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Physical and sensory properties of berry craft sorbet with inulin and effect of storage on total monomeric anthocyanins

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Abstract. Sorbets are sweetened frozen desserts obtained from fruit or fruit juice and are very popular, especially in the summer months. The aim of this study was to evaluate the effect of the addition of inulin and *Stevia rebaudiana* on the viscosity, hardness, total monomeric anthocyanin (TMA) content and sensory attributes of blueberry and raspberry sorbets. Four types of sorbets were produced from each fruit studied – three with inulin (2, 6 and 8% by weight) and the other without inulin – using fresh fruit with the addition of water, stevia extract powder, pectin and lemon juice. The addition of inulin slightly increased the viscosity of blueberry sorbet and had a statistically insignificant influence on the viscosity of raspberry sorbet. Hardness of the berry craft sorbet samples was influenced more by the addition of 2 and 6% inulin. TMA values ranged from 35.85 ± 1.1 (raspberry sorbet sample and 8% inulin) to 43.00 ± 0.8 (blueberry sorbet sample and 6% inulin) mg cyanidin 3-glucoside/g fresh weight. The results indicated that the addition of 8% inulin led to a slight decrease in TMA values compared to the values obtained for samples without inulin for both types of fruit sorbets. Also, the results showed that TMA values were very constant throughout the storage period. A more intense red color was observed in the raspberry sorbets, which increased with the addition of 2 and 6% inulin. The sorbet with the most pleasant taste was the one with blueberries without added inulin (8.8 ± 0.02), while the sorbet with blueberries and 2% inulin was the least liked by the evaluators (8.05 ± 0.01). The raspberry sorbet (without inulin) obtained the highest score for flavor (9 ± 0.02), while the sorbet with blueberries and 8% inulin obtained the lowest score (8.4 ± 0.04).

***Keywords*:** fruit craft sorbets; inulin; stevia; anthocyanin content.

1. Introduction

The sorbet dessert emerged as an alternative to ice cream, made from water and sugar, with a fruit content of at least 25%, being more advantageous in terms of raw materials and their diversity. The structure of sorbets is different from ice cream and less complex. The difference in the structure of the sorbet is represented by the size of the ice crystals, the amount of air incorporated and the viscosity of the base in the sorbet mixture. It can be mentioned that whole fruits can be incorporated into sorbets, even if they have suffered some damage, which is another advantage for widespread consumption and high availability on the market. Sorbets are a healthy alternative to traditional ice cream, which is commonly enjoyed by people of all ages due to their cooling effect and low nutritional value [1]. The health-promoting properties of sorbet result from the fruits used in its production, the beneficial effects associated with fruit and vegetable consumption in the prevention of several chronic diseases such as obesity, cardiovascular disease and others [2]. There is a wide variety of commercial sorbets, from lemon, cherry, kiwi, coconut, to watermelon both yellow and red [3], apricot, tomato [4], blueberry, strawberry, raspberry, passionfruit-mango [5], and poppy [6]. Also, in a study conducted by Malgor et al. [7], amaranth proteins were used as a functional ingredient in the formulation of lemon and amaranth sorbet, and, following the sensory analysis, the product was accepted, being associated with creamy and healthy attributes. In the present study, blueberries and wild raspberries are used in the formulation of sorbets. They are fruits native to the north of Bucovina, which have nutritional and functional properties, and are used not only for food applications, but also for many other purposes, e.g. pharmaceutical, fodder, decorative plants [8]. Blueberries (*Vaccinium corymbosum L.*) are rich in phenolic compounds, vitamins (vitamin C), anthocyanins and have anti-inflammatory, anti-allergic, antioxidant properties, being recommended for eye health, a remedy for gastric and duodenal ulcers and in the prevention of coronary diseases [9]. Raspberry fruits (*Rubus idaeus* L.) have a pleasant taste and a special aroma, which cannot be compared with the aroma of any other fruit [10]. The presence of vitamins, minerals [11, 12], and anthocyanins [13, 14] in raspberries has been reported. They are considered major preventive agents against several degenerative diseases with health-promoting effects [15]. In addition to fruit, the current study considered the addition of inulin to improve the properties of sorbets, stevia as a sugar substitute and pectin as stabilizer.

