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Use of erythritol and maltitol as sucrose substitutes in functional dairy dessert

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ABSTRACT

In recent years, sucrose substitutes for producing low-calorie products have received attention. This study aimed to investigate the effect of erythritol and maltitol as sucrose substitutes on the qualitative characteristics of functional dairy dessert.Sucrose was replaced with erythritol and maltitol at concentrations of 25, 50, 75, and 100 percent, and the physicochemical, textural, and sensory properties of the dairy dessert were evaluated during 14 days of refrigerated storage.The sucrose substitute with erythritol and maltitol increased pH, moisture content, viscosity, hardness, a^* (redness), and b^* (yellowness) values and decreased acidity, sugar content, syneresis, and L^* (lightness) value of dairy dessert samples (*P<0.05*). During storage, acidity, viscosity, and hardness, a^*, and b* values increased, while pH, moisture content, syneresis, and L^* value decreased (*P<0.05*). In sensory evaluations, the sweetness, texture, and overall acceptability of dairy dessert were influenced by sucrose substitutes. The treatment containing 50% sucrose+50% low-calorie sweeteners (erythritol+maltitol) was selected as the best. The results of this study confirmed that sucrose can be replaced with low-calorie sweeteners including maltitol and erythritol without any defects in the qualitative properties of functional dairy dessert.

1- Introduction

Dairy desserts are produced using milk and milk products (such as butter and cream), fruits, cereals, nuts, and additives, and are consumed by several groups, especially children, due to their desirable nutritional, high energy, sensory properties, and a pleasant feeling. Dessert types can be categorized based on various features, such as the main ingredient, texture, place of preparation, and primary preparation method among others. [1]. Dairy desserts are widely consumed worldwide, and the dessert market is rapidly growing with new products. The most important aspect of preparing dairy desserts is developing a formulation that includes the choice of ingredients and their proportions, such as sugar, flavor, and color [2]. Sugar plays an important role in dairy desserts, not only in flavor but also in texture, color, and viscosity, and can contribute to people having too many calories [3]. High-calorie diets lead to weight gain, obesity, cardiovascular diseases, high blood pressure, diabetes, etc. [4, 5]. Diabetes affects 1 of 11 people worldwide and is predicted to increase by more than 40% to 700 million people by 2045. Type 2 diabetes is a chronic metabolic disease that affects glucose homeostasis through several different mechanisms, but manifests itself as prolonged hyperglycemia [6].

In this regard, much attention has been paid to sucrose substitutes with calorie-free or low-calorie sweeteners. The sucrose replacement can alter the taste, texture, and rheological properties of the foods. Therefore, suitable sucrose substitutes should be used to overcome these problems [7]. One of the sugar substitutes is maltitol. Maltitol ($C_{12}H_{24}O_{11}$) has a sweetness of 90% of that of sucrose, provides fewer calories, and does not affect the mouth feel. Maltitol does not participate in the Maillard reaction like other sugar alcohols [8, 9, 10]. Erythritol ($C_4H_{10}O_4$) is also a beneficial low-calorie sweetener that is safe for diabetics as it exerts no effects on blood glucose. Among sugar substitutes, erythritol provides less energy and its regular consumption does not cause gastrointestinal side effects, and it prevents tooth decay [11]. Erythritol is produced through microbial methods using osmophilic yeasts and some bacteria [12]. It has good heat and acid stability, lower molecular weight, and higher osmotic pressure compared to other sugar alcohols [13]. Sugar alcohols are generally less sweet than sucrose, have fewer calories and energy, and reduce the glycemic response. Sugar alcohols are monosaccharide and disaccharide derivatives, such as erythritol and maltitol. They are also widely present in plants and are recognized as generally recognized as safe (GRAS). These compounds have a slow metabolism rate and are absorbed incompletely and slowly in the small intestine, but if completely absorbed, produce about 4 Kcal/g of energy [14, 15]. In addition to a lower glycemic response, sugar alcohols also reduce the glycemic index of other carbohydrates [16].

Due to the increasing awareness of people, the modification of eating habits and the demand for low-calorie and functional food products to maintain the health of the body are increasing. Applications of sugar alcohols as sugar substitutes on the physicochemical properties and overall acceptance of dairy products has been reported previously [17, 18]. So far, no research has been undertaken on the use of erythritol and maltitol in dairy dessert. Therefore, the aim of the present study was to investigate the effect of replacing sucrose with sugar alcohols including erythritol and maltitol on the physicochemical, textural, and sensory properties of milk-based dessert.

