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Physicochemical and qualitative properties of low-calorie jellies formulated with mannitol and maltitol

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Abstract

Background and objective: Considering the high prevalence of non-communicable diseases arisen from unhealthy diet in the world, people are interested in low-calorie diet including sugar-free and/or low-fat foods. Therefore, the aim of current study was investigation of physicochemical and organoleptic properties of reduced sugar jellies formulated with mannitol and maltitol as low-calorie sweetener.

Materials and methods: Mannitol and maltitol at concentration of 25, 50, 75, and 100 g were added to jelly formula. Sucrose at concentration of 50 and 100 g was used in formulation of reduced sugar jellies and control, respectively. Physicochemical tests were included to determination of pH and acidity, brix, syneresis, and moisture. Texture of the products was analyzed by texture analyzer. Sensory attributes were studied by 5-point hedonic test.

Results and conclusion: Substitution of sucrose with maltitol and mannitol had no remarkable effect on pH, acidity, brix, and moisture. In comparison, significant differences were observed in syneresis, so that the reduced sucrose jellies showed higher syneresis. Although, the differences in texture were not significant in sensory evaluation. However, the treatments containing 50 g sucrose and 50 g maltitol or mannitol (T_6 and T_7) were accepted same as control by the sensory panelists. Therefore, up to 50% w/w sucrose substitution with maltitol and/or mannitol is practical in formulation of reduced sugar jellies.

Keywords: Low-calorie jelly, maltitol, mannitol, sucrose

1. Introduction

Consumption of sweet products prepared with natural or synthetic sweeteners is of interest at any age [1]. Sucrose is of main ingredients in formulation of sugary foods, which helps in texture development other than its taste. However, its uncontrolled intake is associated with increased blood sugar, obesity, and tooth decay [2].

Jelly is one of popular snacks among children. It is prepared by gelling agents (e.g., gelatin, pectin, agar, starch), sugar, dyes, essential oils or natural extracts of fruits, and edible organic acids [3]. Jelly has a soft tissue and is chewed easily by the patients suffering from dysphagia and those undergoing radiation therapy as a source of medicine and nutrients. Due to the high concentration of sucrose in jelly (more than 85% w/w),

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its replacement with low-calorie and safer sweeteners is of interest [4].

Maltitol is a low-calorie sweetener produced by hydrogenation of maltose [5]. It is widely used in food formulation due to its desirable physical and chemical properties. For example, maltitol is a texture development compound and possesses 90% of sucrose sweetness. It has 2.1 kcal per g, that is lower than the calories of sucrose (4 kcal/g). It also has lower glycemic index than sucrose (36 vs. 60) and is appropriate for patients with diabetes [6]. Mannitol is another sugar alcohol with zero glycemic index. It is produced by hydrogenation of fructose and is commonly used in preparation of sugar-free foods. It has lower calories than sucrose (1.5 vs. 4 kcal/g) [7].

Hosseini Nejad et al. studied optimization of low-calorie jelly powder formulated with sucralose and isomalt. They found that replacement of sucrose with 50% w/w isomalt and 13% w/w sucralose results in texture hardness. In their study, reduction of isomalt decreased the hardness. In addition, the product containing isomalt was better accepted by sensory evaluators compared to control [1]. Replacement of sucrose with stevia and sucralose in formulation of jelly powder was studied by Shokohi Targhi. Addition of stevia as a single sweetener deteriorated the taste and use of sucralose instead of sucrose made the sample sweeter than control. Therefore, a sample containing 0.05% w/w stevia and 0.1% w/w sucralose was preferred [8]. Khouryeh et al. formulated sugar-free jelly by sucralose, pectin, maltodextrin, xanthan, and carob seed. They showed that addition of xanthan gum and carob seed to the formula reduces syneresis in the samples. Moreover, use of the hydrocolloids could improve the texture [9].