Inulin, belonging to a class of carbohydrates known as fructans, is naturally found in chicory root (*Cichorium intybus*), dandelion, Jerusalem artichoke (*Helianthus tuberosus*) or sea grass. In very small

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amounts, inulin is also found in asparagus, leeks, onions, bananas, wheat, and garlic. Chicory root (*Cichorium intybus*), however, is the most common source of inulin for health food manufacturers, due to its extremely high concentration [16, 17]. Inulin is a popular probiotic that is used in production, especially to improve the consistency and texture of ice cream, but also its organoleptic characteristics. Thus, the effect of inulin addition on the sensory characteristics of sorbet assortments containing avocado, kiwi, melon and mango was evaluated [18]. Two sorbet samples were prepared with inulin (2% and 5%) and the control sample without, with fresh fruit with the addition of water, sucrose and lemon juice. Both fruit type and inulin addition influenced the viscosity of the sorbet mixture, polyphenol content, vitamin C, acidity, DPPH antioxidant capacity and melt strength [18].

Stevia (*Stevia rebaudiana*) is a perennial shrub/plant cultivated for its leaves, which are used as a natural sweetener or flavor enhancer in the food and beverage industry. The extremely popular natural sweetener steviol obtained from Stevia leaves is the best alternative source of sugar, non-toxic especially for diabetic patients and which is about 300 times sweeter than sucrose [19]. Also, it was observed that steviol glycosides have antibacterial, diuretic, anti-inflammatory, hypotensive, anti-diabetic [20], anti-carcinogenic and antioxidant properties [21].

Pectin, probably the most complex natural macromolecule, is a heteropolysaccharide that predominantly contains galacturonic acid residues and is widely used as a gelling agent and stabilizer in the food industry [22]. Pectin is a natural source, present in the composition of many fruits and vegetables. Extraction of pectin from fruit waste has been reported using different techniques [23].

Therefore, the aim of this work was the physico-chemical and sensorial evaluation of new sorbet formulas with berries, water, stevia extract, lemon juice, pectin, with and without the addition of inulin. And also, to evaluate the stability of anthocyanin compounds during storage for 60 days at -18 ºC.

2. Experimental

2.1. Plant material and samples preparation

Blueberries and raspberries were harvested optimally ripe, in Suceava county, Romania. Fruits were cleaned and then stored at 4 ℃ until analysis. Lemons were purchased from a local supermarket, pectin and inulin from Enzymes & Derivates, and stevia extract powder was purchased from a specialty store. Eight craft sorbet samples (Figure 1) were formulated with different concentrations of inulin (sorbets samples with blueberries: without inulin – MB; with inulin - 2% (S1B), 6% (S2B) and 8% (S3B); sorbets samples with raspberries without inulin – MR; with inulin - 2% (S1R), 6% (S2R) and 8% (S3R)) and stevia extract powder (10%) according to Table 1.

Figure 1. Berry craft sorbet samples: a) MB; b) S1B, S2B, S3B; c) MR; d) S4R, S5R, S6R

Table 1. Content of components used in the formulation of the craft sorbet mix

Berry craft sorbet samples	Inulin [%]	Fruits [%]	Lemon juice [%]	Water [%]	Stevia extract powder [%]	Pectin [%]
MB	-	48.9	1	40	10	0.10
S1B	2	46.9	1	40	10	0.10
S2B	6	42.9	1	40	10	0.10
S3B	8	40.9	1	40	10	0.10
MR	-	48.9	1	40	10	0.10
S4R	2	46.9	1	40	10	0.10
S5R	6	42.9	1	40	10	0.10
S6R	8	40.9	1	40	10	0.10

The sorbet mixtures were prepared with deionized water to ensure consistent quality by dispersing the stevia extract powder in water at 60 ℃ under stirring with a magnetic stirrer until completely dissolved.

The fruits were blended in a Thermomix TM5 together with the lemon juice and cooled syrup until a smooth and homogeneous cream was obtained.

Sorbet samples were refrigerated at 4℃ for at least 12 hours before freezing.

2.2. Physico-chemical analysis

Total monomeric anthocyanin (TMA) content was determined using a UV-VIS spectrophotometer (Ocean Optics, Largo, FL, USA) according to Leahu et al. [9] after extraction. Extraction was carried out using 80% aqueous methanol solution containing 1 g/100 g HCl for extraction according to the method described by Karakütük et al. [24].

Absorbance was measured at 530 and 657 nm and the TMA content was expressed in mg of cyanidin-3-glucoside(C3G) equivalent per 100 g of fresh weight.

