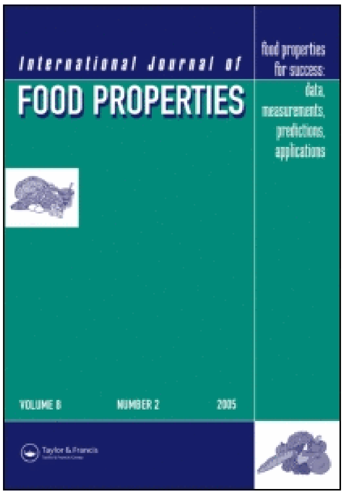

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SENSORY AND MICROBIOLOGICAL QUALITY OF A BAKED PRODUCT CONTAINING XYLITOL AS AN ALTERNATIVE SWEETENER

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The potential application of xylitol, as low energy alternative sweetener, was investigated in baked products. Xylitol was used as sole sweetener in home made cookies, the properties of which were compared to products containing sucrose and glucose. The sensory properties were evaluated by discrimination, descriptive, and affective tests. The storage time of one and two weeks, both at 4–6°C and at 20–22°C did not show significant impact on the flavor and texture properties of all cookies. After being stored for 3 months at 20–22°C, the samples with sucrose showed statistically significant differences in crunchiness (P < 0.001) and tenderness (P < 0.01). The cookies prepared with xylitol, apart from significantly reducing the aftertaste (P < 0.001), did not exhibit any other significant changes. Statistically significant differences (P < 0.001) were detected between the samples containing sucrose and xylitol in all texture attributes and in the cooling effect, but no difference in the sweetness was observed. The most chosen categories on the hedonic scale for the xylitol cookies were "like slightly" and "like moderately," while the extreme categories were not ascribed. Compared to the cookies with sucrose and glucose, xylitol cookies had least microbial loads at different storage and temperature regimes and were microbiologically safe with tendency to have longer shelf-life than the other products.

Keywords: ***Alternative sweetener, Xylitol, Baked product, Sensory quality, Microbiological analysis, Sucrose, Glucose.***

INTRODUCTION

Consumers are, nowadays, better informed about diet and health and as a result desire food, which in addition to convenience, offer high quality, safety, optimum nutrient balance, less fat and sucrose, and certainly less energy. By popular demand there is now a wide range of low-sugar and sugar-free versions of food and beverages available. For the past decade, production of low energy food has expanded and is considered a multibillion-dollar industry.[1] Among reduced or low energy foods available on the market are products prepared with low energy sweeteners. These sweeteners are very popular with the

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weight and health conscious consumers. When used wisely, these products can be useful for losing and controlling weight and for general health condition.

Some of the low energy sweeteners posses very intense sweetness and hence are used in only tiny amounts. Among them are aspartame (E951), cyclamates (E952), saccharin (E954), and thaumatin (E957). Other sweeteners including mostly polyols, such as sorbitol (E420), mannitol (E421), isomalt (E953), maltitol (E965), lactitol (E966) and xylitol (E967) belong to bulk sweeteners.[2] They provide less energy weight for weight compared to sucrose while having the same bulk volume.

Xylitol has been recently attracting a growing attention. It is as sweet as sucrose, and can replace it in 1:1 ratio. The energy provided by xylitol is only 10 kJ/g, which is 40% less than the energy from sucrose. This makes xylitol a good sugar substitute for producing reduced energy foods, which by definition are products that contain 25% less energy than a reference food. At equivalent concentrations, it has a lower water activity than sucrose, contributing to the microbial stability and shelf life of the final product.[3]

Slow adsorption and entry into metabolic pathways independently of insulin and without rapid fluctuation of blood glucose levels support the use of xylitol as a diabetic sweetener.[4] The pleasant taste profile and cooling effect with no unpleasant aftertaste, make it a desirable ingredient for chewing gums. It is convenient for pharmaceuticals and oral care products too. Due to the fact that xylitol is not utilized by the acid-producing bacteria of the human oral cavity, it is regarded as non-cariogenic sweetener.[5,6] A number of long-term field trials in different countries and different nutritional, social and economic environments demonstrated that the consumption of even relatively small amounts of xylitol can significantly reduce the formation of new dental caries.[7–9] Unlike sucrose, xylitol can not invert. This very positive advantage of xylitol can be used in manufacturing sweets together with fruit acids without alteration. Being a nearly inert substance, it can be heated to melting point (95°C) without any changes. The pentahydroxy sugar alcohol has no aldehyde or keto groups and therefore, unlike other sugars does not cause nonenzymatic browning, so called Maillard reaction.