2-MATERIALS AND METHODS

Materials

Erythritol and maltitol were obtained from Pishgaman-shimi Co. (Tehran, Iran). Cow milk was purchased from Iran Dairy Industries Co. (Pegah, Iran). The sugar and starch were obtained from BehinAzma Co. (Shiraz, Iran). All chemicals with analytical grade were provided by Merck Company (Darmstadt, Germany).

Dairy dessert production

Briefly, 40 g of starch was mixed with 200 ml of milk (2.5% fat) and heated at 90°C for 20 min. Then, 60 g of sugar or its substitutes, i.e., maltitol and erythritol, were added at various substitution levels (0%, 25%, 50%, 75%, and 100%). For each substitution level, equal amounts of erythritol and maltitol were used to replace the corresponding percentage of sucrose. The mixture was stirred until reaching the desired consistency and viscosity. After that, the produced dessert samples were poured into polypropylene containers and stored in the refrigerator at 5°C for 14 days until use.

Physicochemical analysis

The sugar content of dairy dessert was measured by the volumetric Lane-Eynon method. The moisture content was determined according to the AOAC method [19].

A pH meter (WTW, Germany) determined the pH value of the dairy dessert.

To measure acidity, 10 g of the dairy dessert and 250 ml of distilled water were poured into an Erlenmeyer flask and titrated with 0.1 N sodium hydroxide (Merck, Germany) in the presence of phenolphthalein reagent (Merck, Germany). The acidity was calculated according to the following equation [20]:

$$\text{Acidity (g lactic acid/ 100 g)} = \frac{\text{V}\times 0.009008}{\text{M}} \times 100 \quad (1)$$

Where M is the weight of the sample (g) and V is the volume of consumed sodium hydroxide (mL).

To measure syneresis, 15 g of the samples were weighed in centrifuge falcons and incubated at 42°C for 4 h. The falcons were transferred to a refrigerator for 24 h, then centrifuged at 3500 rpm for 30 min. The supernatant was drained and the falcons were weighed again. The syneresis was measured according to the following equation [21]:

$$\text{Syneresis} = \frac{\text{weight of the initial sample (g)}}{\text{weight of the supernatant (g)}} \quad (2)$$

Rheological and textural analysis

The viscosity of dairy dessert was measured using a rotational viscometer (RVD, Brookfield, USA) equipped with a spindle No. 64 *with rotation* speeds between 0.5 to 25 rpm at room temperature [22].

To determine hardness, the dairy dessert samples were cut into 20×20×20 mm and compressed by a P/100 probe to a depth of 50% of the initial height using a texture analyzer (TA-TX2, UK). The probe penetration speed was 1 mm/s [23].

Color analysis

A 14-megapixel digital camera (Canon M50 Mark II, Japan) was used to evaluate the color values of dairy dessert samples. The pictures were examined using Photoshop CS5 software and L^*, a^*, and b^* values which indicates the lightness, redness, and yellowness, respectively, were determined [24].

Sensory evaluation

Sensory properties including odor, sweetness, color, texture, and overall acceptability of dairy dessert samples were evaluated by 10 trained panelists using a ranking method [25].

Statistical analysis

A completely randomized design was used to design the treatments. All experiments were performed in triplicate and the results were expressed as mean ± standard deviation (SD). Data were analyzed via analysis of variance (ANOVA). Duncan's test was used to compare the means at a significance level of $P<0.05$ using SPSS software (version 21).

3-RESULTS AND DISCUSSION

Physicochemical properties

As shown in Table 1, the control and T5 treatments showed the highest and lowest sugar content, respectively ($P<0.05$). Therefore, maltitol and erythritol reduced the sugar content of dairy dessert samples. With increasing the concentrations of maltitol and erythritol, the sugar content was significantly reduced ($P<0.05$). The sugar content of all studied treatments was in the range of the Iranian national standard [26].The similar results were reported by Djaoud et al. [27] on the sugar substitution by date syrup in the dairy dessert.