TMA content was calculated according to Eq. (1) using a molar extinction coefficient of cyanidin-3-glucoside of 29,600 L mol^{-1} cm^{-1} and the difference in absorbance between wavelengths:

$$TMA\left(\frac{mg}{g}\right) = \frac{A*MW*DF*V}{\varepsilon*\mathrm{Wt}} \qquad (1)$$

where: *MW* is the molecular weight (449.2 g/mol), *DF* - dilution factor, *V* - total volume (mL), *Wt* - sample weight (g).

The difference in absorbance between wavelengths was calculated with Eq. (2):

$$A = A_{530\,nm} - 0.25 * A_{657\,nm} \qquad (2)$$

where: A_{530nm} and A_{657nm} are the absorbance at 530 and 657 nm, with 25% of the A657 reading subtracted to account for chlorophyll breakdown products according to Helaly et al. [25].

The viscosity of the sorbets mixtures was tested at 4 °C using a digital viscometer (model DV-II; Brookfield Engineering Laboratories, Stoughton, MA).

Hardness analysis. The texture profile evaluation test was carried out using a TVT 6700 texturometer (Perten Instruments, Stockholm, Sweden).

Color measurement. A tristimulus Chroma Meter CR-200 color analyzer (Minolta, Osaka, Japan) was used to measure the color parameters of the crafts sorbet samples using the CIELAB system. The L* (whiteness/darkness; from 0 = black to 100 = white), a* (redness/greenness; − a = green, +a = red), and b* (yellowness/blueness; − b = blue, +b = yellow) values were obtained [26].

2.3. Sensory evaluation

Twenty-eight healthy, untrained students (12 males and 16 females, aged 22 to 32 years, from "Stefan cel Mare" University of Suceava, Romania) evaluated the sorbet samples from a sensory point of view. Each sample was rated for taste, flavor, color, sweetness, texture and overall acceptability on a 9-point hedonic scale, with 1 representing "non-existent or imperceptible" and 9 representing "very intense" properties, after consumption of each 5 g food product (one for each sorbet) [5].

2.4. Statistical analysis

Statistical evaluation was performed using Minitab software (version 17), considering an analysis of variance (ANOVA) with a 95% confidence interval ($p<0.05$) and Tukey test. Correlations between parameters were determined by Pearson correlation method.

3. Results and discussion

3.1. Total monomeric anthocyanin content

The results showed that blueberry sorbet samples had a higher TMA content compared to raspberry sorbet samples (Table 2). The total anthocyanin content for our blueberry samples was higher than the values reported for Chilean blueberry (*Vaccinium corymbosum*) samples (21.41 ± 1.65 mg/g dry weight) [27].

Table 2. Total monomeric anthocyanin (TMA) content in sorbet formulations evaluated before (TMA, 0) and after 60 days of storage at − 18 °C (TMA, 60)

Berry craft sorbet samples	TMA*, 0	TMA, 60
MB	42.32 ± 1.6 ^{a}	43.01 ± 0.7 ^{a}
S1B	42.80 ± 1.1 ^{a}	42.85 ± 0.9 ^{a}
S2B	43.00 ± 0.8 ^{a}	42.03 ± 1.2 ^{a}
S3B	41.50 ± 1.7 ^{ab}	42.16 ± 1.6 ^{a}
MR	36.56 ± 2.7 ^{c}	36.68 ± 1.9 ^{b}
S1R	36.85 ± 2.1 ^{bc}	37.41 ± 1.5 ^{b}
S2R	36.90 ± 1.5 ^{bc}	35.51 ± 1.7 ^{b}
S3R	35.85 ± 1.1 ^{c}	36.77 ± 0.8 ^{b}

*TMA-total monomeric anthocyanin content (mg cyanidin 3-glucoside/g fresh weight); Values with the different letters within one column are significantly different ($p < 0.05$).