In this article, attempts have been made to investigate whether these positive characteristics of xylitol could be also demonstrated in the products where it is used as sugar replacement. The lack of published scientific paper on xylitol application in baked products triggered the interest of the authors of this study, who are well experienced in microbial production of xylitol,[10–16] to use xylitol as a sole sweetener in home-made cookies. Its effect on the quality of the cookies and the shelf life was studied by means of sensory and microbiological analyses and was compared to the effect of the conventional sugar, sucrose. Glucose, as the main source of energy for the human organism and sugar that gives 20% less energy of that of sucrose, was also used in this study. The generated data of this innovative application of xylitol should provid better insight for specific sensory characteristics that might need to be addressed in the formulation of the xylitol containing products.

MATERIALS AND METHODS

Sample Preparation

The baked products evaluated in these experiments were home-made cookies prepared with different sweeteners while following the same recipe. All types of cookies contained (in g substance per 100 g dough): flour (52.4), margarine, (26.2), sweetener (10.5), egg (10.5), and baking powder (0.5). The source of sweetness varied including sucrose, glucose, and xylitol. The baked cookies had a diameter of 35–40 mm, a height of approximately 10 mm and weighed about 7 g. Immediately after the preparation, samples were packed with vacuuming, in a plastic foil, and stored for one and two weeks at two temperature regimes: in a refrigerator at 4–6°C and humidity ~70% and at room temperature of 20–22°C and humidity ~75%. Under the latter conditions, samples were stored also for three and seven months. Additionally, samples were stored in a freezer, at −18°C for eight months.

Sensory Analysis

The test methods used throughout the sensory evaluation of the cookies are listed in Table 1. For testing the sensory quality of the cookies, the relevant flavor and texture attributes were selected. The flavor attributes were: sweet (a pleasurable experience detected on the very tip of the tongue), cool (refreshing sensation in the mouth while the cookie was chewed), and aftertaste (a taste persisting in the mouth after the cookie was swallowed). The texture attributes were: hard (a force to bite through with incisors and to compress between molars), dry (juiceless feeling in the mouth), crunchy (crispy, pleasingly firm and fresh, making a crackling sound), tender (a positive feeling of the crushable texture of the cookie), and soft (infirm, not rough and coarse feeling during the mastification). Sensory attributes were scored on a scale from 1 to 7 points, where higher score meant more expressed attribute. A total of 80 panelists, 47 women and 33 men participated in this study. 35 were students and 45 adults, all from middle class background and age range between 21 and 64. Before the evaluation started, they were briefed on the use of the sensory evaluation techniques. In a duo-trio and in an attribute scaling tests only students took part while all 80 panelists participated in the tests related to the relative sweetness and the acceptability of the samples.

All tests were made under identical conditions. The room temperature was approximately 22°C, and the relative humidity was between 70 and 80%. Artificial neon white light was used throughout the experiment. No strange odors were detected during testing. The panelists were given representative cookie samples of about 7 g placed on a disposable white plastic plate. To neutralize or rinse mouth, they used glass of water. The analysis of variance was used to examine the statistical significance between sensory scores of the same samples and between samples containing different sweeteners during storage.[17]

Table 1 Test methods used in the sensory evaluation of the samples.

Type of test	Question of interest	Panel group
Discrimination		
Duo-trio test	Are the cookies with xylitol, respectively glucose different than those with sucrose?	35 untrained panelists
Descriptive		
Attribute scaling (1–7)	How do the cookies with xylitol respectively glucose	35 untrained panelists
Sweetness intensity scale (9-point)	differ in specific sensory properties compared to those with sucrose?	80 untrained panelists for testing the sweetness
Affective		
Hedonic scale (9-point)	How well are the cookies with xylitol respectively glucose accepted?	80 untrained panelists

Microbiological Analysis

Microbiological analysis of cookies containing all three sweeteners was carried out immediately after their preparation and then after different storage periods. The samples were homogenized in sterile bags using Stomacher laboratory system and appropriate dilutions with sterile distilled water were made. One ml of each prepared dilution was pipetted into a Petri dish with plate count agar (PCA). After incubation at 30°C for 48 h, the grown colonies were counted. The cookies were also checked for *Staphylococcus aureus* (Baird-Parker agar, at 37°C, incubation for 48 h), sulfite reducing clostridia (Wilson-Blair agar, at 37°C, incubation for 24–48 h) and coliforming bacteria (Endo agar, at 37°C, incubation for 24–48 h) after storage of 7 to 8 months.[18] In each experiment, two samples were tested separately for their microbiological status, and mean values of aerobic plate counts from duplicate plates are given.