Gelatin and sugar are the main ingredients of jelly. As mentioned above, excessive consumption of sugar leads to weight gain, tooth decay, high blood sugar, and diabetes. Therefore, we aimed to formulate low-calorie jellies with different concentrations of mannitol and maltitol as sucrose substitute. In our work, physico-chemical and qualitative properties of the low-calorie samples were studied in the laboratory.

2. Materials and methods

2.1. Chemicals

Citric acid, ascorbic acid, Fehling's reagents (A and B), sodium hydroxide 0.1 N, and tetrazole (Merck, Germany), gelatin powder (Kyokab, China), maltitol and mannitol (Bitasuite, Germany), and sucrose (Fariman, Iran) were used in our study.

2.2. Jelly preparation

To prepare the control jelly powder, gelatin (9 g), citric acid (1 g), orange dye (0.014 g), orange essential oil (0.75 g), and sucrose (100 g) were mixed. Then, it was dissolved in 400 ml boiling water followed by cooling in refrigerator for 2-3 h. For other samples, mannitol and maltitol at concentration of 25, 50, 75, and 100 g were used as sugar substitute (Table 1) [1].

Table 1- Formulation of control and reduced sugar jellies

Sample	Mannitol (g)	Maltitol (g)	Sucrose (g)	Citric acid (g)	Gelatin (g)	Orange essential oil (g)	Water (ml)	Orange dye (g)
C (Control)	0	0	100	1	9	0.75	400	0.014
T_1	75	25	0	1	9	0.75	400	0.014
T_2	50	50	0	1	9	0.75	400	0.014
T_3	25	75	0	1	9	0.75	400	0.014
T_4	0	100	0	1	9	0.75	400	0.014
T_5	100	0	0	1	9	0.75	400	0.014
T_6	0	50	50	1	9	0.75	400	0.014
T_7	50	0	50	1	9	0.75	400	0.014

2.3. pH and acidity

Both factors were determined according to national guideline [1]. To measure pH, pH-meter (Metrohm, Switzerland) was used. Acidity was calculated by titration method.

2.4. Brix

This factor was measured at room temperature by desktop refractometer (Model RX-5000α, Japan) [1,10].

2.5. Syneresis

Syneresis was measured at room temperature by using a centrifuge at 5000 ×g. It was calculated according to Eq. 1 [1].

$$\text{Syneresis (\%)} = (W_L/W_{S)}) \times 100 \qquad \text{Eq. 1}$$

Where, W_L is weight of separated liquid, and W_T is weight of jelly sample.

2.6. Moisture

The moisture content was measured by weighing the samples before and after oven drying at 100 ºC for 2 h and calculated according to Eq. 2 as follows [3]:

$$\text{Moisture (\%)} = (W_1\text{-}W_2/W_1) \times 100 \qquad \text{Eq. 2}$$

Where, W_1 (g) is weight of container and sample before drying, and W_2 (g) is weight of container and sample after drying.

2.7. Total sugar

About 5 g of the jelly sample was added to 100-ml flask followed by addition of 25 ml warm water (50 ºC) and 2 ml clarifying solution (zinc acetate and potassium ferrocyanide) by vigorous mixing. It was made up to 100 ml with distilled water at room temperature and filtered for further analysis. Then, 10 ml of filtered solution was transferred to 100-ml flask and mixed with 2 ml glacial hydrochloric acid. The mixture was heated in water bath at 70 °C for 10 min. After cooling, it was titrated with sodium hydroxide 0.1 N in the presence of phenolphthalein reagent until a stable pale pink color was appeared. Then, volume of the mixture was made up with distilled water (solution C). It was used for titration of Fehling solution.

