Agronomy Research **21**(3), 1143–1153, 2023
https://doi.org/10.15159/AR.23.050

Nutritional, physical and sensory quality of gingerbread prepared using different sweeteners

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Received: February 11th, 2023; Accepted: May 28th, 2023; Published: June 16th, 2023

Abstract. The aim of the study was to investigate the effects of replacing refined beet sucrose in gingerbread with different types of sweeteners (cane sugar, sorbitol, xylitol, maple syrup). The content of fat, dry matter, dietary fibre, ash, crude protein, amino acids, selected microelements, and caloric value were determined. Organoleptic and dimensional (3D-analysis) properties were also evaluated.
The fat content in samples ranged from 11.13% to 11.97%, crude fibre content - from 0.53% to 0.55%, ash content - from 0.72% to 1.06%, and crude protein - from 7.92% to 8.12%. The analysis of amino acids revealed that glutamic acid was dominant in the samples with its concentration ranging from 19.14 mg g^{-1} (control sample) to 23.88 mg g^{-1} (sample with maple syrup). The caloric value was the highest in the control sample which contained sucrose from sugar beet and the one containing xylitol (~4,480 cal g^{-1}). The lowest - in the sample with maple syrup (4,247 cal g^{-1}). The total content of selected microelements determined in the tested samples with atomic absorption spectrometry (Fe, Mn, Zn, Cu, Co, Ni, Cr, Cd and Pb) were within the limits permitted by the regulations of the Slovak legislation. The 3D analysis of samples with Volscan Profiler indicated that volume, width and height was better in the samples with sweeteners than in the control sample. The gingerbread with xylitol had best organoleptic properties, as evaluated by sensory panellists.

Key words: bakery product, cane sugar, sorbitol, xylitol, maple syrup, properties.

INTRODUCTION

Sugar is one of the most widely traded products in international market. It is a carbohydrate that occurs naturally in most of the fruits and vegetables. In Central Europe, however, beetroot became the most important raw material for the sugar industry. Sugar has been a component of the human diet since time immemorial. Data that sugar can harm human health has been delivered throughout the decades. The consumption of sugar relates to a high incidence of civilization diseases. Opinions of experts are common that high sugar intake can be responsible for various diseases, such as tooth decay, obesity and adiposity, cardiovascular diseases, diabetes, some types of cancer and hyperactivity, especially in children (Beltrami et al., 2018).

Worldwide consumption of substitute sweeteners is increasing. The European Union legislation the content of artificial sweeteners in food. Many sweeteners that are commonly used in other countries are not authorized for European markets, which may be due to a large sugar industry lobby that could block unwanted competition. Therefore, more and more studies are devoted to the research on various carbohydrates added to food (Edwards et al., 2016).

Sweetener is an important food additive that provides a pleasant sense for humans and other animals. Some sweeteners such as sugars are important nutrient and energy sources. According to the original producing methods of the sweeteners, they can be divided into natural sweeteners (e.g., sugars, sugar alcohols and sweet-tasting proteins) and artificial sweeteners (e.g., sucralose, saccharin and aspartame). Sweeteners can be divided according to their energy value into low-caloric and high-caloric. Low-caloric sweeteners are aspartame, saccharin or acesulfame (Klescht et al., 2006). This means that these artificial sweeteners have no caloric value, and, unlike sugar, they do not support the growth of bacteria in the oral cavity, and therefore also do not cause tooth decay. Low-caloric sweeteners also do not affect glycaemia, on the other hand, caloric sweeteners (e.g. xylitol) have a certain caloric value (Chan et al., 2017). One of the other important properties of all sweeteners, apart from their energy value, is sweetener potency. Sweetener potency is defined as the number of times that a sweetener is sweeter than sucrose. The potency of a sweetener is compared with sucrose mainly in the threshold levels of the sweetener and sucrose. Perceived sweetness depends on several factors. The taste and intensity depend on the chemical and physical composition of the food in which the sweetener is found. The concentration of the sweetener, the temperature at which the food is consumed, the pH, other ingredients of the food and the sensitivity of the individual are also important (Nabors, 2011).