RESULTS AND DISCUSSION

Sensory Evaluation

Sensory evaluation is an essential component of a product development. Whether a food product will be accepted or not depends on the integration of the consumer's perception of the color, texture and flavor into overall impression of quality. Although very important, chemical, physical and microbiological tests of food quality will not provide this type of information.[19] The sensory assessment of the home-made cookies started with a discrimination duo-trio test. The panelists were confronted with three samples and asked to indicate which two samples differ from the referent sample made with sucrose. In the first test, instead of sucrose, the odd sample contained xylitol, and in the second one it contained glucose. Referring to the DIN 10954 tables, it is sufficient for the 0.01 criterion of significance that 25 persons out of 35 have identified the odd sample. In both cases, all 35 panelists were able to identify the cookies that differed from the reference, thus demonstrating that the existing "chemical" differences between the cookies were also perceivable to the consumers through the sensory properties of the samples.

The next step was to investigate the sensory properties of freshly made cookies and to check should they change during storage. The sensory properties of the samples are presented using scaling technique that has gained in popularity thanks to its ability to provide quantitative sensory data.[20] To view the sensory attributes of the cookies, their attribute means are shown in Figure 1. The sucrose cookies were harder, drier, and crunchier than the others. The cookies with glucose were tender, soft with aftertaste and far less sweet than those with sucrose and xylitol. To the cookies with xylitol, the same sweetness as to those with sucrose was attributed, and pronounced cooling effect with some aftertaste. Another polyol, erythritol, applied for partial and total replacement of sucrose in chiffon cakes contributed to the changes of some of the sensory characteristics of the cakes. The cakes with erythritol were lighter in crust and crumb and less sweet in crumbs than those with sucrose.[21]

The influence of the storage conditions (temperature, time and humidity) on the sensory attributes of the cookies is given in Tables 2–4. The cookies were evaluated for flavor and texture attributes. As can be seen from the mean values and the standard deviations, the sensory attributes of all three samples showed little fluctuation. The storage time of one and two weeks, both at 4–6°C and at 20–22°C did not have significant impact on the sensory properties of all cookies. The computed values of the Fisher criterion were always

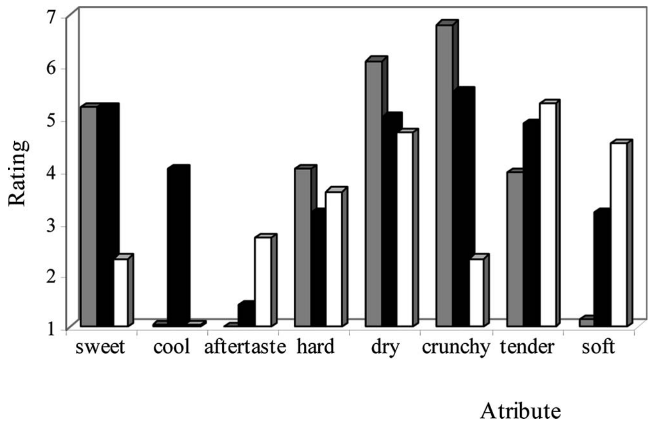

Figure 1 Descriptive test of freshly made cookies with sucrose (■), xylitol (■), and glucose (□).

Table 2 Effect of storage temperature and time on the sensory attributes of the cookies containing sucrose as a sweetener.

Storage time (day)	0		7				14				
Storage temperature (°C)	20–22		4–6		20–22		4–6		20–22		
Sensory attribute	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Significance
Flavor attribute											
Sweet	5.23	0.42	5.20	0.40	5.31	0.46	5.20	0.40	5.34	0.47	ns
Cool	1.03	0.17	1.06	0.23	1.03	0.17	1.09	0.37	1.03	0.17	ns
Aftertaste	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	ns
Texture attribute											
Hard	4.03	0.17	3.97	0.17	4.06	0.23	3.97	0.17	4.03	0.17	ns
Dry	6.11	0.32	6.06	0.23	6.09	0.28	6.06	0.23	6.09	0.28	ns
Crunchy	6.80	0.40	6.74	0.44	6.77	0.42	6.71	0.45	6.77	0.42	ns
Tender	3.97	0.17	3.94	0.23	3.89	0.32	3.97	0.17	3.86	0.35	ns
Soft	1.14	0.35	1.14	0.35	1.11	0.75	1.20	0.98	1.17	0.91	ns

ns: statistically non-significant ($P > 0.05$).

