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Formulation and characterization of a functional dairy dessert containing *Moringa oleifera* extract and Inulin

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ABSTRACT

Background & Aim: Today, due to the importance of nutrition and the role of food on human health, attention has been paid towards the production of foods rich in functional and beneficial compounds, as well as low calorie products to reduce various diseases such as diabetes, obesity, cardiovascular diseases, etc. The aim of this research was to develop a functional and low-calorie dairy dessert using long-chain inulin and *Moringa oleifera* extract.

Experimental: *Moringa oleifera* extract (ME) was prepared by the percolation method and used in combination with inulin in the formulation of low-calorie dairy dessert based on maltitol and sucralose as sweeteners. ME was used at 1%, 2% and 3% (w/w) levels and inulin at 5% and 7% levels. The moisture, ash, fat, protein and carbohydrate content, as well as calorie, pH, acidity, soluble solids (brix), syneresis, viscosity, color indices, antioxidant capacity and sensory characteristics (color, flavor, texture, mouth feel and overall acceptability) of the dairy dessert treatments were examined after production.

Results: The addition of inulin and ME showed a significant effect on the chemical composition of the desserts and reduced the calories of the treatments compared to the control. Increasing the level of ME did not affect the syneresis and viscosity of the desserts, while by increasing the level of inulin from 5% to 7%, viscosity increased and syneresis decreased significantly ($P<0.05$). Incorporation of ME into the formulation of dairy dessert also reduced the L^* and a^* and increased the b^* values of the samples ($P<0.05$). By adding ME and increasing its level from 1% to 3% in the formulation, significant improvement in the antioxidant capacity of the desserts was observed, so that the highest antioxidants capacity was evaluated in the samples containing 7% ME (37.53-37.82%). The results of sensory evaluation indicated that all treatments were acceptable, and the desserts containing lower levels of ME obtained higher flavor, color and overall acceptability scores.

Recommended applications/industries: The results of this research demonstrated that inulin as a prebiotic and *Moringa oleifera* extract as a rich source of bioactive and antioxidant compounds can be used to develop a functional low-calorie dairy dessert.

1. Introduction

Today, due to the increasing awareness of consumers about the impact of proper nutrition on health, the attention of foods manufactures has focused on the production of low-calorie and functional products with higher nutritional value. Functional foods are products that, in addition to meeting the nutritional needs of the body, also have health-benefits and are able to regular one or more physiological functions of the body (Toliaty *et al.,* 2022). Dairy desserts are one of the most popular products among different age groups (Ghanbarzadeh *et al.,* 2023). The main component of the formulation of dairy desserts is milk, and these products contain permitted additives and are produced after a thermal process. These desserts provide high energy and create a pleasant feeling for the consumers. Overall, dairy desserts are a complex mixture of various components including milk, starch, sugar, flavorings, hydrocolloids and colors, and have a semi-solid consistency (Aguilar-Raymundo and Vélez-Ruiz, 2018).

Since excessive consumption of sugar causes many health related problems such as obesity, diabetes and cardiovascular diseases, products that are healthier and less calorie and taste similar to caloric products have become popular (Gałkowska *et al.,* 2020; Seyed Mahmoodzade and Ahmadi, 2021). In addition to the direct effect on the taste of dairy products, sugar also has a noticeable effect on texture, viscosity and color of products, and therefore replacing sugar have significant negative effects on the quality and acceptance of low-sugar products. In order to mimic the properties created by sugar, various additives are usually used (da Silva Faresin *et al.,* 2022).

On the other hand, the addition of nutritious compounds useful for health, such as bioactive compounds, antioxidants, antimicrobials and dietary fibers improve the safety and quality of food products, which among these compounds prebiotics have remarkable effects. Prebiotics are non-digestible polysaccharides that, when used, promote the growth of natural intestinal flora and probiotic bacteria, and have several health effects (Bhanja *et al.,* 2022). One of the most widely used prebiotics in dairy products is long-chain inulin, which is a fermentable dietary fiber and improves intestinal function. Inulin can also increase calcium absorption and lower triglycerides levels in people with high blood fat (Mudannayake *et al.,* 2022).

