

ASSESSMENT OF POSSIBILITIES OF STRAWBERRY JAM REFORMULATION

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ABSTRACT

The prevalence of excessive weight gain, obesity, and associated diseases are permanently increasing. Therefore, the interest in food products with a composition suitable for people with the aforementioned health problems is also on the rise. The changes in food composition, nowadays often called reformulation, are mainly focused on reducing the amount of salt, sugar, or fat. Strawberry spreads with different sugar (10 – 40%) and strawberry (20 – 50%) content were prepared and the influence of strawberry jam composition on gel stiffness, colour, and sensory parameters was studied. This study aimed to determine the sensorial and technological limits (sugar and strawberry content) of strawberry jam reformulation. Carrageenan was chosen as a suitable gelling agent for the preparation of these reformulated strawberry products. strawberry spreads. The applicable concentration of carrageenan for the ideal stiffness of strawberry spreads was 2%. The results of the maximum compression force show a statistically significant increase of gel stiffness with increasing addition of strawberry puree, the effect of sugar content was also statistically significant ($p = 0.05$). This study showed that strawberry spreads with low strawberry and/or sugar content are sensorially acceptable.

Keywords: fruit spreads; carrageenan; texture characteristics; colour

INTRODUCTION

At the end of 2011, the world population had reached 7 billion and it is supposed the increase of one billion people to 2025. Around one billion people in the 21st century are starving and another billion people are suffering from micronutrient deficiency. On the other hand, over a billion people worldwide are deemed overweight or obese, with increased risk of associated diseases. Even with sufficient intake or excessive energy, consumed food can remain a poor source of essential nutrients. Opportunities to improve the nutritional profile and sustainability of the diet are found throughout the food chain, farm production, retail, and households. These include crop diversification, food enrichment, improvements in the efficiency of transport, waste minimisation, and last but not least food reformulation (Buttriss, 2013).

The food industry has two main approaches to product reformulation: gradual reduction of nutrient content without introducing further changes in product formulation or partial/total replacement with other nutrients such as hydrocolloids, fat substitutes, and sweeteners (Ares et al., 2018). However, some studies have found that products without added salt or sugars leave a negative sensory impression (Phelps et al., 2006; DuBois and Prakash, 2012). Added sugars are defined as sugars that are added to foods during processing, preparation, or “on the table”. They contribute to the energy value of the diet but have a

little nutritional benefit and their high intake is associated with increased dietary energy, dental caries, and other adverse health effects such as excessive weight gain and reduced bone density. The current WHO recommendation is that the intake of added sugars should be less than 10% of the total energy intake (WHO, 2015; Yeung et al., 2017). Replacing sugars in reformulated foods could represent a strategy to reduce sugar intake in the population without a significant change in the normal diet. However, reducing the sugar content of food is not easy because it results in changes to taste, texture, functionality and shelf life (van Raaij, Hendriksen and Verhagen, 2009; Cruz et al., 2010). The hygroscopic nature of sugar plays an important role in reducing water activity in foods and helps maintain and prolong the shelf life of foods. Sugar prevents for example microbial spoilage of jams after opening. It is therefore always necessary to understand the function of sucrose in a particular food product before it is replaced (Goldfein and Slavin, 2015).

Fruit, vegetables, and related products are often perceived by the consumer as “healthy” and consumable in any quantity. However, fruit and in particular for fruit products should be consumed with caution. Fruit products (compotes, fruit spreads, candied fruit, and other) often contain high sugar content. The effort to reformulate is then significant for the aforementioned reasons (Rýdlová et al., 2019). The term “fruit spreads” is generally used in the food processing industry for marmalades, jams, jellies, and similar products. Fruit spreads have traditionally high

sugar content (60 – 65%), and there is the possibility for their reformulation. The formation of the desired jelly consistency of a fruit spread with reduced sugar content can be achieved by the use of low-esterified pectins or alternatively gelling agents based on gums or extracellular products of microorganisms (Kadlec, Melzoch and Voldřich, 2012).

Scientific hypothesis

It is possible to reduce sugar content (up to 10%) and/or strawberry content (up to 20%) of the strawberry jam without it will result in less acceptable products.

There are technological and sensory acceptance limits for the sugar and/or strawberry content in strawberry spreads.