smaller than 1. This means that all home-made cookies can be shortly stored at home without changing their sensory quality. Since the main interest was on the evaluation of the acceptance of the cookies with xylitol, they, as well as those containing sucrose, were stored also for 3 months at room temperature (Table 5). This time, in contrast to short time storage, there were significant changes in some of the sensory attributes. The samples with sucrose showed statistically significant differences in crunchiness ($P < 0.001$) and tenderness ($P < 0.01$); they got less crunchy and less tender. The cookies prepared with xylitol, apart from significantly reducing the aftertaste ($P < 0.001$), did not exhibit any other significant changes in the sensory attributes. These data suggested that the cookies with xylitol can be stored longer without changing their original flavor and texture attributes.

The discrimination test proved that the cookies with sucrose and xylitol differ between themselves but it was also important to see in which properties they differ after being stored for 3 months at room temperature. The panelists detected statistically significant

Table 3 Effect of storage temperature and time on the sensory attributes of the cookies containing xylitol as a sweetener.

Storage time (day)	0		7				14				
Storage temperature (°C)	20–22		4–6		20–22		4–6		20–22		
Sensory attribute	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Significance
Flavor attribute											
Sweet	5.23	0.42	5.20	0.40	5.31	0.46	5.17	0.38	5.34	0.53	ns
Cool	4.03	0.17	4.06	0.23	4.03	0.38	4.06	0.23	4.03	0.38	ns
Aftertaste	1.43	0.49	1.37	0.48	1.40	0.49	1.40	0.49	1.40	0.49	ns
Texture attribute											
Hard	3.20	0.40	3.14	0.35	3.14	0.35	3.11	0.32	3.14	0.35	ns
Dry	5.03	0.17	4.97	0.17	5.00	0.00	5.00	0.24	5.03	0.17	ns
Crunchy	5.51	0.50	5.46	0.50	5.54	0.50	5.46	0.50	5.57	0.49	ns
Tender	4.91	0.28	4.86	0.35	4.80	0.40	4.86	0.35	4.83	0.38	ns
Soft	3.20	0.40	3.23	0.42	3.14	0.35	3.23	0.42	3.11	0.32	ns

ns: statistically non-significant ($P > 0.05$).

Table 4 Effect of storage temperature and time on the sensory attributes of the cookies containing glucose as a sweetener.

Storage time (day)	0		7				14				
Storage temperature (°C)	20–22		4–6		20–22		4–6		20–22		
Sensory attribute	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Significance
Flavor attribute											
Sweet	2.31	0.46	2.26	0.44	2.34	0.47	2.26	0.44	2.34	0.47	ns
Cool	1.03	0.17	1.09	0.37	1.03	0.17	1.06	0.23	1.03	0.17	ns
Aftertaste	2.71	0.45	2.77	0.42	2.77	0.42	2.80	0.40	2.80	0.40	ns
Texture attribute											
Hard	3.60	0.49	3.57	0.49	3.60	0.49	3.54	0.50	3.51	0.50	ns
Dry	4.74	0.44	4.69	0.46	4.71	0.45	4.66	0.47	4.69	0.46	ns
Crunchy	2.31	0.46	2.23	0.42	2.26	0.44	2.20	0.40	2.20	0.40	ns
Tender	5.29	0.45	5.37	0.48	5.34	0.47	5.40	0.50	5.37	0.48	ns
Soft	4.51	0.50	4.57	0.50	4.57	0.50	4.66	0.47	4.63	0.48	ns

ns: statistically non-significant ($P > 0.05$).

differences at $P < 0.001$ level between the samples containing sucrose and xylitol in all texture attributes and in the cooling effect (Table 5). The difference in the aftertaste was significant at $P < 0.01$ level whereas no difference in the sweetness was observed.

To better illustrate the differences of the sensory attributes in the samples with sucrose and xylitol, the average attribute intensities of the both samples are depicted in the spider web graph (Figure 2). It can be clearly seen that the cookies with sucrose are crunchier, drier and harder than those with xylitol while the latter are softer, tenderer with cooling effect and a little bit of aftertaste. This type of polar diagram was found very useful for the sensory evaluation of a variety of biscuits and was recommended to be used regularly in the control of the production.[22]

Table 5 Significance of the changes in the sensory attributes of the cookies containing sucrose and xylitol after storage at room temperature for 3 months.

