameters**		
	Hardness, N	**Adhesiveness, N.mm**	**Cohesiveness**
S	10.12±0.09[2, a]	0.08±0.00[a]	0.59±0.01[a]
F	8.70±0.06[b]	0.15±0.00[a]	0.41±0.01[b]
M	11.81±0.10[c]	0.42±0.01[b]	0.45±0.01[b]

[1] S – with sugar; F – with fructose; M – with maltitol and maltitol syrup;
[2] data expressed as mean ± standard deviation (n = 3);
[a–c] means with different superscripts in a column differed significantly ($p < 0.05$).

From the data in Table 3 it can be seen that sample M had the highest hardness, as well as the highest adhesiveness values compared to sample S and sample F. These results suggest that matlitol and maltitol syrup make a good combination with physalis juice, in terms of jelly texture profile. In that way, the jelly obtained after the formulation of sample M would be more suitable for both individual use (for example as jelly candies) and as a part of different confectionery and other sweet foods (such as fruit jelly desserts, candy or pastry filling and others), compared to the rest of the samples. Respectively, the lowest value in terms of adhesiveness was observed in sample S, and it was significantly lower (about five times) than that of sample M. With regard to cohesiveness, samples F and M were both with lower values than sample S, with no significant difference between them. The observed differences in the values of jelly texture indicators were obviously related to the variation in their composition in terms of the used components with sweetening properties, i.e. sugars (sucrose and fructose) and sweeteners (maltitol and maltitol syrup).

To the best of our knowledge, there are no previous studies on jellies from physalis juice and sugar substitutes (maltitol in particular), so it is difficult to make comparisons to literature data. Our results for sample S differed numerically from the texture characteristics of physalis jellies, made from 59.25% physalis juice, 40% sucrose and 0.75% high methoxyl pectin, reported by Curi et al. [11] – hardness 0.22 N, adhesiveness 0.47 N/s, and cohesiveness 0.39, explicable by the different jelly matrix composition and analysis conditions. Obviously, the weaker hardness of sample F was associated to the bigger hygroscopic potential due to the presence of fructose (absorption of moisture after storing for 24 h), thus being in accordance with the results for the sorption properties of the jellies described above.