It was observed that the addition of inulin in 2 and 6% increases the TMA content, while the addition of 8% slightly decreases the TMA content in blueberry and raspberry sorbet samples. Before storage, TMA content ranged from 41.50 ± 1.7 (8% inulin sample) to 43.00 ± 0.8 (6% inulin sample) mg cyanidin 3-glucoside/g fresh weight, while after 60 days of storage it ranged from 42.03 ± 1.2 (6% inulin sample) to 43.01 ± 0.7 (without inulin sample) mg cyanidin 3-glucoside/g fresh weight. The anthocyanin content did not show significant changes during the storage period of the sorbets (Table 2), the quantified values were very constant throughout the storage period. Marinho et al. [28] also evaluated the stability of anthocyanins in probiotic and symbiotic sorbets produced with jussara pulp (*Euterpe edulis*) and analyzed for 120 days. They reported similar results, the values are very close and showed no changes in the anthocyanin content during the storage of the products for about 120 days [28].

3.2. Apparent viscosity and hardness of sorbet craft mix samples

The apparent viscosity values (Table 3) are similar but differ depending on the fruits used as raw material. The sorbet samples analyzed are dense, but moderately thick samples due to the raw material (berries).

Table 3. Apparent viscosity and hardness values of sorbet craft mix samples

Berry craft sorbet samples	Apparent viscosity (Pa·s)	Hardness (Force g^{-1})
MB	0.034 ± 0.001 ^{b}	9301 ± 0.01 ^{b}
S1B	0.042 ± 0.003 ^{a}	8485 ± 0.03 ^{e}
S2B	0.042 ± 0.001 ^{a}	9003 ± 0.01 ^{d}
S3B	0.04 ± 0.005 ^{ab}	9216 ± 0.05 ^{c}
MR	0.02 ± 0.002 ^{c}	9568 ± 0.02 ^{a}
S1R	0.023 ± 0.001 ^{c}	8241 ± 0.01 ^{g}
S2R	0.022 ± 0.003 ^{c}	7651 ± 0.03 ^{h}
S3R	0.022 ± 0.001 ^{c}	8277± 0.01 ^{f}

Values with the different letters within one column are significantly different ($p < 0.05$).

It was observed that the inulin addition increased the viscosity of craft berries sorbets. Similar results were obtained by other authors: Palka and Skotnicka [18] stated that the addition of inulin (both 2 and 5% wt.) increased the viscosity of avocado, kiwi, honey melon, yellow melon, and mango sorbets. Also, the use of arrowroot in combination with ultrasonic pasteurization had a positive effect on reducing the apparent viscosity of the ice cream mix [29].

Hardness of the craft berries sorbets decreased with the addition of inulin (Table 3), the highest decrease was observed for blueberry sorbet sample with 2% inulin (8485 ± 0.03 Force g^{-1}) and for raspberries sorbet sample with 6% inulin (7651 ± 0.03 Force g^{-1}) comparative with control samples (MB and MR). This was consistent with the results obtained by Akbari et al. [30] who reported that the addition of inulin caused a significant decrease in the hardness of low-fat ice creams. A higher concentration of dissolved substances, but also the absorption of water by inulin can lead to a decrease in hardness [30]. Ürkek [31] found that the ice cream hardness values for the control sample were higher than those of the samples formulated with salep and chia seed powder (0.2, 0.4, 0.6, 0.8%).

*3.3. Color measurement in the CIE L*a*b* system*

According to Table 4, the L* values (indicating the level of brightness) increased for the blueberry sorbet samples with added inulin compared to the control sample values, while it decreased for the raspberry sorbet samples with 2 and 6% inulin.