Sorbitol is produced from glucose. Specifically, from glucose syrup which is a by- product of the production of starch. It is found naturally in fruits like apples, plums, pears, and berries. It is about half as sweet as sucrose. Unlike sugar, it is less susceptible to bacterial break down the mouth, which is why it is used in chewing gum, as it does not cause tooth decay (Vrbová, 2011). Sorbitol is difficult for the human body to absorb and therefore provides fewer calories than sucrose. Xylitol is a five-carbon sugar alcohol which is present in natural sources (raspberries, corn, and oat). It is produced industrially from wood waste or from corn. Despite the cheap and easily available raw materials to produce xylitol, its production is more complex than the production of sugar from sugar cane or sugar beet. That is why this sweetener is also more expensive. It has about the same sweetness as sucrose, but fewer calories are released when it is metabolized (Chan et al., 2017). Cane sugar contains molasses, which is not removed during cane processing, and therefore cane sugar is a source of a certain amount of minerals - iron, calcium, magnesium, phosphorus, zinc, potassium, copper, and vitamins, especially B vitamins (Zaitoun et al., 2018). Maple syrup is industrially produced from sugar maple

(*Acer saccharum* L.). Maple sap is boiled down to syrup and sugar is refined from it. About 10 million kilograms of maple syrup are produced annually (Perkins & Berg, 2009).

In this study, the effect of replacing sucrose (beetroot sugar) with different types of sweeteners (cane sugar, sorbitol, xylitol, maple syrup) in gingerbread were investigated.

MATERIALS AND METHODS

Chemicals

All the chemicals used were of analytical grade and were purchased from Sigma-Aldrich (St. Louis, MO, USA) - ninhydrin, aminoacid standards, mineral compound standards and CentralChem (Bratislava, Slovak republic) - petroleum ether, nitric acid, sulphuric acid, potassium hydroxide, sodium hydroxide, acetylene.

Preparation of gingerbread

The gingerbread was prepared in accordance with an old family recipe provided by one of the authors (Mošaťová). The ingredients were purchased from local market and included wheat flour (00 extra), beet sugar, cane sugar, sorbitol, xylitol, maple syrup, sodium bicarbonate, honey, cinnamon, cocoa powder, butter, and eggs. Each type of gingerbread was made using one type of sweeteners and baked separately. Altogether five variants of gingerbread were prepared: with beet sugar (control sample), cane sugar, sorbitol, xylitol, maple syrup (Table 1). After kneading, the dough was allowed to rest for 60 min at +4 °C. The dough was rolled with a roller to obtain a thickness about 6–7 mm. The desired shapes of gingerbread were cut out of the dough and formed by hand. Later they were coated with egg and baked at 170 °C for 15 min in a traditional brick oven. After cooling for 30 min, the biscuits were packed in polyethylene zipper resealable food bags and stored at +21 °C and 50% relative humidity prior to the analyses of their physical, chemical, and sensory characteristics.

Table 1. The recipe with amount of ingredients of prepared gingerbreads

Ingredients	Control	Cane sugar	Sorbitol	Xylitol	Maple syrup
Wheat flour T 550	300 g	300 g	300 g	300 g	300 g
Beetroot sugar	80 g	-	-	-	-
Cane sugar	-	80 g	-	-	-
Sorbitol	-	-	80 g	-	-
Xylitol	-	-	-	80 g	-
Maple syrup	-	-	-	-	80 g
Egg	90 g	90 g	90 g	90 g	90 g
Butter	75 g	75 g	75 g	75 g	75 g
Cacao powder	10 g	10 g	10 g	10 g	10 g
Honey	50 g	50 g	50 g	50 g	50 g
Cinnamon	2 g	2 g	2 g	2 g	2 g
Sodium bicarbonate	1 g	1 g	1 g	1 g	1 g

Nutritional evaluation

Dry matter, ash and protein were determined following the standard AACC method 08-01 (AACC 1996). Nitrogen content was measured by the semi micro-Kjeldahl method. Nitrogen was converted to protein using the conventional factor of 5.7 for wheat.