In parallel, 5 ml Fehling A solution and 5 ml Fehling B solution were mixed and boiled for 2 min. Glass pellets were added to avoid evaporation. After boiling, 3-4 drops of methylene blue reagent were added. The final Fehling solution was titrated with solution C until a dark red color was appeared. Amount of total sugar was calculated according to Eq. 3 as follows [3]:

$$\text{Total sugar (\%)} = \frac{F \times 100 \times 100}{V \times m \times 10 \times 1000} \times 100 \qquad \text{Eq. 3}$$

F = Fehling factor
V (ml) = volume of solution C used for titration of Fehling solution
m (g) = weight of sample
1000 = conversion factor of mg to g

2.8. Hardness

Texture of the jelly samples was measured by a texture analyzer (TA.XTExpressC, UK) with 22 mm cylindrical probe, penetration depth of 4 mm, and speed of 2 mm/s [11].

2.9. Sensory evaluation

Organoleptic attributes of taste, texture, transparency, and overall acceptance were evaluated by five trained evaluators. The samples were coded randomly and tested by 5-point hedonic method. The scales were included to 1 = extremely dislike, 2 = dislike, 3 = neither like nor dislike, 4 = like, and 5 = extremely like [1].

2.10. Statistical analysis

The data were analyzed by SPSS software version 21. One-way analysis of variance was used to compare the means and Duncan test was used to find the significant differences. The experiments were done in three replicates. Differences were significant at $p \leq 0.05$.

3. Results and discussion

3.1. pH and acidity

As seen in Table 2, substitution of sucrose with maltitol and mannitol had no significant effect on pH of the samples (except for T_5), while slight increase in acidity of T_6 was observed compared to control. However, acidity of all samples was acceptable according to the permitted range (less than 3%) determined by the national regulation [3]. In agreement, Hosseini Nejad et al. found similar results in low-calorie fruit jelly containing isomalt and sucralose [1]. Moreover, no significant change was observed in pH of sugar-free jelly containing sucralose (as sugar substitute), pectin, and maltodextrin compared to control by Khouryieh et al. [9]. On the contrary, Kaveh et al. investigated physicochemical properties of spray-dried stevia extract as a sugar substitute in formulation of Aloe vera jelly. They reported that acidity of the sugar-free samples increased in comparison to control [12]. In our opinion, concentration of sugar substitute has a significant role in this regard. In fact, stevia is 250-300 times sweeter than sugar and is used at low concentration in the products. Nonetheless, both mannitol and maltitol have less sweetness than sucrose and are used at similar or higher concentrations than sucrose in the formula.

Table 2– Physicochemical properties of jelly samples containing sucrose, maltitol, and mannitol

Sample	pH	Acidity (%)	Brix (%)	Moisture (%)
Control	3.47 ±0.09^{a}	0.31 ±0.01^{a}	14.87 ±0.56^{ac}	83.67 ±3.08^{a}
T_1	3.42 ±0.09^{ab}	0.33 ±0.03^{ab}	14.51 ±0.41^{ac}	84.83 ±1.26^{a}
T_2	3.34 ±0.15^{ab}	0.34 ±0.04^{ab}	14.50 ±0.72^{ac}	85.01 ±1.37^{a}
T_3	3.45 ±0.18^{ab}	0.34 ±0.02^{ab}	14.41 ±0.32^{ac}	84.15 ±1.22^{a}
T_4	3.44 ±0.10^{ab}	0.33 ±0.02^{ab}	14.56 ±0.29^{ac}	84.49 ±0.88^{a}
T_5	3.17 ±0.19^{b}	0.34 ±0.02^{ab}	14.33 ±0.27^{a}	86.28 ±0.96^{a}
T_6	3.34 ±0.14^{ab}	0.34 ±0.01^{b}	14.85 ±0.20^{c}	85.14 ±1.36^{a}
T_7	3.35 ±0.19^{ab}	0.34 ±0.02^{ab}	14.74 ±0.12^{c}	85.23 ±1.50^{a}

Different letters in the columns indicate significant differences ($P \leq 0.05$).