Plant extracts are one of the most interesting functional additives in various food products. Plant extracts contain a wide range of bioactive compounds and exhibit various biological activities such as antioxidant, anti-inflammatory, antimicrobial activities, etc., and have beneficial effects on human health (Maleš *et al.,* 2022; Okur, 2023). *Moringa oleifera* is a valuable plant from the *Moringaceae* family that is widely used in traditional medicine and as a food additive. The leaves of this plant contain various phytochemical compounds, such as phenolic acids, polyphenols, alkaloids, glucosinolates and flavonoids, and they indicate different biological activities, including anti-diabetic, anti-cancer, antioxidant and antimicrobial activities (Al-Ghanayem *et al.,* 2022). Moringa has high quality protein that is easily digested (Beigmohammadi *et al.,* 2023). Adding moringa leaves acts as a rich ingredient in various food products such as yogurt, cheese, bread and cake in order to improve their shelf life and quality characteristics (Owusu *et al.,* 2008). In this research, the formulation of a functional dietary dairy dessert containing *Moringa oleifera* extract prepared by replacing sucrose with maltitol and sucralose and using long-chain inulin as a prebiotic additive was investigated.

2. Materials and Methods

2.1. Materials

Moringaoleifera powder was obtained from Sabzroyan Co. (Iran). Long-chain inulin was purchased from Benco Co. (Germany), gelatin powder from Farmand Co. (Iran), maltitol and sucralose from Foodchem Co. (China) and Dalian New Fortune Tech Co., LTD (China), respectively. Low-fat pasteurized milk (1.5% fat) was prepared from Damdaran Dairy (Iran). The chemicals used for the tests were purchased from Merck Co. (Germany) with high purity.

2.2. Preparation of Moringa oleifera extract (ME)

The percolation method was used to prepare *Moringa oleifera*extract (ME). At first, 300 g of powder was transferred to the percolator device and 96% ethanol solvent was added (3-4 cm above the powder) and then the sample was exposed to solvent extraction for 72 h. These steps were carried out two times for 48 h and 24 h, and the resulting extracts were collected in a glass and concentrated by a rotary evaporator under vacuum

(45°C). The obtained extract was kept in a refrigerator (4°C) until the next use (Sahrakary *et al.*, 2017).

2.3. Preparation of dairy dessert treatments

The formulation of the current research had two main variables including ME (1%, 2% and 3%) and inulin (5% and 7%). Also, ingredients including 100 mL low-fat pasteurized milk, maltitol and sucralose sweeteners (1:1) with certain proportions (3%), 0.5 mL vanilla and 4 g gelatin were considered in the dairy dessert formulation in constant values. To prepare dairy dessert, milk was placed in a water bath until its temperature reached 40 °C. Then, the mixture of dry ingredients including maltitol, sucralose, inulin and gelatin was slowly added to milk and stirred continuously for 10 min at 40°C. After that, the temperature of the mixture reached 90°C in the hot water and kept at this temperature for 10 min. After this period, the dairy desserts were placed in the cooling flask until their temperature reached 40 °C. Finally, vanilla and ME were added and stirred for 60 s. The temperature of the desserts was then reached 4°C and kept at this temperature until the tests were performed.

2.4. Chemical composition and physicochemical properties analysis

The moisture, ash, fat (Soxhlet method) and protein content (micro-Kjeldahl method; protein factor 6.25) of the desserts were determined according to the AACC method (2000). The carbohydrate content was obtained by difference, i.e., the residual weight after subtracting amounts of water, protein, fat, and ash found by analysis. The calories of the samples were calculated through the following equation (Karp *et al.*, 2017):

$$\text{Calorie} = [(\text{Fat\%} \times 9) + (\text{Protein\%} \times 4) + (\text{Carbohydrate\%} \times 4)]$$

pH and acidity were measured by using a digital pH-meter and titration using 0.1 N NaOH, respectively (AACC, 2000). The soluble solids (Brix) of the samples was determined using a LH-T90 manual refractometer. The method describe by Jridi *et al.* (2015) was used to measure the syneresis percentage of desserts. The color of the samples was evaluated by determining L*, a* and b* color indices using a colorimeter (Minolta, Japan).