MATERIAL AND METHODOLOGY

Carrageenan C (CEAMGEL 9205; CEAMSA, Spain), citric acid (Hubka-Petrášek a vnuci s.r.o., Czech Republic), sucrose (DIAMANT; 1. Cukerní společnost Praha, s.r.o., Czech Republic), strawberry puree (100%) (Fruta Podivín, a.s., Hamé s.r.o., Czech Republic), distilled water, potassium hydrogen phthalate (SIGMA-ALDRICH, USA).

Sample preparation

Carrageenan gels (n = 2). 36 samples of carrageenan gels (C1 – C36, Table 1) with different sugar (10%, 20%, 30% and 40%), citric acid (0%, 0.25% and 0.5%) and carrageenan (1%, 1.5% and 2%) content were prepared. The calculated amount of sugar and carrageenan was added to boiling water in a multifunctional blender (Thermomix TM31, VORWERK, France), and the batch was agitated at 80 °C for 15 minutes. After 13 minutes of agitation, the calculated amount of citric acid was added (as a 50% water solution). The preparation of samples was carried out in the closed cooking blender. The total mass of one batch was 500 g. From each batch, 10 identical samples were prepared in 25 mL beakers. The cooked samples were stored in a refrigerator at 10 °C for 16 hours.

Strawberry spreads (n = 3). 16 samples of strawberry spreads (J1 – J16, Table 2, Figure 1) with different content of strawberry puree (20%, 30%, 40%, and 50%) and sugar (10%, 20%, 30%, and 40%) were prepared. Samples were prepared in the same way as carrageenan gels except that the strawberry puree was used instead of boiling water and heat-treated in a mixer at 90 °C for 10 min. The final mass of each batch was 500 g.

Methods

Gel stiffness (n = 10). Gel stiffness was analysed according to the method of Sinthusamran, Benjakul and Kishimura (2014) with a slight modification. The tests were performed with an Instron Model 5544 (Instron Ltd., USA). For the measurement, a 1-cm wide cylindrical plunger with a straight tip was used. The plunger's movement velocity was 80 mm.min⁻¹. The maximum force required to retract the plunger to a depth of 4 mm into the gel was recorded.

Titration acidity (n = 3) was measured by titration with 0.1 M NaOH (pH 8.1) and calculated as citric acid content

(DL-22 Food & Beverage Analyzer, Mettler Toledo Co., Switzerland). Titration acidity was determined by (AOAC, 2002).

Colour (n = 6). Colour determination was performed in the CIEL*a*b* (*L** lightness, *a** redness, *b** yellowness) colour space on a Minolta CM-5 spectrophotometer (Konica Minolta, Osaka, Japan). The parameters *L**, *a**, and *b** of strawberry spreads (J1 – J16) were determined (Igual, Contreras, and Martínez-Navarrete, 2014). Samples were always dispensed into a cylindrical glass cell up to a height of 3 cm. The cell was placed on a measuring window with 30 mm diameters. Measurements were carried out in both the specular component included (SCI) mode and the specular component excluded (SCE) mode. The values measured in SCE mode were used for further processing in this study.

Soluble solid content (n = 3) of strawberry puree and strawberry spreads were measured using a digital refractometer (KRÜSS DR301-95, Germany).

Sensory analysis. The test room was equipped according to the requirements of the international standard (UNI ISO 8589, 2007). The strawberry spread samples were evaluated by untrained sensory panellists (n = 30). The strawberry spread samples were evaluated for texture, sweet taste, sour taste, fruity taste, and overall acceptability. Sensory attributes were recorded using a nine-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike, 9 = like extremely).

Statistical analysis

Outliers, identified according to a Dean-Dixon test, were excluded at the significance level of $p = 0.05$. Results are presented as mean ± standard deviation. Data obtained from texture analysis, colour measurement, and sensory analysis were analysed using the Student t-test. Statistical analyses were carried out using the Statistica 12.0 software (Statsoft Inc., Tulsa, OK, USA). All the measurements of titration acidity and soluble solids were performed in triplicate. The measurement of colour was performed in six replicates, and the measurement of gel stiffness was performed ten times for each sample.