T_1: 75 g mannitol and 25 g maltitol; T_2: 50 g mannitol and 50 g maltitol; T_3: 25 g mannitol and 75 g maltitol; T_4: 100 g maltitol; T_5: 100 g mannitol; T_6: 50 g maltitol and 50 g sucrose; T_7: 50 g mannitol and 50 g sucrose

3.2. Brix

Replacement of sucrose with maltitol and mannitol did not have significant effect on the content of water-soluble solids in the samples except for T_5 (Table 2). It is due to the same amounts of sucrose and its alternatives in the formula. Similar results were observed in study of Baba Qassab and Abdul Maleki in substation of sucrose with sucralose and maltitol in jelly [13], Aggarwal and Michael in substitution of sucrose with fructose in tangerine candy [14], and Khouryieh et al. in replacement of sugar with sucralose in sugar-free jelly [9].

3.3. Moisture

Replacement of sucrose with maltitol and mannitol did not change the moisture significantly (Table 2). Moisture of all samples were around the maximum permitted level of 85% determined by the national regulation [3]. The high moisture might be due to the activity of OH groups in the sweeteners able to interact with water by hydrogen bond [1,8,9,12,14].

3.4. Syneresis

As observed in Table 3, the reduced sugar jellies showed higher syneresis than control. It might be due to the chemical structure of maltitol and mannitol that is different from sucrose. Water holding capacity of a chemical depends on its ability to entrap water physically or develop chemical interactions with water molecules. Indeed, mannitol has a linear structure and contains lower hydroxyl groups than sucrose. Nonetheless, maltitol has sufficient hydroxyl groups to form hydrogen bond but their steric hindrance may interfere in the chemical reactions. In comparison, hydroxyl groups of sucrose with their appropriate arrangement are high enough for development of hydrogen bonds in favor of lower syneresis in the final product [7]. Our finding is in agreement with those reported in other studies [1,12,13]. Although, use of appropriate hydrocolloids in formulation of sugar-free jelly can avoid syneresis [9].

Table 3- Total sugar and textural properties of jelly samples containing sucrose, maltitol, and mannitol

Sample	Syneresis (%)	Total sugar (%)	Hardness (N/mm^2)
Control	0.33 ±0.02^{a}	32.23 ±0.91^{a}	19.38 ±0.07^{a}
T_1	0.52 ±0.02^{b}	13.07 ±0.90^{b}	19.33 ±0.07^{a}
T_2	0.54 ±0.02^{b}	15.51 ±0.09^{cf}	19.70 ±0.05^{bd}
T_3	0.53 ±0.03^{b}	17.27±0.41^{dg}	19.98 ±0.08^{c}
T_4	0.55 ±0.02^{b}	14.89 ±0.25^{e}	19.55 ±0.26^{abde}
T_5	0.52 ±0.01^{b}	15.39 ±0.70^{cdef}	19.52 ±0.21^{abe}
T_6	0.44 ±0.01^{c}	16.11 ±0.70^{f}	19.76 ±0.02^{d}
T_7	0.42 ±0.01^{c}	17.98 ±0.49^{g}	19.40 ±0.08^{ae}

Different letters in the columns indicate significant differences ($P \leq 0.05$).
T_1: 75 g mannitol and 25 g maltitol; T_2: 50 g mannitol and 50 g maltitol; T_3: 25 g mannitol and 75 g maltitol; T_4: 100 g maltitol; T_5: 100 g mannitol; T_6: 50 g maltitol and 50 g sucrose; T_7: 50 g mannitol and 50 g sucrose

3.5. Total sugar

In this study, same quantity of sucrose was replaced with maltitol and mannitol. However, differences of total sugar in the samples were significant (Table 3). It might be due to the chemical structure of the sweeteners. The highest sugar contents were observed in the samples containing sucrose and maltitol as disaccharide rather than mannitol as monosaccharide. Significant change of total sugar is of concern in formulation of sugar-free products with other alternatives used at very low concentrations, which may also have significant effect on the texture [14-19]. Our results were in agreement with those reported in study of Chatchavanthatri et al., in which complete replacement of sucrose with maltitol significantly reduced total sugar content in jam [20].