2.5. Analysis of viscosity

The viscosity of dairy desserts was determined using Brookfield Rotary Viscometer (AMETEC, CT3 model). The samples were poured into the cylinder of the device and reached to a temperature of 25°C by the circulator. The shear rate was also in the range of 0-100 s^{-1}(Guénard-Lampron *et al.*, 2019).

2.6. Evaluation of antioxidant capacity

Antioxidant capacity of dairy desserts was investigated using DPPH radical scavenging method. After mixing the sample (1 g) with ethanol (10 mL) for half an hour on a magnetic stirrer, the mixture was left alone for 2 h, and after separating the suspended material, one milliliter of it was mixed with 96% ethanol (4 mL) and 0.044% DPPH reagent (1 mL), and after being placed in the dark for 20 min, its absorbance was recorded by a UV-VIS spectrophotometer at 517 nm (Almeida Neta *et al.*, 2018).

2.7. Sensory evaluation

The sensory evaluation of the dairy desserts was performed one day after production according to the 9-point hedonic test (9= the highest quality, 5= intermediate, and 1= the lowest quality) by 20 trained evaluators, including 12 female and 8 male in the age range of 25 to 50 years (Saha *et al.*, 2018).

2.8. Statistical analysis

A factorial experiment was used in the form of a completely random design to analyze the data. Duncan's multiply test was used to determine the difference between the means at the 95% confidence level ($P<0.05$). Also, SPSS 23.0 software was used for statistical analysis and graphs were dawn with Excel.

3. Results and discussion

3.1. Chemical composition of desserts

The results of examining the chemical composition, including the moisture, ash, fat, protein and carbohydrate content, as well as the calories of dairy dessert treatments are presented in Table 1. The level of the ME had no significant effect on the moisture content of the desserts, but the increase in the level of inulin led to a significant increase in the moisture content of the treatments ($P<0.05$). The treatments containing 7% inulin showed the highest moisture content (77.74-77.85%), and the control had the lowest amount (67.92%). The increase in moisture content of desserts due to the addition of inulin and increase in its level can be attributed to the presence of hydrophilic groups and the hygroscopic nature of inulin. Both the increase in the level of ME (from 1% to 3%) and the level of inulin (from 5% to 7%) caused a significant increase in the ash content of the desserts. So that the highest ash content was observed in ME3In7 treatments (1.02%) and the lowest amount was for control (0.55%). Ash is a collection of minerals and carbohydrates that are burned in the furnace, so according to the results, since *Moringa oleifera* is rich in minerals such as iron, the ash content increased with the increase in the level of extract. Similarly,El-Gammal *et al*. (2017) reported that the addition of ME due to its richness in essential nutrients such as phosphorus, calcium and potassium, led to an increase in the ash content of yogurt. The increase in the ME was also increased the level of proteins in the desserts due to the presence of proteins in the *Moringa oleifera* and its extract (P<0.05), however, the level of inulin didn't show a significant effect. The protein content of the treatments were in the range of 5.84% to 7.41%. According to reports, *Moringa oleifera* contains 35.37% protein (Compaoré *et al.*, 2011). The presence of protein in *Moringa oleifera* and its extract was also confirmed in the research of Abo-Rhyem (2018). The fat content of the treatments was obtained in the range of 1.57% to 1.64%, and was not affected by the addition of ME and inulin. The fat content of the dairy desserts produced in this research were consistent with the fat values of the dairy dessert (1.44-2.16%) produced in the study of Djaoud *et al*. (2020). No significant change in the carbohydrate content and calories of the treatments was observed with the increase of the ME level, while with the increase in the level of inulin from 5% to 7%, the carbohydrate content increased and calorie values decreased significantly (P<0.05). So that the highest amount of carbohydrates and the lowest value of calories were obtained in the treatments containing 7% inulin (15.52-15.63%, and 86.35-86.83 Kcal, respectively). Since inulin is in the category of carbohydrates, the increase in the carbohydrate content of desserts due to the increase in the level of this additive was not far from expected. Inulin is also known as a dietary fiber and therefore can reduce the calorie of products.