According to Table 1, the lowest and highest moisture content was observed in the control and T5 samples, respectively. The moisture content decreased significantly during storage time ($P<0.05$). Therefore, the addition of maltitol and erythritol increased the moisture content of dairy dessert, due to the hydrophilic properties of sugar alcohols. Since moisture variations between days 7 and 14 are minimal and within measurement error, it suggests that the product's storage and manufacturing processes remain stable over time. Similarly, Giri et al. [28] observed that the higher concentrations of stevia increased the moisture content of dairy desserts. Date syrup in dairy dessert formulations significantly increased the moisture content [27]. The results are in agreement with other researchers who have also reported the moisture content, water activity, and total and reducing sugars decreased during the storage of date desserts [29].

Table 1. Physicochemical characteristics of dairy dessert samples during storage (mean ± standard deviation)

Parameters	Samples	First day	7th day	14th day
Sugar (%)	T1	10.677±0.040Aa	10.599±0.063Ba	10.311±0.014Ca
	T2	8.452±0.026Ab	8.414±0.054Bb	8.198±0.011Cb
	T3	6.161±0.048Ac	6.171±0.023Bc	5.926±0.067Cc
	T4	3.550±0.022Ad	3.398±0.069Bd	3.118±0.025Cd
	T5	0.613±0.452Ce	0.812±0.069Ae	0.709±0.012Be
Moisture (%)	T1	75.173±0.116Ac	74.973±0.116Bc	74.670±0.082Ca
	T2	75.370±0.062Abc	75.230±0.130Bb	75.063±0.163Ca
	T3	75.500±0.254Ab	75.310±0.171Bb	74.883±0.425Ca
	T4	75.593±0.050Aab	75.390±0.065Bab	75.013±0.121Ca
	T5	75.810±0.110Aa	75.587±0.065Ba	74.937±0.207Ca
pH	T1	6.293±0.006Ad	6.203±0.006Bd	6.067±0.006Ce
	T2	6.303±0.006Acd	6.237±0.006Bc	6.090±0.000Cd
	T3	6.313±0.006Abc	6.240±0.000Bc	6.117±0.006Cc
	T4	6.323±0.006Ab	6.277±0.006Bb	6.137±0.006Cb
	T5	6.337±0.006Aa	6.317±0.006Ba	6.163±0.006Ca
Acidity (%)	T1	0.107±0.002Ca	0.162±0.004Ba	0.211±0.003Aa
	T2	0.103±0.001Cb	0.150±0.002Bb	0.205±0.004Ab
	T3	0.100±0.001Cc	0.147±0.001Bb	0.184±0.004Ac
	T4	0.098±0.002Cc	0.132±0.003Bc	0.172±0.003Ad
	T5	0.095±0.001Cd	0.119±0.002Bd	0.163±0.003Ae
Syneresis (%)	T1	11.507±0.081Aa	11.017±0.065Ba	10.103±0.055Ca
	T2	11.360±0.026Ab	9.843±0.121Bb	9.240±0.053Cb
	T3	11.197±0.040Ac	9.473±0.064Bc	9.063±0.047Cc
	T4	11.120±0.075Ac	9.173±0.050Bd	8.877±0.025Cc
	T5	10.860±0.0120Ad	9.113±0.032Bd	9.043±0.040Cd

Dissimilar capital letters indicate a significant difference in the row (*P <0.05*). Different lowercase letters denote significant statistically difference within the column (*P < 0.05*).

T1: control (100% sucrose), T2: 75% sucrose+25% low-calorie sweeteners (erythritol+maltitol), T3: 50% sucrose+50% low-calorie sweeteners (erythritol + maltitol), T4: 25% sucrose+75% low-calorie sweeteners (erythritol + maltitol), T5: 100% low-calorie sweeteners (erythritol + maltitol).

As shown in Table 1, the pH decreased and the acidity increased during storage (*P<0.05)*. The lowest pH and highest acidity belonged to the control sample, while T5 treatment showed the highest pH and lowest acidity (*P<0.05*). pH and acidity of dairy products are mostly affected by the storage time and the activity of microorganisms. Therefore, the acidity of dairy dessert samples is affected by the balance between the nitrogenous compounds resulting from proteolytic reactions and lactic acid production from the metabolic activity of lactic acid bacteria (LAB). During the storage period, acidity increased and pH decreased due to increased metabolic activity of lactic acid bacteria. Sucrose intensifies the growth of LAB in dairy dessert, thus the acidity of control treatments is higher than the other treatments. According to the Iranian National Standard [26], the permissible limit of pH in dairy dessert is 6.3-6.8, and the results of the present study confirmed that all tested groups were acceptable. These results are in agreement with other researchers who have also reported the presence of stevia and sucralose, stevia and coconut syrup in dairy dessert decreased pH and increased acidity [30]. The addition of fig syrup [31], grape syrup [32], and date paste [29] to dairy dessert decreased pH and increased acidity during the storage period. Similar findings were obtained by Lisak et al. [33] by adding inulin and isomalt to low-fat frozen yogurt. According to these findings, the growth of LAB during storage increased the acidity of yogurt. Akalın and Erişir [20], Akın et al.) [34] also reported a decrease in the pH value of ice cream with the addition of inulin and oligofructose.