Sensory attribute	Significance of the attribute changes in cookies with: Sucrose	Xylitol	Significance of the differences between the cookies with sucrose and xylitol
Flavor attribute			
Sweet	ns	ns	ns
Cool	ns	ns	***
Aftertaste	ns	***	**
Texture attribute			
Hard	ns	ns	***
Dry	ns	ns	***
Crunchy	***	ns	***
Tender	**	ns	***
Soft	ns	ns	***

ns: statistically non-significant ($P > 0.05$);
*: statistically significant ($P \leq 0.05$);
**: statistically significant ($P \leq 0.01$);
***: statistically significant ($P \leq 0.001$).

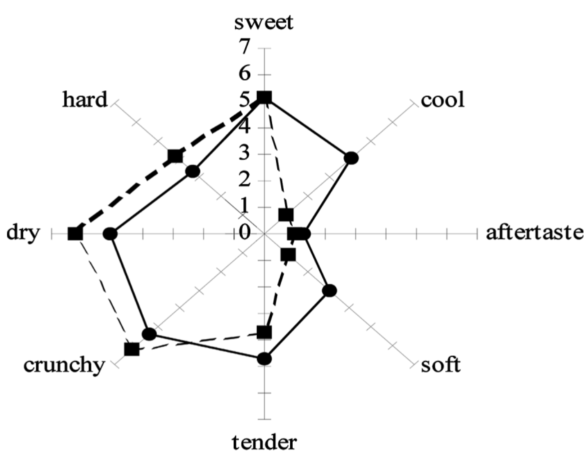

Figure 2 Spider web graph of flavor and texture attributes of cookies made with sucrose (--■--) and xylitol (—●—).

Figure 3 provides the panelists opinion on the sweetness intensity of xylitol and glucose samples compared to the reference made with sucrose. Results revealed that, when confronted only with the sweetness of the cookies, most of the panelists (46%) agreed that the sweetness of xylitol cookies was the same as those with sucrose, and some of them (total of 15%) pointed out values even higher than the reference. Glucose cookies were considered by 97% of the panelists less sweet than those with sucrose, and only 3% of the panelists rated them as sweet as the reference.

The acceptance of the cookies was tested according to the 9-point hedonic scale used to assess liking or disliking of the panelists (Figure 4). This scale, originally developed at the U.S. Army Food and Container Institute, has achieved widespread use in

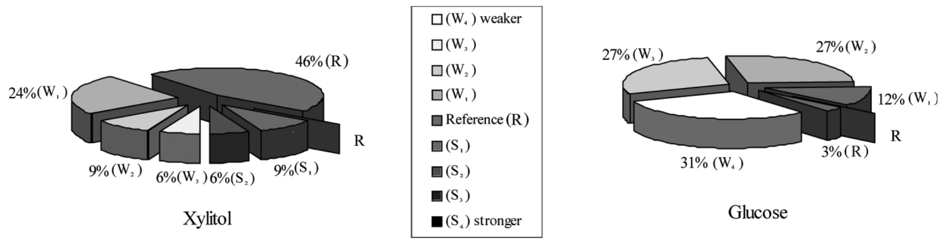

Figure 3 Sweetenes intensity scale of cookies with xylitol and glucose related to sucrose as a reference.

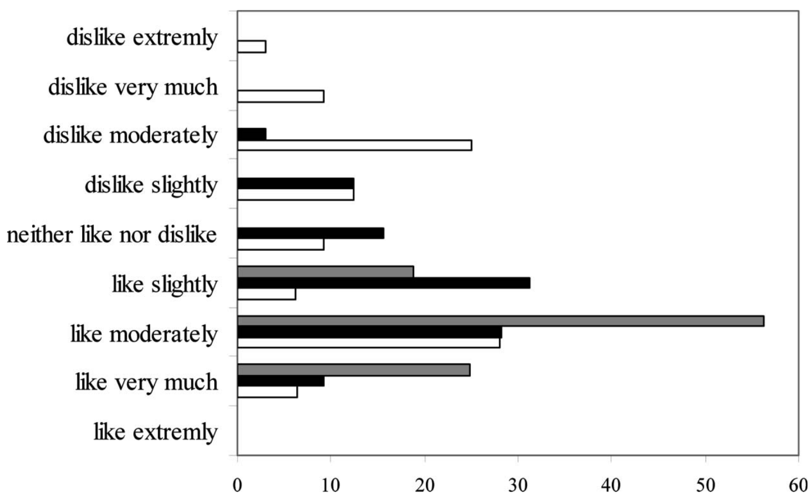

Figure 4 9-point hedonic scale for cookies with sucrose (■), xylitol (■), and glucose (●).