Table 1. Chemical composition of dairy desserts treatments containing moringa extract (ME) and inulin (In).

Treatments	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrates (%)	Calorie (Kcal)
Control	67.92 ± 0.47 [c]	0.55 ± 0.13 [c]	5.84 ± 0.17 [d]	1.64 ± 0.27 [a]	11.94 ± 0.47 [c]	91.26 ± 0.44 [a]
ME1In7	74.85 ± 0.21 [a]	0.83 ± 0.23 [a]	6.32 ± 0.21 [c]	1.60 ± 0.21 [a]	15.52 ± 0.21 [a]	86.83 ± 0.25 [c]
ME2In7	74.79 ± 0.36 [a]	0.93 ± 0.37 [a]	6.86 ± 0.36 [b]	1.59 ± 0.36 [a]	15.63 ± 0.36 [a]	86.36 ± 0.42 [c]
ME3In7	74.74 ± 0.23 [a]	1.02 ± 0.42 [a]	7.41 ± 0.23 [a]	1.58 ± 0.23 [a]	15.58 ± 0.23 [a]	86.35 ± 0.28 [b]
ME1In5	73.54 ± 0.63 [b]	0.68 ± 0.23 [b]	6.20 ± 0.07 [c]	1.57 ± 0.33 [a]	13.42 ± 0.63 [b]	89.42 ± 0.73 [b]
ME2In5	73.78 ± 0.45 [b]	0.76 ± 0.16 [b]	6.79 ± 0.11 [b]	1.62 ± 0.21 [a]	13.37 ± 0.30 [b]	89.47 ± 0.29 [b]
ME3In5	73.59 ± 0.39 [b]	0.86 ± 0.26 [b]	7.34 ± 0.23 [a]	1.61 ± 0.18 [a]	13.44 ± 1.41 [b]	89.63 ± 0.51 [b]

*The results are reported as mean ± standard deviation. Different letters in the columns indicate significant differences (P<0.05). ME1In7: 1% moringa extract and 7% inulin; ME2In7: 2% moringa extract and 7% inulin; ME3In7: 3% moringa extract and 7% inulin; ME1In5: 1% moringa extract and 5% inulin; ME2In5: 2% moringa extract and 5% inulin; ME3In5: 3% moringa extract and 5% inulin.

3.2. Physicochemical properties of desserts

The results (Table 2) showed that there was no significant difference between the pH and acidity values of the treatments and the control samples, and their values were in the range of 6.59-6.95 and 13.21-13.79°D, respectively. Since the pH of the ME (6.00) and inulin (6.72) was close to neutral pH, these results wasn't far from expected. These results are consistent with the findings of Windari *et al*. (2021) and Chand *et al*. (2021), who found that ME and inulin had no effect on the pH and acidity of the pudding and yogurt, respectively.

The results of the soluble solids content in dairy desserts (Table 2) showed that there was no significant change in the brix of the treatments with the increase in ME, but the increase in the level of inulin led to an increase in the brix of the desserts (P<0.05), so that the treatments containing 7% inulin had the highest brix (29.1-29.4) and the lowest amount was for the control (22.2). Hydrocolloids with stabilizing properties such as inulin have a great effect on the amount of brix. Stabilizing molecules can establish a network between themselves and the components of the mixture in the formulation, which will increase the brix of the compounds and, as a result, increase their consistency (Morreale *et al.*, 2019). In general, milk components, food additives and hydrocolloids such as inulin have a very important effect on increasing brix of desserts.