RESULTS AND DISCUSSION

According to the literature review (Tang et al., 2019; Ellis et al., 2019; Ortiz-Tafuya et al., 2018), carrageenan was chosen as a gelling agent for reformulated strawberry jam. The model samples of carrageenan gel were prepared (Table 1), and gel stiffness was measured. The results of the carrageenan gel stiffness are shown in Figure 2, Figure 3, and Figure 4. The results show that carrageenan, sugar, and citric acid content influence the gelling ability and gel stiffness of carrageenan gels. The gel stiffness increased significantly with increasing amounts of carrageenan. Likewise, the addition of sugar slightly increased the gel stiffness, as confirmed by the results of studies by Lopez-Sanchez et al. (2018), Maurer, Junghans, and Vilgis (2012), Deszczynski, Kasapis and Mitchell (2003) and Watase et al. (1990). However, the addition of citric acid significantly reduces the gel stiffness of carrageenan gels ($p = 0.05$).

Table 1 Recipes of carrageenan gels for evaluation of sugar and citric acid content on the gelling ability of carrageenan.

Content of citric acid = 0%		Content of carrageenan C [%]		
		1	1.5	2
Sugar content [%]	10	C1	C5	C9
	20	C2	C6	C10
	30	C3	C7	C11
	40	C4	C8	C12
Content of citric acid = 0.25%		Content of carrageenan C [%]		
		1	1.5	2
Sugar content [%]	10	C13	C17	C21
	20	C14	C18	C22
	30	C15	C19	C23
	40	C16	C20	C24
Content of citric acid = 0.5%		Content of carrageenan C [%]		
		1	1.5	2
Sugar content [%]	10	C25	C29	C33
	20	C26	C30	C34
	30	C27	C31	C35
	40	C28	C32	C36

Table 2 Recipes of strawberry spreads with carrageenan as the gelling agent.

Content of carrageenan C = 2%		Content of strawberry puree [%]			
		20	30	40	50
Sugar content [%]	10	J1	J5	J9	J13
	20	J2	J6	J10	J14
	30	J3	J7	J11	J15
	40	J4	J8	J12	J16
Addition of citric acid [%]		0.32	0.23	0.14	0.05



Figure 1 Measurement of strawberry spread gel stiffness.

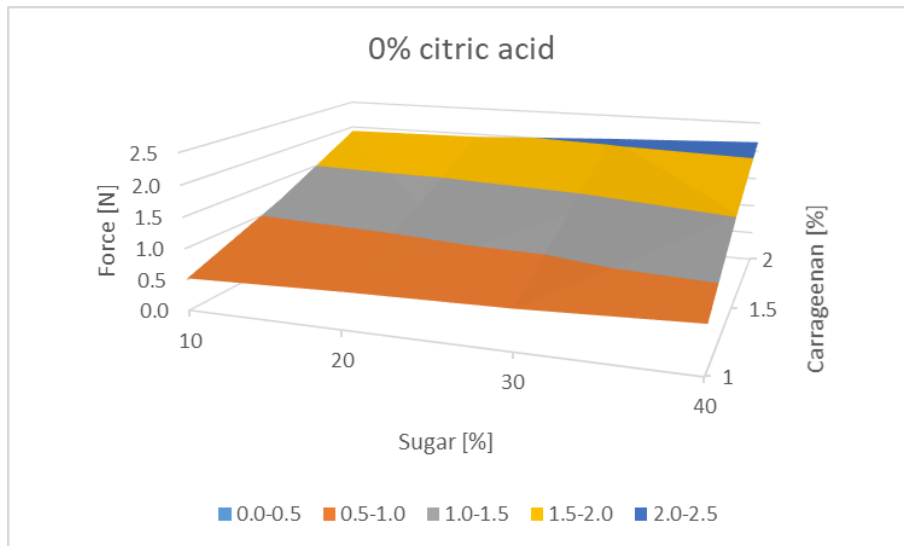


Figure 2 Dependence of gel stiffness on sugar and carrageenan C content, content of citric acid = 0.00%.