According to Table 1, the highest syneresis belonged to the control sample and the lowest syneresis belonged to T5 treatment ($P<0.05$). All treatments showed a remarkable decrease in syneresis during the storage period. The syneresis decreased in T5 treatment from 10.860% on the first day to 9.043% on the 14th day of storage ($P<0.05$). Therefore, replacing sucrose with maltitol and erythritol reduced the syneresis of dairy dessert samples. Syneresis is a natural phenomenon during storage in which excess water is removed from the gel network. The syneresis depends on the hardness of the gel, gel permeability, and size of the pores in the gel matrix. It should be discussed that higher hardness results in lower syneresis. Lower viscosity can cause weak gel structure and increase syneresisin dairy dessert [35]. Sugar alcohols due to the presence of hydroxyl groups and hydrogen bond formation retain the moisture and decrease syneresis. Furlán and Campderrós [36] showed that stevia and sucralose decrease the syneresis in dairy dessert during storage.

Rheological and textural properties

The measurement of viscosity is important in selecting the required equipment for transfer and determining the most appropriate formulation. Viscosity is influenced by the type and concentration of components, processing method, and temperature [37]. Figure 1 shows the changes in viscosity and texture hardness of dairy dessert samples during storage. The lowest and highest viscosity and texture hardness belonged to the control and T5 samples, respectively ($P<0.05$). The viscosity and texture hardness of the samples increased with increasing concentrations of maltitol and erythritol ($P<0.05$). Viscosity and texture hardness also increased during storage, and in the T5 treatment reaching from 6060 cP and 11.483 N on the first day to 7210 cP and 12.667 N at the end of the storage, respectively.

Due to their low proton mobility, erythritol and maltitol increase viscosity, facilitating air incorporation during mixing. Beyond sweetness, these polyols also alter the physical characteristics of the final product, making them effective substitutes for conventional sugars [38]. Maltitol has been found to produce a texture similar to sucrose-sweetened products, making it a preferred choice for preserving quality [39-40]. Valencia García and co-workers [41] also noted that although erythritol adds sweetness, it does not achieve the same hardness as sucrose; however, when combined with maltitol, it can improve the product’s texture.

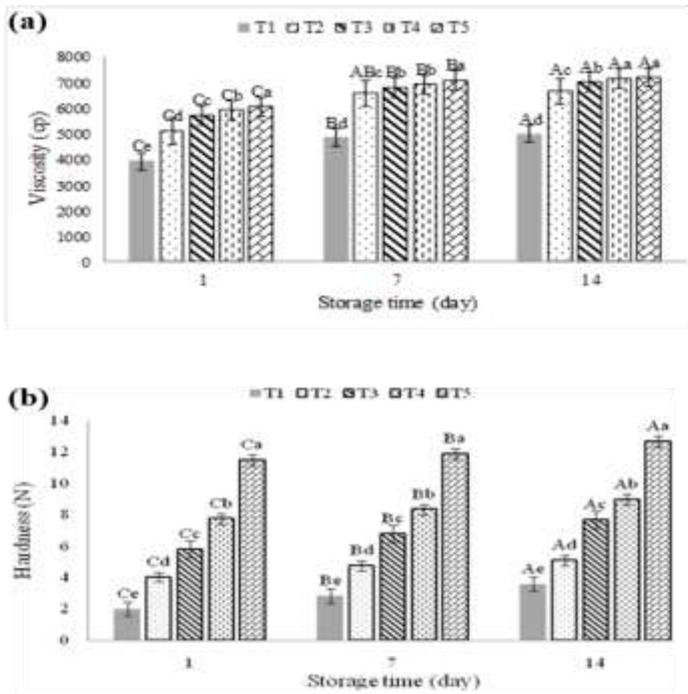

Figure 1. Viscosity (a) and texture hardness (b) of dairy dessert during storage.
T1: control (100% sucrose), T2: 75% sucrose+25% low-calorie sweeteners (erythritol + maltitol), T3: 50% sucrose+50% low-calorie sweeteners (erythritol + maltitol), T4: 25% sucrose+75% low-calorie sweeteners (erythritol + maltitol), T5: 100% low-calorie sweeteners (erythritol + maltitol).
Different lowercase letters indicate significant differences (*P<0.05*) between treatments on each day. Different capital letters indicate significant differences (*P<0.05*) between the values of each treatment during storage.