The water binding capacity of inulin makes it possible to produce the final product with less syneresis, high consistency and better sensory characteristics (Ayar *et al.*, 2009).

Table 2. Physicochemical properties of dairy desserts treatments containing moringa extract (ME) and inulin (In).

Treatments	pH	Acidity (°D)	Brix (°)	Syneresis (%)
Control	6.69 ± 0.73 [a]	13.50 ± 0.27 [a]	22.2 ± 0.5 [c]	83.20 ± 0.03 [a]
ME1In7	6.88 ± 0.28 [a]	13.54 ± 0.36 [a]	29.4 ± 0.2 [a]	73.64 ± 0.41 [c]
ME2In7	6.93 ± 0.01 [a]	13.58 ± 0.26 [a]	29.1 ± 0.4 [a]	73.54 ± 0.36 [c]
ME3In7	6.95 ± 0.68 [a]	13.21 ± 0.78 [a]	29.3 ± 0.2 [a]	73.40 ± 0.21 [c]
ME1In5	6.71 ± 0.51 [a]	13.34 ± 0.35 [a]	27.8 ± 0.6 [b]	76.70 ± 0.09 [b]
ME2In5	6.59 ± 0.22 [a]	13.43 ± 0.31 [a]	27.6 ± 0.3 [b]	76.91 ± 0.18 [b]
ME3In5	6.78 ± 0.39 [a]	13.79 ± 0.64 [a]	27.5 ± 0.6 [b]	76.42 ± 0.57 [b]

*The results are reported as mean ± standard deviation. Different letters in the columns indicate significant differences (P<0.05).

The comparison of the syneresis values of different dairy desserts (Table 2) indicated that the syneresis of the desserts was not affected by the ME level, however, the increase in the level of inulin from 5% to 7% increased the syneresis significantly (P<0.05). The control sample had the highest percentage of syneresis (83.20%), and the lowest values was for the treatments containing 7% inulin (73.40-73.64%). The separation of the aqueous phase from the continuous phase (gel network) is called syneresis. Synersis is generally related to the amount of casein compounds in milk and the addition of stabilizer, and the higher the amount of added stabilizer, the lower the percentage of syneresis (Arab *et al.*, 2023). In the present research, inulin has been used as a stabilizer, and by increasing its level, due to the increase in the strength of the gel structure and the high water holding capacity of inulin, the syneresis has decreased. The decrease in syneresis with the increase in the level of inulin can also be related to the presence of larger amounts of solids in the formulation, as well as increase the density and decrease the size of holes in the protein network of the desserts. These results were consistent with the results reported by Chand *et al*. (2021) and El-Kholy *et al*. (2020).

3.3. Viscosity of desserts

The effect of adding ME and inulin on the viscosity of dairy desserts is shown in Figure 1. The viscosity of the desserts increased slightly due to the increase in the ME level, which is probably related to the reactions between the polyphenols in the extract and milk casein proteins (Vital *et al.*, 2015). In the research of Zhang *et al*. (2019), similar results were reported due to the addition of ME to the yogurt formulation. Inulin had a significant effect on the viscosity of the desserts, and the treatments containing a higher level of inulin (7%) indicated the highest viscosity (210.0-228.9 cP), and these results were consistent with the results of other researcher's studies (El-Kholy *et al.*, 2023; Sulejmani *et al.*, 2021; Żbikowska *et al.*, 2020). The main reason for the increase in viscosity due to the addition of inulin is the formation of a gel structure, so that the molecules of inulin are dispersed inside the milk mixture and after cooling, they being to form a gel structure, and the texture of the formed gel can be similar to yogurt or butter depending on the concentration of inulin used (Paseephol *et al.*, 2008). The increase in the solids content and the high water holding capacity of inulin can also be a reason for increasing the viscosity in the product formulation. Researchers have also stated that inulin can react with dairy proteins to increase viscosity (El-Kholy *et al.*, 2023). According to the previous findings, the ability of inulin to bind and absorb water molecules and form a gel network can improve the structure of the product, and when the product is placed in the refrigerator, the solubility of inulin decreases and due to the phenomenon of recrystallization of inulin microcrystals, the texture and viscosity increases (Franck, 2002).