Crude fibre content was evaluated with Ancom200 Fibre Analyzer (USA) according to the method provided by the manufacturer - one gram (W2) of the sample was weighted to special filter bag (W1 – bag tare weight; F57, Ancom, USA). Samples were defatted with petroleum ether, air-dried, and placed in the analyser; 2,000 mL of 0.1 M sulphuric acid were added, and the samples were hydrolysed for 45 minutes at 100 °C. The samples were then washed with hot distilled water 3 times, and 2,000 mL of 0.1 M potassium hydroxide were added. The samples were hydrolysed again for 45 minutes at 100 °C, after which they were washed with hot distilled water 3 times. Water was gently pressed from the bags and the bags were soaked in acetone for 5 minutes, removed, air-dried, and placed in the oven at 105 °C (WTB, Binder, Germany) for 2 hours. After cooling to room temperature, the bags were re-weighted and mineralized in pre-weighted crucibles for 2 hours at 550 °C. The crucibles were then weighted to calculate the loss of weight of organic matter (W3). Crude fibre content (%) was calculated by following formula: [W3-(W1xC1)/W2] x100; C1 – ash corrected blank bag factor (running average of loss of weight on combustion of a blank bag/original blank bag).

Fat content was determined with Ancom XT15 Fat Extractor (USA) in line with producer instructions - the sample (1.5 g, W1) was weighted to special filter bag (XT4, Ancom, USA) and dried for 3 hours in an oven (WTB, Binder, Germany) at 105 °C to remove moisture prior to the extraction. Samples were placed in a desiccant pouch for 15 minutes, re-weighted (W2) afterwards, and extracted for 60 minutes at 90 °C with petroleum ether. After the process, the samples were removed, dried in an oven at 105 °C for 30 minutes, placed in a desiccant pouch and re-weighted (W3). Fat content (%) was calculated using the following formula: [(W2-W3)/W1] x100.

Ion-exchange chromatography with a strong cation ion exchanger and a sodium-citrate elution buffer system followed by post-column derivatization with ninhydrin and spectrophotometric detection was used to determine the amino acid composition according to method described by manufacturer of the amino acid analyser (Ingos, Prague, Czech Republic). An amino acid standard solution was used for calibration of the amino acid analyser. Tryptophan was not quantified because of its destruction during acid hydrolysis. As glutamine and asparagine change to glutamic acid and aspartic acid, they were determined in these forms.

The analysis of mineral compounds was performed with Varian model AA 240 FS equipped with a D2 lamp background correction system using an air-acetylene flame (air 13.5 L min^{-1}, acetylene 2.0 L min^{-1}, Varian, Ltd., Mulgrave, Australia). The results were compared with multielemental standard for GF AAS (CertiPUR®, Merck, Germany). A 1 g of sample was digested with mixture of HNO_3: redistilled water (1:1). Samples were digested in a closed vessel high-pressure microwave digester (MARS X-press, USA) for 55 min. After cooling to room temperature, the suspension was filtered through Munktell filter paper (grade 390.84 g m^{-2}, Germany) and diluted to 50 mL with distilled water. Then, the samples extracts were subsequently analysed for Cd, Pb, Cu, Zn, Co, Cr, Ni, Mn, and Fe. The wavelengths at which the heavy metals were analysed following the calibration process were as follows: Cd – 228.8 nm, Pb – 217.0 nm, Cu – 324.8 nm, Zn – 213.9 nm, Co – 240.7 nm, Cr – 357.9 nm, Ni – 232.0 nm, Mn – 279.5 nm, Fe – 241.8 nm.

Physical evaluation

The calorific values of samples were determined with a bomb calorimeter IKA C 5000 (IKA Works, Inc., Wilmington, USA). The adiabatic method was used for the measurement as it is more suitable for loose samples. The samples were placed in the crucible of the bomb calorimeter and were electrically ignited to burn in the presence of pure oxygen. Samples were weighed using external scales (Libra Axis AG1000C, Poland), their masses ranged from 0.63 mg to 0.89 mg. Cotton threads were used to ignite the samples, and quartz crucibles with a diameter of 20 mm and a height of 20.5 mm were used. During the combustion, heat was released and the increase of temperature was measured. Dry benzoic acid was used to calibrate the effective heat capacity of water in the calorimeter.