The viscoelastic parameters of dairy dessert depend on the sucrose concentration [37]. The increase in viscosity due to the addition of maltitol and erythritol can be attributed to their hygroscopic properties and water-binding ability. It seems that maltitol and erythritol, due to thefreehydroxyl groups than sucrose, increase hydrogen bonds with water molecules and reduce the water mobility, and as a result, increase the viscosity of the product.

The tendency of sweeteners to absorb water is a function of size and their molecular weight. The lower the molecular weight, the greater the tendency for water absorption and the higher the viscosity [42]. In this study, erythritol with a molecular weight of 122 g/mol had a higher effect on increasing viscosity compared to maltitol (344 g/mol) and sucrose (342 g/mol). Also, with increasing storage time in the refrigerator, the jelly network of the milk dessert expanded and the viscosity increased. Akin et al. [34] stated that inulin increases the viscosity of the product due to the water absorption and acidity increasing. With increasing inulin concentration, the consistency, viscosity, and elasticity of the dairy dessert increased, which indicated the strengthening of matrix [43]. The highest viscosity of starch-based dairy dessert was obtained for the 100% stevia and 50% stevia + sucralose samples [36]. In contrast, in research, sucrose replaced with stevia decreased the viscosity of the product [44].

The texture changes are related to the mechanisms of the viscosity changes. The textural characteristics of dairy dessert samples also depend on the interaction between components. One of the most important components affecting the texture is sugar. The hardness of low-calorie samples can be attributed to the water-binding capacity of the alcoholic sugars and increasing viscosity. Also, the increase in the hardness over time can be attributed to the decrease in the moisture content of the samples and the strengthening of the gel matrix at low storage temperatures. Maltitol and erythritol cause a denser protein structure and more homogenous gel networks and increase the hardness and viscosity [41]. Similar findings have been reported in the literature by Nepovinnykh et al. [23] in the production of dairy dessert by replacing sucrose with fructose. Replacing sucrose with stevia also increased the hardness of dairy dessert [28]. In date dessert, the hardness increased during storage [29]. These results are contradictory to those obtained by Arora et al. [46] and Protonotariou et al. [47] in which it was reported that replacing sucrose with various sweeteners reduces the hardness of dairy dessert.

Color values

The color of dairy products is an important quality characteristic that is influenced by the ingredients and additives. The colloidal particles such as fat globules and casein micelles are affected on the lightness of dairy products [35]. As shown in Figure 2, the control sample showed the highest L^* and the lowest a* and b* values, while the T5 treatment showed the lowest L^* and the highest a^* and b^* values (*P<0.05*). The reduction in lightness and the increase in redness and yellowness of the dairy dessert samples can be attributed to maltitol, which likely causes browning through thermal degradation. Overally, maltitol's tendency to produce a darker color contributed to these changes. Therefore, a^* and b^* values increased significantly over time *(P<0.05*). These are similar to results reported by Abd El-Khair et al. [48], Tarrega and Costell [49] in the addition of inulin to dairy dessert. Erythritol's replacement in sponge cakes reduced lightness, negatively impacting sensory appeal [50]. Similarly, Tyutkov and collageous (2025) found that in ice cream, erythritol altered crystallization and glass transition temperatures, resulting in a firmer texture and affecting the product's visual qualities [51]. In contrast, Javanmardi et al. [52] found that substituting sucrose with maltitol and xylitol led to lighter coloration, likely due to the absence of reactive groups in these sugar alcohols that prevents Maillard reactions. In another study by Lin et a. [53], erythritol-rich cakes with 100% and 75% substitution had significantly lighter and less red crusts than other variants. As erythritol levels rose, crumb lightness increased gradually, while redness and yellowness remained relatively unchanged. Because erythritol is more thermostable than sucrose and does not participate in Maillard reactions with amino acids, these factors likely explain the observed results.