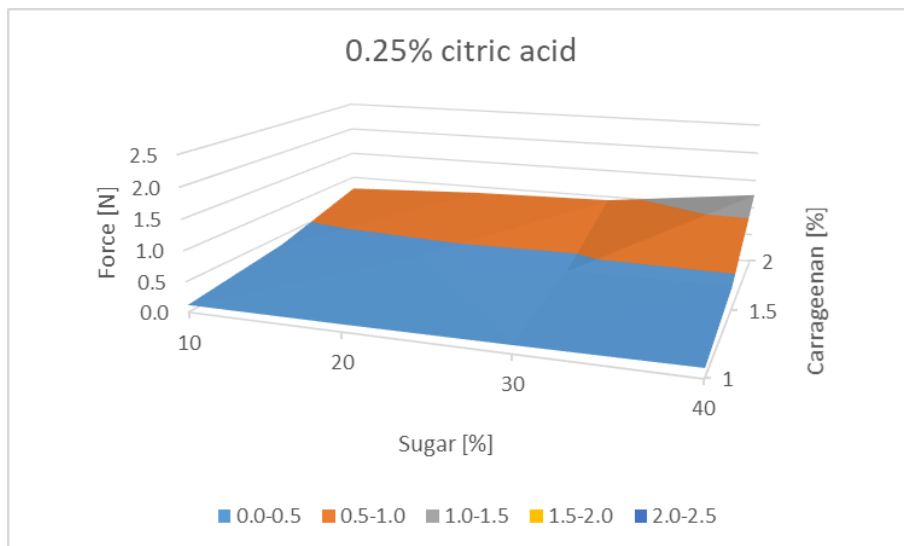


Figure 3 Dependence of gel stiffness on sugar and carrageenan C content, content of citric acid = 0.25%.

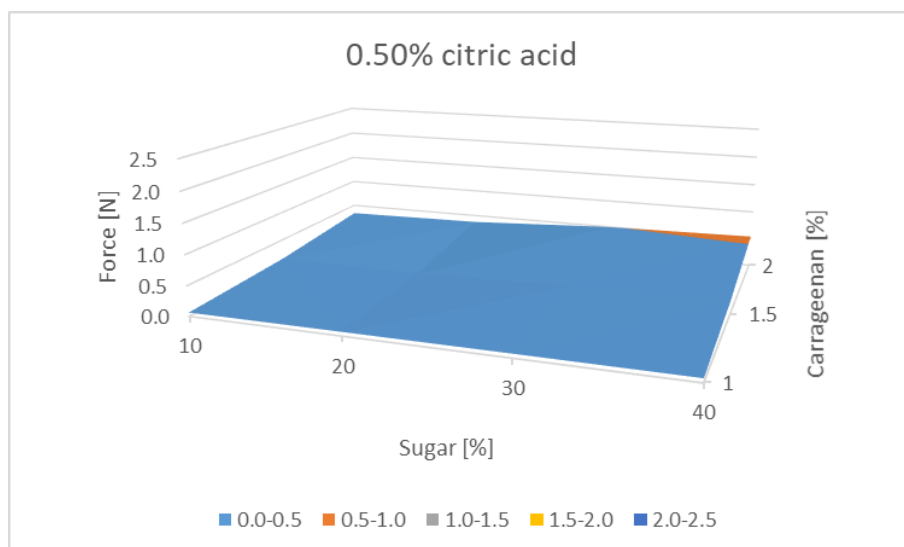


Figure 4 Dependence of gel stiffness on sugar and carrageenan C content, content of citric acid = 0.50%.