The volume, maximum width, maximum height, the aspect ratio (width/ height) of gingerbread were determined with the laser-based scanner - Volscan Profiler 300 (Stable Micro Systems, England).

Sensory characteristic

The organoleptic properties of the prepared gingerbread were determined by a taste panel consisting of 25 evaluators (in age from 25 to 65; 15 women and 10 men). The panellists were asked to evaluate general appearance, flavour, taste, overall acceptability, and aftertaste. A 9-point hedonic scale was used to rate the samples, with scores ranging from 9 (like extremely) to 1 (dislike extremely) for each characteristic.

Statistical analysis

All experiments were carried out in triplicate and the results reported are mean values of these replicates with standard deviation. The experimental data were subjected to the analysis of variance (Duncan's test), at a confidence level of 0.05, using SAS 2009 software.

RESULTS AND DISCUSSION

Nutritional evaluation of gingerbread

Dry matter content ranged in tested samples from 90.46% to 91.13% (Table 2). The tested gingerbread contained more than 80% of dry matter and less than 20% of water that is typically for products with long shelf-life.

Crude protein content (Table 2) ranged from 7.92 to 8.12%. Compared to other samples, the lowest content of crude protein was detected in the sample with maple syrup - 7.92%. In samples with cane sugar and sorbitol the content of crude protein was very similar. The National Nutrient Database (USDA, 2014) states the nutritional values for honey biscuit - the protein content in biscuits per 100 g must be ~3.9 g. The recommended daily dose of protein is 44 g, which is set for an adult with a weigh of 80 kg and carrying out normal day-to-day activity. Compared to USDA (2014), our result was higher. This makes gingerbread a good source of protein in the human diet. The crude fibre content (Table 2) was similar (~0.53%) in all the tested samples. The term 'crude fibre' refers to the sum of cellulose, hemicellulose and lignin in foods. Similar results were also determined by Hercegová et al. (2019) in honey biscuits containing different kinds of flours.

The amount of fat (Table 2) was similar in all the samples. This is not surprising because the amount of fat in recipes was the same. In a study of Hercegová et al. (2019), the amount of fat in honey biscuits was ~11%, comparable to our results. In their recipes, butter was also used. Fat affects the taste of products because the vast majority of substances responsible for aroma are fat soluble. The increase or decrease of fat in biscuits is mainly reflected in a change of texture of biscuits (Hasmadi & Sandra, 2018).

Table 2. The results of dry matter, dietary fibre, crude protein, fat and ash contend in tested gingerbreads

Sample	Dry matter [%]	Dietary fibre [%]	Crude protein [%]	Fat [%]	Ash [%]
Control sample	90.91 ± 0.02^{d}	0.54 ± 0.02^{a}	8.12 ± 0.02^{a}	11.47 ± 0.41^{b}	0.72 ± 0.03^{e}
Sample with cane sugar	90.90 ± 0.07^{b}	0.54 ± 0.02^{a}	8.04 ± 0.03^{a}	11.15 ± 0.03^{b}	0.79 ± 0.01^{d}
Sample with sorbitol	90.46 ± 0.12^{c}	0.53 ± 0.01^{a}	8.05 ± 0.02^{a}	11.13 ± 0.09^{b}	0.91 ± 0.02^{b}
Sample with xylitol	91.13 ± 0.14^{a}	0.53 ± 0.02^{a}	7.93 ± 0.09^{b}	11.97 ± 0.09^{a}	0.83 ± 0.02^{c}
Sample with maple syrup	91.02 ± 0.13^{ab}	0.55 ± 0.03^{a}	7.92 ± 0.08^{b}	11.91 ± 0.09^{a}	1.06 ± 0.02^{a}

mean ± standard deviation; different letters in rows denote mean values that statistically differ one from another.

The ash content in the tested gingerbread ranged from 0.72% to 1.06% (Table 2). The highest amount was determined in sample with maple syrup. Berg et al. (2018) reported that maple syrup is rich in mineral compounds, especially calcium and potassium. Our results are in accordance to USDA, (2014) which states that the amount of total ash in gingerbread is ~1.8%. The ash content is dependent on ingredients - type of flour, addition of eggs, spices and other raw materials.