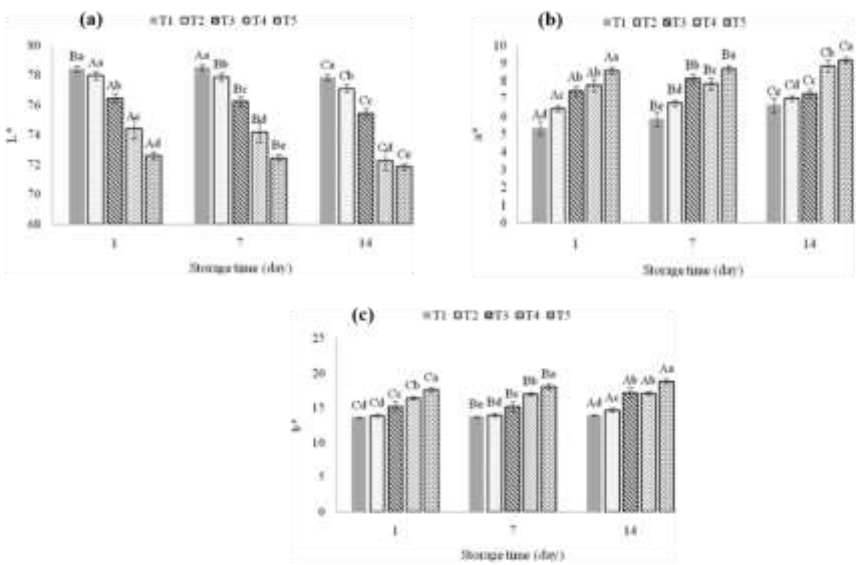

Figure 2. Color values (a: L*, b: a*, and c: b*) of dairy dessert samples during storage
T1: control (100% sucrose), T2: 75% sucrose+25% low-calorie sweeteners (erythritol + maltitol), T3: 50% sucrose+50% low-calorie sweeteners (erythritol + maltitol), T4: 25% sucrose+75% low-calorie sweeteners (erythritol + maltitol), T5: 100% low-calorie sweeteners (erythritol + maltitol).
Different lowercase letters indicate significant differences *(P<0.05*) between treatments on each day. Different capital letters indicate significant differences (*P<0.05*) between the values of each treatment during storage.

Sensory properties

Figure 3 shows the sensory properties of dairy dessert samples during storage. The highest sweetness score belonged to the control, T2 and T3 samples, and the lowest sweetness belonged to T5 and T4 treatments. The odor and sweetness score in T5 significantly decreased on the 14th day (*P<0.05*) (Figure 3c). The lowest and the highest texture scores belonged to T5 and T3 treatments, respectively. Texture scores in T4 and T5 treatments decreased at the end of storage (*P<0.05*). During the storage, the color and overall acceptability of the samples did not show a significant difference (*P>0.05*). Overall acceptability decreased in T4 and T5 treatments at the end of the storage (*P<0.05*). At the end of storage, the lowest and highest overall acceptability belonged to T5 and T3 treatments, respectively.