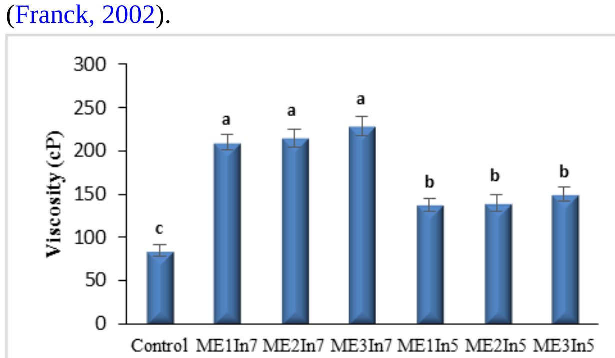

Figure 1. Viscosity of dairy desserts treatments containing moringa extract (ME) and inulin (In) Different letters indicate significant differences (P<0.05).

3.4. Color of desserts

Color is an important and influential factor on the quality and acceptance of food products, and the most important and effective factors in the color of the final products are the colors of the compounds used in the formulation of dairy products (Milovanovic *et al.*, 2020). According to the results obtained from the evaluation of the color indices of dairy desserts by colorimeter device (Table 3), it can be stated that with the increase in the inulin level, the brightness (L*) decreased significantly (P<0.05), which is related to the high water absorption capacity of inulin and as a result, the reduction of light scattering. However, the level of inulin didn't show a significant effect on the a* and b* values of desserts. SeyedMahmoodzade and Ahmadi (2021) also obtained similar results in their research. On the other hand, increasing the level of the ME also caused the color of the desserts to darken, and with the increase in the percentage of ME, a decrease in L* and a* and an increase in b* values were observed. All treatments had a negative a* and were in the green area. Similarly, in the study of Zhang *et al*. (2019), it was reported that the color of yogurt became greener and yellower due to the addition of ME. In general, although the color of dairy desserts was white through our sense of sight, the colorimeter device recognized the color of these products in green, white and yellow area.

Table 3. Color indexes of dairy desserts treatments containing moringa extract (ME) and inulin (In).

Treatments	L*	a*	b*
Control	86.62 ± 0.23 ᵃ	1.14 ± 0.47 ᵃ	5.70 ± 0.47 ᵈ
ME1In7	80.24 ± 0.34 ᵇ	-1.09 ± 0.21 ᵇ	7.44 ± 0.21 ᶜ
ME2In7	79.69 ± 0.56 ᵇ	-1.72 ± 0.36 ᶜ	11.70 ± 0.36 ᵇ
ME3In7	73.58 ± 0.62 ᵈ	-2.53 ± 0.23 ᵈ	17.29 ± 0.23 ᵃ
ME1In5	86.44 ± 0.43 ᵃ	-1.13 ± 0.63 ᵇ	7.36 ± 0.63 ᶜ
ME2In5	78.25 ± 0.35 ᶜ	-1.70 ± 0.11 ᶜ	11.22 ± 0.24 ᵇ
ME3In5	77.86 ± 0.39 ᶜ	-2.56 ± 0.19ᵈ	16.68 ± 0.58 ᵃ

The results are reported as mean ± standard deviation. Different letters in the columns indicate significant differences (P<0.05).