The nutritional value of bakery products is determined by the content of essential amino acids (lysine, methionine, tryptophan), whose representation in cereals, especially in wheat and wheat flour, is relatively low. Amino acids are the precursors of many compounds (Ertas et al., 2015; Tomčić et al., 2022). In samples of gingerbread (Table 3) was determined almost all essential amino acids. The control sample was showed the lowest content of all detected amino acid compared to samples with sweeteners. In gingerbread with cane sugar, the highest content of lysine was determined. Lysine is one of the most limiting amino acids in plants consumed by humans. The proteins of cereals are low in lysine, one of the amino acids that cannot be synthesized in humans, and must therefore be obtained entirely from dietary sources. Thus, lysine content is an important determinant of the nutritive value of flour obtained from cereals (Himani et al., 2018). In the sample of gingerbread with sorbitol, the amounts of all amino acid were comparable to the ones in the control sample. Gingerbread with xylitol showed the highest content of aspartic acid, threonine, serine, isoleucine, and arginine. The highest concentration of threonine, serine, glutamic acid, proline, glycine, alanine, valine, tyrosine, phenylalanine, histidine, and arginine was determined in the samples with maple syrup. According to Saraiva et al. (2022), amino acids found in maple syrup include glycine, alanine, asparagine, threonine, leucine, isoleucine, valine, and methionine. The quantities and types of amino acids vary depending on harvest time, with the largest variety of amino acids present near the end of the annual sap running season.

Table 3. The composition of amino acid in tested gingerbread

Amino acid	Control sample [mg g^{-1}]	Sample with CS [mg g^{-1}]	Sample with S [mg g^{-1}]	Sample with X [mg g^{-1}]	Sample with MS [mg g^{-1}]
Aspartic acid (Asp)	4.96 ± 0.01^{e}	5.34 ± 0.06^{b}	5.02 ± 0.01^{d}	5.39 ± 0.02^{a}	5.25 ± 0.02^{c}
Threonine (Thr)	2.15 ± 0.01^{d}	2.36 ± 0.01^{b}	2.30 ± 0.02^{c}	2.50 ± 0.04^{a}	2.48 ± 0.03^{a}
Serine (Ser)	3.72 ± 0.04^{d}	4.14 ± 0.01^{b}	4.09 ± 0.01^{c}	4.33 ± 0.02^{a}	4.32 ± 0.01^{a}
Glutamic acid (Glu)	19.14 ± 0.04^{e}	19.43 ± 0.03^{d}	19.86 ± 0.07^{c}	21.49 ± 0.05^{b}	23.88 ± 0.02^{a}
Proline (Pro)	7.39 ± 0.02^{e}	7.67 ± 0.02^{d}	7.74 ± 0.02^{c}	8.56 ± 0.03^{b}	9.27 ± 0.01^{a}
Glycine (Gly)	2.36 ± 0.01^{e}	2.49 ± 0.01^{d}	2.52 ± 0.01^{c}	2.65 ± 0.01^{b}	2.74 ± 0.01^{a}
Alanine (Ala)	2.33 ± 0.01^{e}	2.49 ± 0.01^{d}	2.52 ± 0.01^{c}	2.65 ± 0.01^{b}	2.74 ± 0.01^{a}
Valine (Val)	2.64 ± 0.03^{e}	2.95 ± 0.02^{e}	2.87 ± 0.02^{d}	3.03 ± 0.02^{b}	3.14 ± 0.01^{a}
Isoleucine (Ile)	2.17 ± 0.06^{c}	2.62 ± 0.04^{b}	2.64 ± 0.04^{b}	2.73 ± 0.02^{a}	2.65 ± 0.04^{b}
Leucine (Leu)	4.92 ± 0.02^{e}	5.55 ± 0.03^{c}	5.35 ± 0.03^{d}	5.71 ± 0.01^{a}	5.65 ± 0.03^{b}
Tyrosine (Tyr)	3.01 ± 0.02^{d}	3.17 ± 0.01^{c}	3.21 ± 0.01^{b}	3.30 ± 0.01^{a}	3.33 ± 0.01^{a}
Phenylalanine (Phe)	3.93 ± 0.02^{d}	4.23 ± 0.03^{c}	4.24 ± 0.03^{c}	4.42 ± 0.04^{b}	4.60 ± 0.02^{a}
Histidine (His)	1.50 ± 0.01^{d}	1.64 ± 0.01^{c}	1.64 ± 0.01^{c}	1.72 ± 0.02^{b}	1.77 ± 0.02^{a}
Lysine (Lys)	1.59 ± 0.01^{c}	1.70 ± 0.01^{a}	1.65 ± 0.02^{b}	1.66 ± 0.02^{b}	1.62 ± 0.02^{c}
Arginine (Arg)	3.12 ± 0.00^{e}	3.27 ± 0.02^{b}	3.27 ± 0.02^{b}	3.42 ± 0.01^{a}	3.42 ± 0.01^{a}