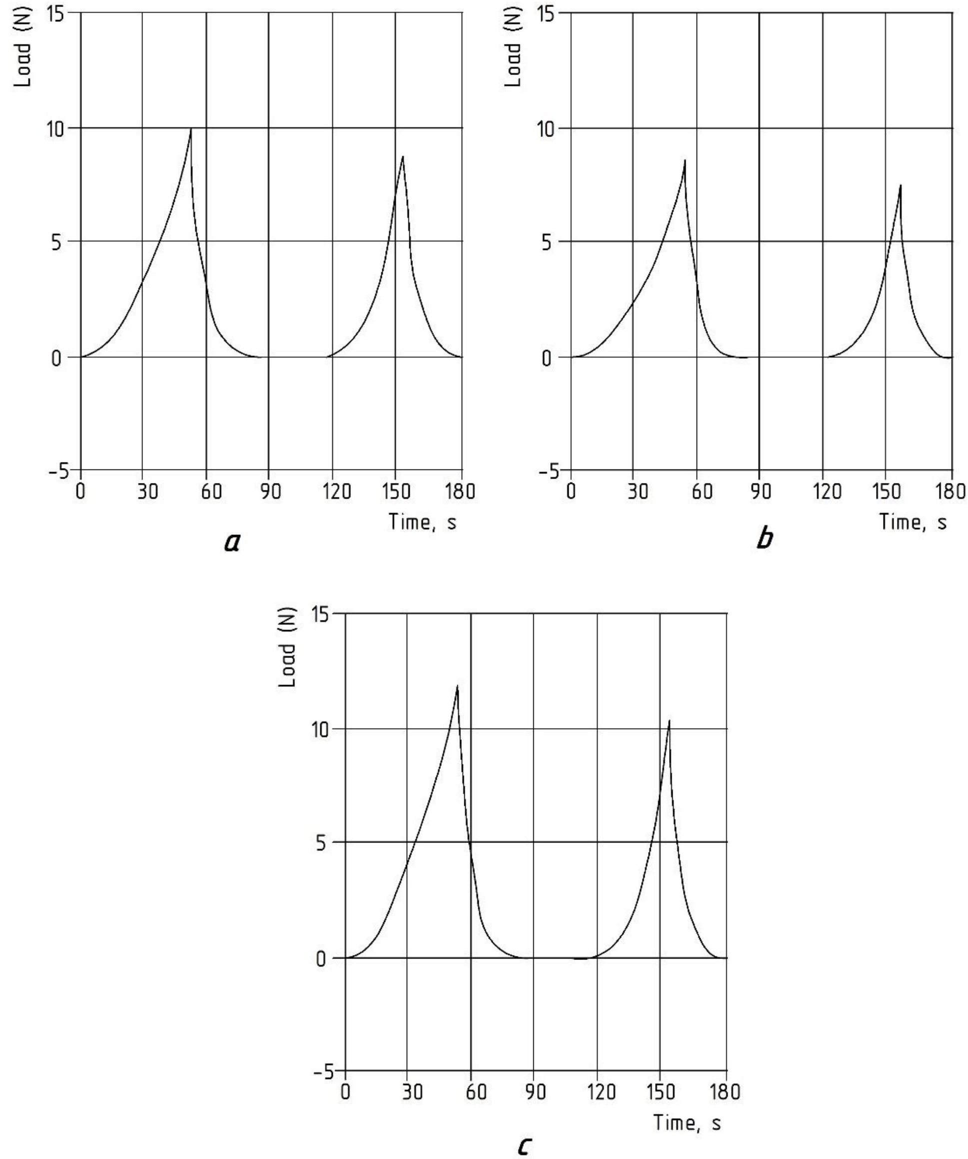

Figure 4. Texture profile of jellies from physalis juice:
a – with sugar (S); b – with fructose (F); c – with maltitol/maltitol syrup (M)

Energy value and glycemic indicator of the jellies

Based on the composition of the jellies, their energy value was calculated in accordance with Regulation No 1169/2001 of the EU [23], by applying the respective conversion factors listed in the Regulation. The results are shown in Table 4.

From the calculated energy values of the jellies (Table 4), it can be seen that sample M has about 40% lower energy value than sample S. This allows the jelly from physalis juice with maltitol and maltitol syrup to be classified with a nutritional claim “Energy-reduced food” under the terms of Regulation (EC) No 1924/2006 [25], compared to the respective sugar-containing jelly.

Table 4

Energy value and value of the glycemic indicator of jellies from physalis juice

Sample*	Energy value, kJ/100 g	Glycemic indicator
S	1142	39.2
F	1128	14.6
M	680	23.5

* S – with sugar; F – with fructose; M – with maltitol and maltitol syrup

From the data presented in Table 4 it can be seen that sample F has the lowest value of the glycemic indicator (about 63% lower than sample S). This is due to the fact that its formulation contained fructose, which has a lower glycemic index (GI) than both sugar and maltitol [27]. The glycemic indicator value of sample M was also significantly lower (by about 40 %) than that of the sugar-containing jelly, which can be considered a promising result in terms of jelly use and promotion.

Conclusion

From the comparative analysis and the obtained results, it can be concluded that physalis juice is an appropriate ingredient for the preparation of jellies with sugar, fructose and maltitol/maltitol syrup. All jellies revealed physicochemical and textural properties, which make them promising material for use in different foods with sweet taste and provide grounds for future research.

The results from the study suggested that maltitol/maltitol syrup sweetener could be selected as the most functional sugar substitute in the composition of jellies from physalis juice. The fruit jelly with maltitol and maltitol syrup had a total sugar content that was 90% lower than that of the jelly made with sucrose and 83% of that with fructose. Additionally, the jelly obtained with maltitol and maltitol syrup had the lowest energy value compared to the jellies obtained with sugar and fructose. With the lowest glycemic indicator was the jelly obtained from a formulation with the participation of physalis juice and fructose. The jelly with maltitol and maltitol syrup had the highest hardness and adhesiveness, which – together with the lower sorption capacity – facilitates the use of the jelly in a wider range of sweet foods.

The jellies with physalis juice and maltitol/maltitol syrup can be classified with the nutrition claims “Energy-reduced food” and “Food with no added sugars” under the terms of the respective European regulations, and can be promoted as such if commercialized in the future.

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