consumer testing of foods.[23] The fact that the cookies with xylitol were evaluated almost as sweet as those with sucrose, although very important, was not sufficient to make them equally likable. Sucrose cookies were labeled from “like slightly” to “like very much” with “like moderately” (56%) being the most chosen attribute. Although xylitol and glucose cookies got the same score under “like moderately” (28%), xylitol cookies were “liked slightly” by 31% of the panelists in contrast to 6% in the case of glucose cookies. “Dislike extremely” and “dislike very much” were ascribed only to the glucose cookies, which together with 25% of the panelists who “disliked them moderately” made them the least likable.

By giving the advantage to the cookies with sucrose over those with xylitol, the panelists proved that they hold to the traditional comprehension of what good and tasty cookies are. The reason for such behavior lies in the attitude and expectations of the consumers in spite of the existing recommendation of the nutrition experts to restrict the intake of foods high in refined sugars.[24] The expectations of the consumers, that according to Hutchings[25] arise from two major sources, from the belief and from the sensory input (a particular smell, touch or a visual stimulus), are closely connected with the century-long usage of the sucrose as sweetener. As Kratcher[26] stated, “as soon as we taste sweetness we expect the familiar taste and the texture of sucrose, and if we detect another tonality, a cooling effect or harshness, an uncontrollable mechanism in our subconscious triggers suspicion." These aspects are not in favor of xylitol. On the other hand, xylitol has some outstanding properties: it has less energy content than sucrose, it gives no browning reaction, it is suitable for diabetics and it is recognized as non-cariogenic. All these properties are currently considered as very important for the consumers. The question is then, how to stimulate people to change their diets towards non conventional new products, in this case with xylitol, that are beneficial for their health. The continuous education in nutrition can change the dietary behavior of the individuals. Studies have already shown that the general health interest of the consumers is a good predictor for food choices.[27–29] Therefore, one way could be to advise people of the health benefits of the products with xylitol whereas another way could be to introduce this product to the individuals as early as their childhood. For them, with time, the products with xylitol will no longer have "strange" taste.

Microbiological Evaluation

In addition to the sensory evaluation of the baked products, a microbiological evaluation, as an objective and widely used test in studying the food quality, was performed. The analysis of the freshly made cookies showed no bacterial growth after 48 h. *Staphylococcus aureus*, sulfite reducing clostridia and coliforming bacteria were not registered in any of the samples under all conditions investigated. The results of the microbiological tests after prolonged storage are summarized in Table 6. The number of the total aerobic viable cells, in all samples investigated, even after 7 or 8 months of storage, was acceptable according to the national regulations.[18] Under all conditions, the cookies with xylitol had the least microbial loads, being even 0 for the samples stored at −18°C. The presence of low number of CFU in the cookies with xylitol is associated with rather rare ability of microorganisms to metabolize xylitol compared with the microbial utilization of hexoses.[4] In view of these observations, the baked products with xylitol are not only microbiologically safe but their shelf-life could be much longer too. This feature of xylitol could be compared to the quality of calcium propionate as an antimicrobial agent used in bread making. It was found that the addition of calcium propionate significantly decreased total aerobic mesophilic bacteria, coliform bacteria, *Bacillus* spores and yeast and mold counts in bread formulations.[30]

To summarize, the present investigation demonstrated that the cookies containing xylitol instead of sucrose are sensorially acceptable and microbiologically safe with tendency to have prolonged shelf-life. This makes xylitol not only promising sugar substitute

Table 6 Viable cell counts in cookies containing different sweeteners during storage.

Storage time (day)	Storage temperature (°C)	Sweetener	Colony forming units (CFU/g)
190	20–22	Sucrose	400
		Xylitol	100
		Glucose	500
190	4–6	Sucrose	800
		Xylitol	700
		Glucose	800
220	−18	Sucrose	100
		Xylitol	0
		Glucose	200

but alternative sweetener with real practical applicability in this type of products. However, for wider acceptance of products with xylitol, consumers should be educated and learn more about the benefits of xylitol itself.

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