CS – cane sugar; S – sorbitol; X – xylitol; MP – maple syrup; mean ± standard deviation; different letters in rows denote mean values that statistically differ one from another.

The prepared gingerbread samples were also analysed in terms of the content of mineral compounds especially iron, manganese, zinc, copper, cobalt, nickel, chrome, cadmium, and lead (Table 4). In the control sample, the highest level of manganese and cadmium was observed. In sample with cane sugar, the highest amount of chrome was found, while the other minerals were present in amounts close to those of the control sample.

Table 4. The composition of mineral compounds in gingerbreads

Mineral compounds [mg kg^{-1}]	Control sample	Sample with CS	Sample with S	Sample with X	Sample with MS
Iron (Fe)	13.82 ± 0.06^{d}	13.91 ± 0.05^{e}	16.00 ± 0.01^{c}	18.20 ± 0.01^{b}	21.40 ± 0.02^{a}
Manganese (Mn)	5.02 ± 0.01^{a}	1.69 ± 0.01^{d}	1.89 ± 0.01^{c}	1.70 ± 0.01^{d}	2.10 ± 0.01^{b}
Zinc (Zn)	6.39 ± 0.01^{d}	6.50 ± 0.01^{c}	6.70 ± 0.01^{b}	6.19 ± 0.01^{e}	7.41 ± 0.01^{a}
Copper (Cu)	1.90 ± 0.01^{b}	1.69 ± 0.01^{c}	1.89 ± 0.01^{b}	1.70 ± 0.01^{c}	2.10 ± 0.01^{a}
Cobalt (Co)	0.19 ± 0.01^{e}	0.40 ± 0.01^{d}	0.50 ± 0.02^{c}	0.60 ± 0.01^{a}	0.59 ± 0.02^{b}
Nickel (Ni)	0.21 ± 0.01^{e}	0.41 ± 0.01^{d}	0.83 ± 0.02^{c}	0.91 ± 0.02^{b}	2.07 ± 0.05^{a}
Chrome (Cr)	0.29 ± 0.01^{d}	0.63 ± 0.04^{a}	0.50 ± 0.01^{b}	0.20 ± 0.01^{e}	0.40 ± 0.01^{c}
Cadmium (Cd)	0.09 ± 0.01^{a}	0.06 ± 0.01^{c}	0.05 ± 0.01^{c}	0.08 ± 0.01^{ab}	0.71 ± 0.01^{a}
Lead (Pb)	0.59 ± 0.01^{b}	0.39 ± 0.01^{c}	0.40 ± 0.01^{c}	0.59 ± 0.01^{b}	0.07 ± 0.01^{bc}

CS – cane sugar; S – sorbitol; X – xylitol; MP – maple syrup; mean ± standard deviation; different letters in rows denote mean values that statistically differ one from another.

In the sample with sorbitol, the amounts of mineral compounds were similar to those in the control variant as well. Generally, the highest content of mineral compounds was detected in the sample with maple syrup, which was especially rich in iron, zinc, copper, nickel, and cadmium. Zhang et al. (2014) reported that maple syrup is rich in iron, zinc, copper as well as vitamins and amino acids, and can be a good ingredient for preparing bakery products with improved nutritional value. The content of heavy metals in the analysed samples was within legal limits. The following regulations were used for the interpetation of the results on the content of mineral compounds in the gingerbread: ministry of Agriculture and ministry of Health of Slovak Republic dated March 15, 2004 no. 608/3/2004 - 100, which issues the Food Codex of the Slovak Republic, regulating contaminants in food, ministry of Agriculture and ministry of Health of Slovak Republic from 11 September 2006 no. 18558/2006-SL, which issues the Slovak Food Code of the Republic, regulating contaminants in foodstuffs (Slovak legislative, 2014).