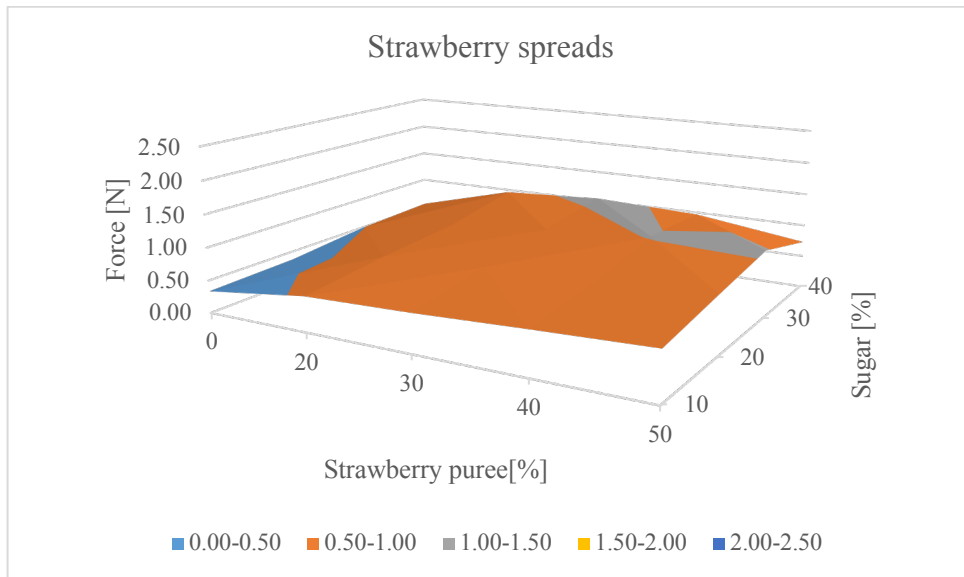


Figure 5 Dependence of strawberry spread stiffness on the content of strawberry puree and sugar, addition of carrageenan C = 2% and addition of citric acid to the total content of 0.50%.

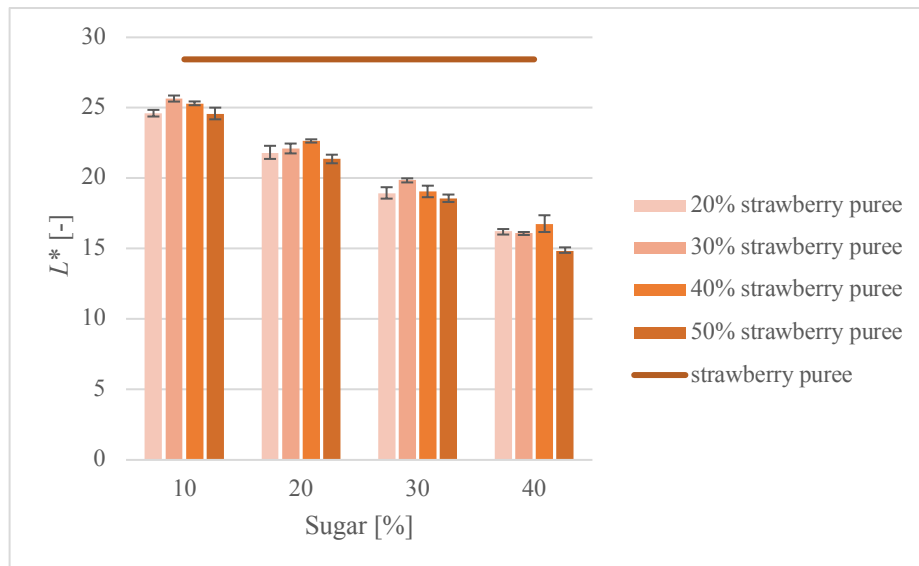


Figure 6 Dependence of L* on sugar content and strawberry puree content in the samples J1 – J16 in comparison with strawberry puree.

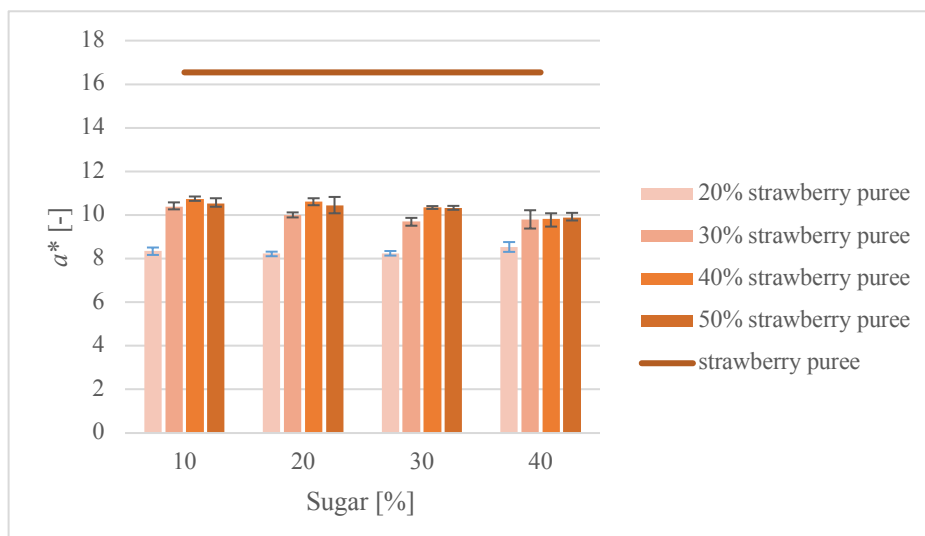


Figure 7 Dependence of a* on sugar content and strawberry puree content in the samples J1 – J16 in comparison with strawberry puree.