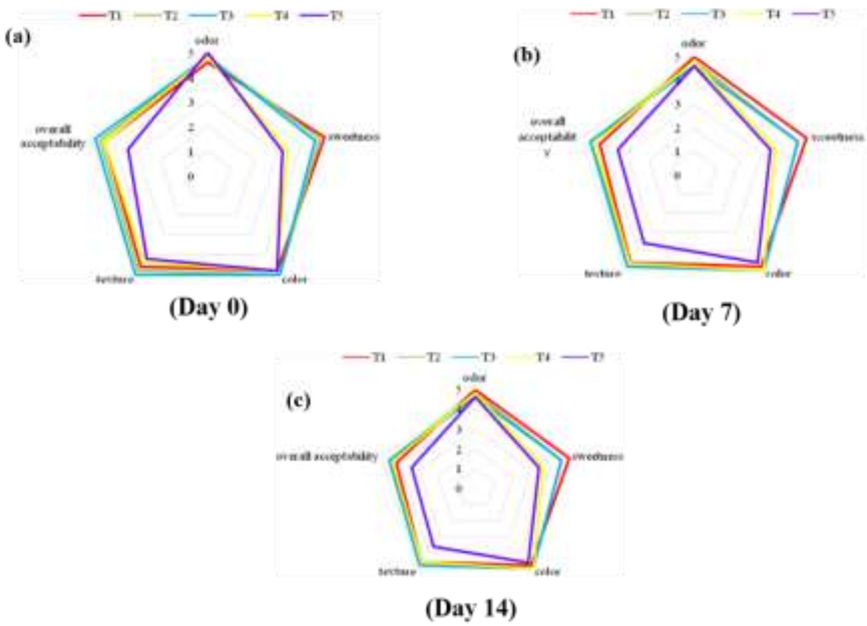

Figure 3. Sensory properties of dairy dessert samples during storage
T1: control (100% sucrose), T2: 75% sucrose+25% low-calorie sweeteners (erythritol + maltitol), T3: 50% sucrose+50% low-calorie sweeteners (erythritol + maltitol), T4: 25% sucrose+75% low-calorie sweeteners (erythritol + maltitol), T5: 100% low-calorie sweeteners (erythritol + maltitol).

Erythritol and maltitol have a white color without a specific aroma and odor, thus it is obvious that has no significant effect on the color and odor of dairy dessert samples. The difference between the sweetness of the samples is due to the higher sweetness of maltitol and erythritol compared to sucrose. Maltitol is about 90% as sweet as sugar and erythritol sweetness is about 70-80% of sucrose. Also, the texture difference between treatments could be due to differences in their viscosity. Lisak et al. [33] showed that the sweetness and rheological properties of dairy dessert were increased by carrageenan. Similar results were reported in dairy dessert containing stevia and sucralose. The mixture of stevia and sucralose induced the highest overall acceptability in starch-based dairy dessert [36]. Kaur et al. [29] showed that increasing the concentration of coconut syrup and stevia decreased the sensory scores of dairy desserts.

4-CONCLUSION

This study reported the sugar content of dairy dessert was reduced by sucrose replacement by erythritol and maltitol. Erythritol and maltitol improved the texture and viscosity and reduced syneresis in dairy dessert samples. These low-calorie sweeteners increased the pH and reduced acidity of dairy dessert samples. These results confirmed the potential of maltitol and erythritol as sucrose substitutes in improving the physicochemical, textural, and sensory characteristics of sugar-reduced dairy dessert. This study can develop a functional dairy dessert with nutritional and health benefits as an alternative to common dairy desserts.

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استفاده از اریتریتول و مالتیتول به عنوان جایگزین های ساکارز در دسر لبنی فراسودمند

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چکیده

در سال‌های اخیر، جایگزین‌های ساکارز برای تولید محصولات کم‌کالری مورد توجه قرار گرفته‌اند. این مطالعه با هدف بررسی تأثیر اریتریتول و مالتیتول به عنوان جایگزین‌های ساکارز بر ویژگی‌های کیفی دسر لبنی فراسودمند انجام شد. ساکارز با غلظت‌های ۲۵، ۵۰، ۷۵ و ۱۰۰ درصد با اریتریتول و مالتیتول جایگزین شد و ویژگی‌های فیزیکوشیمیایی، بافتی و حسی دسر لبنی طی ۱۴ روز نگهداری در یخچال ارزیابی شد. جایگزینی ساکارز با اریتریتول و مالتیتول، pH، میزان رطوبت، ویسکوزیته، سختی، مقادیر *a (قرمزی) و *b (زردی) را افزایش و اسیدیته، میزان قند، آب اندازی و مقدار *L (روشنایی) نمونه‌های دسر لبنی را کاهش داد ($p<0.05$). در طول نگهداری، اسیدیته، ویسکوزیته و سختی، مقادیر *a و *b افزایش یافت، در حالی که pH، میزان رطوبت، آب اندازی و مقدار *L کاهش یافت ($P<0.05$). در ارزیابی‌های حسی، شیرینی، بافت و پذیرش کلی دسر لبنی تحت تأثیر جایگزین‌های ساکارز قرار گرفت. تیمار حاوی ۵۰٪ ساکارز + ۵۰٪ شیرین‌کننده‌های کم‌کالری (اریتریتول + مالتیتول) به عنوان بهترین تیمار انتخاب شد. نتایج این مطالعه تأیید کرد که ساکارز را می‌توان با شیرین‌کننده‌های کم‌کالری شامل مالتیتول و اریتریتول، بدون هیچ گونه اثر سوئی بر خواص کیفی دسر لبنی فراسودمند جایگزین کرد.