Physical evaluation of gingerbread

The results of the physical evaluation of gingerbread with Volscan Profiler 3D are presented in Table 5. The highest volume was determined for the sample with xylitol, it was followed by cane sugar-, maple syrup-, and sorbitol-containing samples. The lowest volume was determined for the control sample. The obtained results showed, that the addition of sweeteners positively influences the volume of gingerbread. A similar tendency was also detected for maximum width - the lowest was determined for the control variant, while the variant with xylitol showed the highest value of this parameter, it was followed by samples with sorbitol, maple syrup, and cane sugar. In the sample with sorbitol, the highest value of maximum height was found. The volume is not a parameter so crucial for biscuits and gingerbread as it is for bread. Nonetheless, sweeteners can have an influence on the physical properties of products - volume, width and height. Ivanišová et al. (2020) evaluated the physical properties of biscuits with chicory inulin in amount of 1, 3 and 5% by using the Volscan Profiler 3D. The enriched biscuits had a greater volume, width and height compared to control sample without the addition.

Table 5. Results of physical evaluation of prepared gingerbreads

Parameter	Control sample	Sample with CS	Sample with S	Sample with X	Sample with MS
Volume [mL]	13.67 ± 0.58^{c}	15.67 ± 0.58^{b}	14.67 ± 0.58^{bc}	17.00 ± 1.00^{a}	14.67 ± 0.58^{bc}
Maximum width [mm]	9.60 ± 0.02^{e}	11.74 ± 0.01^{d}	13.70 ± 0.02^{b}	23.97 ± 0.02^{a}	12.60 ± 0.01^{c}
Maximum height [mm]	49.02 ± 0.67^{b}	49.97 ± 0.06^{a}	50.02 ± 0.02^{a}	48.41 ± 0.18^{c}	47.48 ± 0.14^{d}
Aspect ratio at max. width	0.24 ± 0.04^{c}	0.28 ± 0.01^{c}	0.35 ± 0.02^{b}	0.53 ± 0.02^{a}	0.32 ± 0.01^{b}
Aspect ratio at max. height	0.18 ± 0.01^{c}	0.23 ± 0.01^{b}	0.18 ± 0.01^{c}	0.46 ± 0.01^{a}	0.22 ± 0.01^{b}

CS – cane sugar; S – sorbitol; X – xylitol; MP – maple syrup; mean ± standard deviation; different letters in rows denote mean values that statistically differ one from another.

In study of Asghar et al. (2012) addition of sorbitol and mannitol at the level of 2% on four weight basis improved the quality of frozen dough pizza. Xylitol and sorbitol can low the water activity and improve texture and mouthfeel in biscuits. In study of Sun et al., 2013 was increased the springiness of bread with 10% xylitol with compared to the control, while the hardness was decreased by 21.5%. These authors by scanning electron microscopy images found a discontinuous gluten matrix in which starch granules were not covered completely with gluten when containing xylitol. The results of caloric values showed that the use of sweeteners can decrease the calories (Table 6), which can be beneficial for people who wish to lose weight as well as obese and diabetic patients who do not want completely exclude sweet treats from their diets. The lowest caloric value was detected in the sample with maple syrup followed by samples containing cane sugar, sorbitol and xylitol.

Table 6. Results of caloric value of prepared gingerbreads

Parameter	Control sample	Sample with CS	Sample with S	Sample with X	Sample with MS
Caloric value [cal g^{-1}]	4,480 ± 18.25^{a}	4,424 ± 3.57^{b}	4,470 ± 13.23^{a}	4,479 ± 1.00^{a}	4,247 ± 7.75^{c}

CS – cane sugar; S – sorbitol; X – xylitol; MP – maple syrup; mean ± standard deviation; different letters in rows denote mean values that statistically differ one from another.