Table 4. Color parameters (L^*, a^*, b^*), of sorbets craft samples

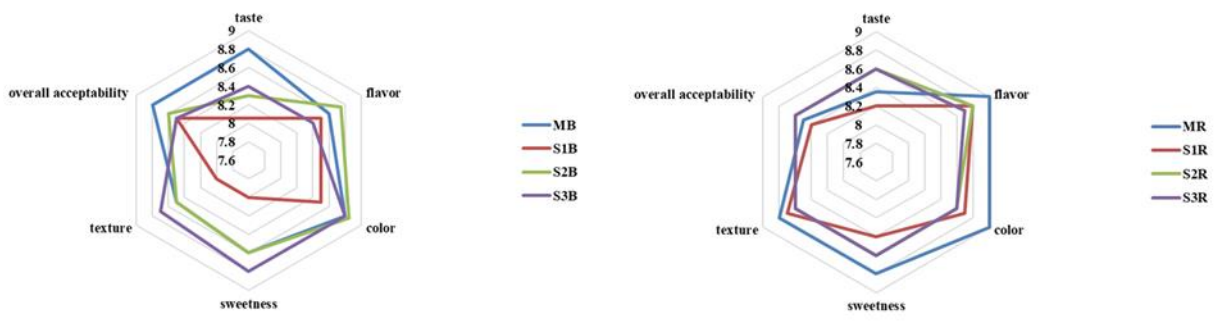
Berry craft sorbet samples	L*	a*	b*
MB	24.20 ± 0.02 ^{c}	10.94 ± 0.01 ^{h}	6.06 ± 0.02 ^{h}
S1B	25.41 ± 0.03 ^{a}	12.76 ± 0.01 ^{g}	6.40 ± 0.05 ^{g}
S2B	25.07 ± 0.04 ^{b}	13.08 ± 0.04 ^{f}	6.61 ± 0.03 ^{f}
S3B	25.14 ± 0.05 ^{b}	13.24 ± 0.04 ^{e}	6.85 ± 0.01 ^{e}
MR	20.80 ± 0.05 ^{e}	31.10 ± 0.05 ^{c}	17.90 ± 0.05 ^{c}
S1R	19.60 ± 0.01 ^{f}	32.30 ± 0.02 ^{b}	17.30 ± 0.05 ^{d}
S2R	19.20 ± 0.01 ^{g}	32.70 ± 0.03 ^{a}	18.20 ± 0.01 ^{a}
S3R	20.90 ± 0.03 ^{d}	30.90 ± 0.04 ^{d}	18.10 ± 0.02 ^{b}

Values with the different letters within one column are significantly different ($p < 0.05$).

The highest a* values, due to the more intense red color shown, were found in raspberry sorbet (ranged between 30.9±0.04 for sample with 8% inulin and 32.70±0.03 for sample with 6% inulin). The parameter b* which gives the yellow color of the sorbet samples had higher values for raspberry sorbet compared to blueberry sorbet. The b* values increased with the inulin addition. The results indicate that the color difference between the sorbets was easily perceptible. Ekici [32] reported that the microwave method preserved L*, hue angle ($h°$ = arctan (b^*/a^*)) and Chroma (C^*) values of poppy sorbet better than that of vacuum and conventional methods.

3.4. Sensory evaluation

The sensory scores of the eight sorbets craft products are presented in Figure 2. Blueberry sorbet sample without inulin (MB) obtained the highest score for taste (8.8±0.02), while blueberry sorbet sample with 6% inulin (S2B) obtained the highest score for flavor (8.75±0.01) and color (8.85±0.01), and the blueberry sorbet sample with 8% inulin scored the highest for sweetness (8.8±0.05) and texture (8.7±0.02) (Figure 2a). The most appreciated raspberry sorbets for taste were those with the addition of 6 and 8% inulin (Figure 2b), while the sample without inulin received the highest score for flavor (9.0±0.02). Also, the raspberry sorbet sample without inulin scored highest for color (9.0±0.04), sweetness (8.8±0.02) and texture (8.8±0.03) compared to the samples with added inulin.



a) b)

Figure 2. Sensory evaluation of the sorbet samples

The texture of the samples was appreciated because the berries are rich in pectin, which acts as thickening agents, resulting in a creamy sorbet that approximates the texture of ice cream. The sorbets preserved much of the nutrients and presented very intense colors, mainly in the case of blueberry sorbet. Blueberry and raspberry sorbets are an additional means of increasing fruit consumption, especially in restaurants, because today sorbet is used gastronomically in main dishes and desserts, offering a pleasant and tasty aroma.

3.5. Principal component analysis

Principal component analysis (PCA) was performed to group and classify samples of craft berry sorbet based on their characteristics and to determine the interrelationships between characteristics. With an eigenvalue of 6.213, PC1 explained 51.8% of the total variation, while PC2 explained 25.8% (eigenvalue - 3.096). Figure 3 illustrates the combined scores and loadings plot for two components (PC1 and PC2). Parameters like color, taste sweetness, texture, flavor (sensory attributes) had positive loadings on PC1 and PC2, while color parameters like a* and b* had positive loadings on PC1 (0.391 and 0.393) and negative loadings on PC2 (-0.125 and -0.101). L* (-0.387), TMA (-0.390), Av (-0.389), H (-0.143), overall acceptability (-0.107) had negative loadings on PC1 and positive loadings on PC2. Figure 3 shows that blueberry sorbet samples MB, S2B and S3B are located to the left in the biplot of scores and had negative values for PC1 and positive values for PC2, while S1B, also located to the left, had negative values for both PC1 and PC2. Raspberry sorbets samples were located to the right in the biplot and S1R, S2R, S3R had positive values for PC1 and negative values for PC2, while MR had positive values for both PC1 and PC2. It was observed that sensory attributes (except overall acceptability), and color parameters (a* and b*) were more representative for raspberry sorbets samples, while overall acceptability, L*, TMA, H and Av were more representative for blueberry sorbet samples.