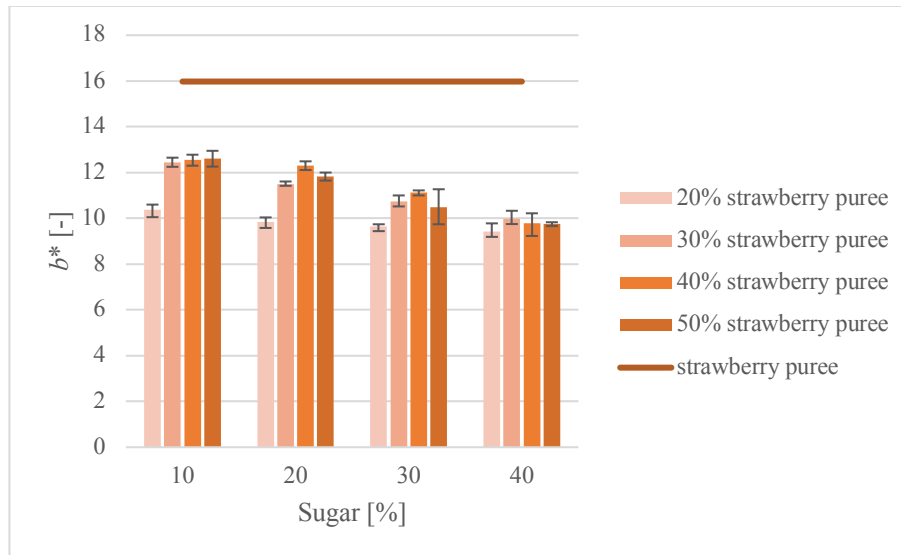


Figure 8 Dependence of b* on sugar content and strawberry puree content in the samples J1–J16 in comparison with strawberry puree.

Table 3 Sensory analysis results of the strawberry spread samples (J1 – J16).

Sample	Sensory attributes				
	Texture	Sweet taste	Sour taste	Fruity taste	Overall acceptability
J1	4.00 ± 1.56 ^b	3.70 ± 1.77 ^c	3.20 ± 1.99	2.30 ± 1.70 ^a	3.35 ± 2.86
J2	4.60 ± 1.58 ^a	5.80 ± 1.55 ^b	3.60 ± 2.12	3.80 ± 2.15	4.87 ± 2.65
J3	5.40 ± 1.96	7.00 ± 1.94 ^c	3.70 ± 1.34	4.00 ± 1.56 ^a	4.92 ± 2.56
J4	5.50 ± 1.27 ^a	7.70 ± 1.49 ^c	3.70 ± 1.34	4.00 ± 1.49 ^a	4.20 ± 2.83
J5	4.50 ± 1.51 ^a	4.00 ± 1.70 ^c	3.20 ± 2.15	2.80 ± 1.40	4.00 ± 3.03
J6	4.90 ± 1.60	6.10 ± 1.79 ^b	3.60 ± 1.43	3.60 ± 1.26	4.95 ± 2.60
J7	5.80 ± 2.20 ^a	6.90 ± 1.85 ^c	3.00 ± 1.56	3.90 ± 1.60 ^a	4.25 ± 2.41
J8	6.20 ± 1.48 ^b	7.60 ± 1.58 ^c	3.40 ± 1.26	3.90 ± 1.45 ^a	4.51 ± 2.37
J9	4.30 ± 1.77 ^a	4.90 ± 1.29 ^c	3.30 ± 1.83	3.20 ± 1.23	4.29 ± 2.88
J10	5.00 ± 1.76	6.00 ± 1.49 ^b	2.50 ± 1.35	3.70 ± 1.34	4.60 ± 2.41
J11	6.10 ± 2.18 ^a	6.80 ± 2.20 ^b	2.60 ± 1.51	3.40 ± 1.43	3.82 ± 2.62
J12	6.00 ± 1.76 ^a	7.50 ± 1.96 ^c	2.50 ± 1.51	3.60 ± 1.78	4.05 ± 2.82
J13	4.70 ± 1.83	4.50 ± 1.65 ^c	2.50 ± 1.65	3.00 ± 1.83	4.14 ± 2.95
J14	5.00 ± 1.70	5.90 ± 2.38 ^a	2.70 ± 1.89	3.30 ± 2.26	4.48 ± 2.96
J15	6.20 ± 2.39 ^a	7.50 ± 1.78 ^c	2.70 ± 1.77	3.30 ± 1.77	3.53 ± 2.54
J16	5.70 ± 1.70 ^a	8.30 ± 1.83 ^c	2.70 ± 1.49	3.60 ± 1.78	3.91 ± 3.16

Note: ^a Significant difference by Student's t-test ($p = 0.05$), ^b Significant difference by Student's t-test ($p = 0.01$), ^c Significant difference by Student's t-test ($p = 0.001$).