3.6. Hardness

Hardness of gel is directly associated with its microstructure and moisture content [1]. As mentioned before, no significant differences were observed in moisture content of the samples due to the similar quantity of all three sweeteners. However, significant difference in hardness was observed in the samples (Table 3). It seems that chemical interactions of sucrose and maltitol in the matrix created a harder texture than those developed by mannitol and sucrose alone or in combination.

3.7. Sensory evaluation

As seen in Table 4, control (the sample formulated with 100 g sucrose) had the highest sensory score for all attributes.

Table 4- Sensory scores of jelly samples containing sucrose, maltitol, and mannitol

Sample	Taste	Texture	Transparency	Overall acceptance
Control	5.00 ±0.00^{a}	4.67 ±0.58^{a}	5.00 ±0.00^{a}	5.00 ±0.58^{a}
T_1	3.68 ±0.58^{b}	3.67 ±0.58^{abd}	3.67 ±0.58^{bc}	3.67 ±0.58^{b}
T_2	4.00 ±0.00^{b}	3.33 ±1.15^{abd}	3.67 ±0.58^{bc}	3.67 ±0.58^{b}
T_3	3.33 ±0.58^{bc}	4.00 ±1.00^{abd}	4.00 ±1.00^{abc}	3.33 ±0.58^{b}
T_4	2.67 ±0.58^{c}	3.67 ±0.58^{abd}	3.00 ±1.00^{c}	3.67 ±0.58^{b}
T_5	2.67 ±0.58^{c}	3.33 ±0.58^{b}	4.00 ±0.00^{c}	3.33 ±0.58^{b}
T_6	3.67 ±0.58^{b}	4.00 ±0.00^{d}	4.33 ±0.58^{cd}	4.33 ±0.58^{ab}
T_7	3.67 ±0.58^{b}	3.67 ±0.58^{abd}	4.67 ±0.58^{abd}	4.33 ±0.58^{ab}

Different letters in the columns indicate significant differences ($P \leq 0.05$).
T_1: 75 g mannitol and 25 g maltitol; T_2: 50 g mannitol and 50 g maltitol; T_3: 25 g mannitol and 75 g maltitol; T_4: 100 g maltitol; T_5: 100 g mannitol; T_6: 50 g maltitol and 50 g sucrose; T_7: 50 g mannitol and 50 g sucrose

Other than taste, addition of sucrose to food products such as jelly has significant role in texture development [21]. However, sucrose can be substituted with other sweeteners such as maltitol and sucralose in confectioneries without significant change in sensory attributes [22,23]. In this regard, impact of food matrix should not be ignored. It is clear that complicated matrixes could mask unacceptable sensory attributes. According to Table 4, the samples containing mannitol and maltitol as single sweetener (T_4 and T_5) had the lowest score, but scores of T_6 and T_7 (containing 50 g sucrose) were closer to the control's score. It might be due to the fact that consumers are not familiar with taste of polyols and prefer to consume conventional products containing sucrose [24].

4. Conclusion

In technical point, substitution of sucrose with mannitol and maltitol did not change physico-chemical properties of jelly significantly. Although, syneresis increased in the samples containing alternative sweeteners that might be due to the higher involvement of sucrose in formation of hydrogen bond in the matrix. Importantly, sensory scores of reduced sugar samples were lower than control. However, T_6 (containing 50 g sucrose and 50 g maltitol) and T_7 (containing 50 g sucrose and 50 g mannitol) were similar to control in overall acceptance. Therefore, with respect to the low glycemic index of maltitol and zero glycemic index of mannitol, up to 50% sucrose substitution with maltitol and mannitol in jelly is of interest especially for those suffering from high blood sugar.

5. Conflict of interest

The authors declare that there is no conflict of interest.

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