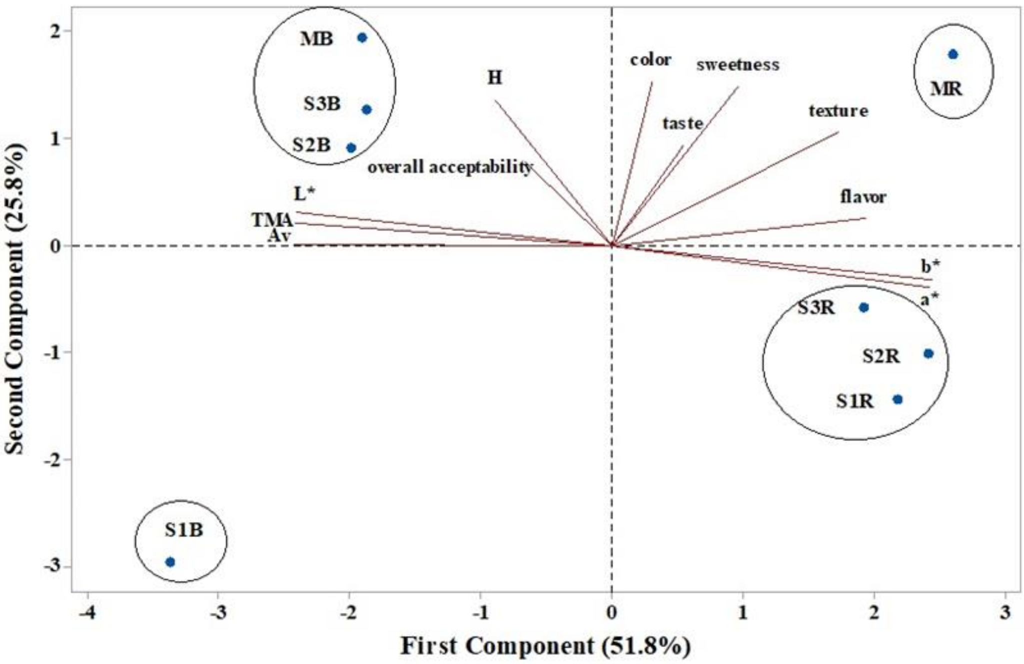


Figure 3. Biplot of scores and loadings of data obtained from physico-chemical parameters (apparent viscosity (Av), total monomeric anthocyanin content (TMA)), color parameters (L*—lightness; a*—greenness; b*—yellowness), texture attribute (hardness (H)) and sensory attributes (taste, flavor, color, sweetness, texture, overall acceptability) of berry craft sorbet samples (control samples with blueberry (MB) and with raspberry (MR); samples with 2, 6 and 8% inulin addition (S1B, S2B, S3B and S1R, S2R, S3R, respectively)

4. Conclusions

The quality, colors, texture and sensory analysis of craft blueberry and raspberry sorbets with stevia extract and with and without added inulin were compared. Adding a content of 2 to 6% inulin leads to an increase in TMA content, but a higher percentage of inulin leads to a decrease in this content. There were significant differences between the samples due to the fruit used in terms of apparent viscosity. As the proportion of inulin was increased the viscosity of craft berries sorbet samples increased, from 0.034 ± 0.001 for MB (blueberries without inulin) to 0.04 ± 0.005 for S3B (blueberries with 8% inulin).

The addition of inulin intensifies the red color in the raspberry's sorbet. The most appreciated sorbets among those with inulin were: blueberries sorbet with 6% inulin and raspberries sorbet with 8% inulin. Investigation of the sorbet samples revealed outstanding sensory properties, blueberries and raspberries are a confirmed source of health-promoting biochemical compounds with antioxidant activity. In addition, blueberries and raspberries are suitable for application in food matrices such as sorbet and can retain their functional properties during storage at low temperatures.

Conflict of interest

Authors declare no conflict of interest.

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