Sensory evaluation of gingerbread

The scores for general appearance, flavour, taste, aftertaste and overall acceptance of the gingerbread samples evaluated by the panellists are summarized in Table 7. The control gingerbread was prepared according to recipe with refined beet sugar. The product was compact and had a pleasant aroma, and it also had no specific aftertaste. The sample with cane sugar had a pleasant aroma, was fluffy, compact and had a regular shape. When chewing, the sample was crumbly and the evaluators perceived a floury aftertaste. Compared to the other samples, it showed less intensive parameters.

Table 7. The results of sensory analysis of evaluated gingerbreads

Parameter	Control Sample [p]	Sample with CS [p]	Sample with S [p]	Sample with X [p]	Sample with MS [p]
General appearence	6.07 ± 0.07^{b}	5.88 ± 0.01^{d}	6.49 ± 0.04^{a}	5.98 ± 0.05^{c}	6.48 ± 0.04^{a}
Flavour	7.09 ± 0.04^{b}	6.41 ± 0.15^{d}	6.72 ± 0.14^{c}	7.61 ± 0.05^{a}	6.52 ± 0.14^{d}
Taste	6.75 ± 0.04^{a}	7.09 ± 0.03^{b}	5.85 ± 0.03^{e}	7.76 ± 0.17^{a}	6.15 ± 0.09^{d}
Aftertaste	3.04 ± 0.06^{c}	3.26 ± 0.17^{b}	2.94 ± 0.04^{c}	4.19 ± 0.02^{a}	2.93 ± 0.02^{c}
Overall acceptance	6.15 ± 0.03^{c}	6.50 ± 0.02^{b}	5.32 ± 0.05^{e}	7.87 ± 0.04^{a}	5.82 ± 0.07^{d}

CS – cane sugar; S – sorbitol; X – xylitol; MP – maple syrup; mean ± standard deviation; p – points; different letters in rows denote mean values that statistically differ one from another.

The sample with sorbitol had a regular shape and was compact, non-crumbly. The evaluators perceived a foreign chemical smell and a faint aftertaste. In the comparison of individual samples, the sample with xylitol was evaluated as the best from several points of view (aroma, taste, aftertaste and overall acceptance). The aroma and taste, of this sample was clear with a cinnamon aftertaste. Some of the evaluators also described a foreign metallic, sandy or floury aftertaste. The product was slightly crumbly and fluffy. The sample with maple syrup was compact in shape and had a pleasant smell. It offered a slight resistance to chewing and had a harder consistency. According to the overall acceptance, it was evaluated as good (5.82). Mushtaq et al. (2010) evaluated the physicochemical, microbial and sensory properties, especially taste and consistency, of biscuits with xylitol and confirmed very good sensory attributes compared to control sample with sucrose. Skripleva & Arsneva, (2015) used Jerusalem artichoke instead of sucrose to improve the sensory and nutritional attributes of yoghurt. The application of Jerusalem artichoke can reduce blood sugar level, making this kind of yogurt be especially suitable for diabetic patients.

CONCLUSIONS

Nowadays, both the consumer and the food technologist can choose from a wide range of sweeteners and additives. These ingredients offer different qualities in terms of taste, intensity of sweetness, nutritional and glycaemic potential, side effects, etc. Economic pressure on the one hand, and dietary objections to sweeteners with a higher glycaemic index on the other, push food manufacturers towards replacing the traditional sugar with cheaper ingredients or ones more suitable for a low-carbohydrate diet.

In our study, gingerbread containing beetroot sugar (control), sorbitol, xylitol, cane sugar and maple syrup was evaluated. The results showed that these substitutes of beet sugar not only enable obtaining products of proper physical and sensory quality, but also introduce nutritional benefits. Especially the use of maple syrup which can improve the profiles of mineral compounds (primarily iron and zinc). Based on our findings, we can recommended maple syrup and xylitol for application in bakery industry for producing gingerbread with properties attractive for consumers.

ACKNOWLEDGEMENTS. This research was funded by the Operational Program Integrated Infrastructure within the project: Demand-driven research for the sustainable and innovative food, Drive4SIFood 313011V336, co-financed by the European Regional Development Fund.

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