The results show that it is not necessary to add citric acid to strawberry spreads because of the natural occurrence of organic acids in a strawberry puree to improve the texture parameters (Kallio et al., 2000; Sturm, Koron and Stampar, 2003). However, the addition of citric acid is necessary for the sensory parameter of the final product (balance of sweet and sour taste). Therefore, the same final

concentration of 0.5% of citric acid was chosen for the preparation of all strawberry spreads.

One of the parameters of the overall sensory perception of this type of product for the consumer is gel stiffness (Pérez-Herrera et al., 2020). The results of the strawberry spreads gel stiffness (Figure 5) show, that both, sugar and strawberry puree content contribute to this ability to form a gel ($p = 0.05$). The maximum force required to compress

the gel was higher than that of carrageenan gels with the same sugar and citric acid addition ($p = 0.05$). Samples containing 40 – 50% of strawberry puree and 30 – 40% of sugar achieved the highest gel stiffness. Only samples without strawberry puree and low sugar content (10 – 20%) showed low gel stiffness.

Colour is one of the most important parameters of strawberries and strawberry products for their final perception and attractiveness to consumers (Bursać Kovačević et al., 2015). Parameter (L^*) of prepared strawberry spreads J1 – J16 is shown in Figure 6. The results show that the addition of sugar significantly reduces product lightness ($p = 0.001$). This fact is probably due to the amount of sugar, which contributes to the Maillard reaction (Li et al., 2020; Liao et al., 2020; Shen, Chen and Li, 2018; Basu, Shivhare and Singh, 2013). The addition of strawberry puree also had a significant effect on parameter L^* of strawberry spreads ($p = 0.05$), but less than that of sugar.

The parameter a^* (redness, Figure 7) was not affected by the amount of sugar added ($p = 0.05$). Significantly lower was the redness (a^*) of the strawberry spreads with a strawberry puree content of 20%. On the other hand, the addition of strawberry puree affected the colour parameter a^* ($p = 0.05$).

Colour parameter b^* (yellowness, Figure 8) was lower for samples with a strawberry puree content of 20% ($p = 0.05$). Like the parameter L^* , parameter b^* decreased with the addition of sugar. This difference is statistically significant ($p = 0.05$).

The results of the sensory analysis of strawberry spreads (J1 – J16) are shown in Table 3. It is visible, that the evaluation of all samples was very subjective. The results of sensory evaluation of texture and sweet taste show that panellists identify differences between samples. In contrast to this fact, the differences in acid taste and overall acceptability ($p = 0.05$) were not perceived between samples. The overall acceptability values ranged across the whole hedonic scale for all samples. No statistically significant differences between the overall acceptability value of tested samples were observed ($p = 0.05$).

CONCLUSION

The reduction of sugar content in strawberry spreads was carried out with a focus on people with special nutritional requirements, specifically suffering from obesity and type 2 diabetes. Carrageenan is a suitable gelling agent for the preparation of reformulated strawberry spreads. The applicable concentration of carrageenan C in strawberry spreads for the ideal stiffness of strawberry spreads was 2%. The results of the maximum compression force show a statistically significant increase of gel stiffness ($p = 0.05$) with the increasing addition of strawberry puree. As the sugar content in the model increases, the maximum compression force values increase. This effect is also statistically significant ($p = 0.05$) but not as much as the effect of strawberry puree. It was possible to reduce the sugar content in strawberry spreads up to 10% with acceptable sensory perception. The production of this type of fruit spreads with standard characteristics is a complex task influenced by many factors, including the type of used gelling agent and characteristics of input raw material. These reformulated strawberry spreads may be an

alternative to jams, which are not recommended because of their high sugar content, for people suffering from these diseases.

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