3.5. Antioxidant capacity of desserts

The DPPH free radical scavenging method was used to evaluate the antioxidant capacity of dairy desserts, and the results are presented in Figure 2. The control sample showed the lowest antioxidant capacity (1.41%). Inulin addition showed no significant effect on the antioxidant capacity of desserts. However, as expected, due to the richness of ME in bioactive compounds, especially phenols, increasing the level of this extract from 1% to 3% caused a significant increase in the antioxidant activity of desserts (P<0.05), and the highest values were observed in ME3IN7 (37.82%) and ME3In5 (37.53%), respectively. Phenolic compounds include simple phenols with an aromatic ring containing at least one hydroxyl group. Flavonoids are important subgroups of polyphenols with antioxidant properties that allow them to donate hydrogen and trap free radicals. Kaempferol and quercetin are two major bioactive compounds in the category of flavonoids found in ME, which have been introduced as strong antioxidants (Wang *et al.*, 2017). The remarkable antioxidant activity of *Moringa oleifera* extracts in different dairy products has been confirmed by previous researchers (Lisak Jakopović *et al.*, 2022; Zhang *et al.*, 2019).

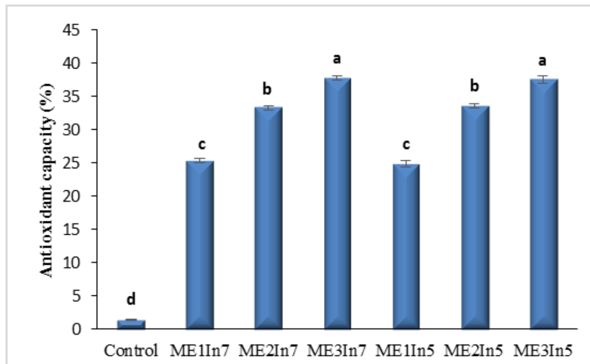

Figure 2. Antioxidant capacity of dairy desserts treatments containing moringa extract (ME) and inulin (In). Different letters in the columns indicate significant differences (P<0.05).

3.6. Sensory evaluation

The sensory characteristics of various dairy dessert treatments, including color, flavor, texture, mouthfeel, and overall acceptability, were investigated using the 9-point hedonic method. The results are presented in Table 4. The control sample exhibited the highest color score (8.50). The addition of the ME and inulin combination led to a significant decrease in the color score (P<0.05), attributed to reduced color brightness and the development of yellower and greener hues in the desserts due to the incorporation of these additives. An increase in ME resulted in a decrease in the color score due to the presence of pigments in the extract. However, an increase in inulin did not have a significant effect on this sensory characteristic. Flavor was significantly impacted by the addition of the ME and inulin combination (P<0.05). The control sample had the highest flavor score (8.20). The score of the desserts decreased with an increase in ME from 1% to 3% at each constant level of inulin, while an increase in inulin from 5% to 7% did not show a significant effect.

Treatments with different levels of inulin and ME exhibited higher texture and mouthfeel scores than the control. While an increase in ME level did not significantly affect these sensory characteristics, a significant improvement in texture and mouthfeel was observed with an increase in inulin from 5% to 7% ($P<0.05$). This improvement is attributed to the stabilization properties, increased viscosity, and decreased syneresis of inulin.Texture is a crucial aspect of food quality and is sometimes even more important than flavor and color in a product. The evaluation of the overall acceptability of various dairy desserts revealed that the ME1In5 treatment had the highest score (8.30), linked to its high texture, mouthfeel, and color scores, along with a good and desirable flavor. Increasing ME from 1% to 3% and inulin from 5% to 7% decreased the overall acceptability score, reaching the lowest score in the ME3In7 treatment (5.60). However, all treatments in this research were deemed acceptable in terms of sensory characteristics, as the acceptable limit for the sensory characteristics of desserts in this study was set at 5 (intermediate). In general, inulin has a mild sweet taste and easily combines with other sweeteners without creating any aftertastes in the product. Its gelling effects prevent syneresis and improve the sensory properties of the products. Sulejmani *et al.* (2021) observed an improvement in the sensory acceptance of low-fat milk jam due to the use of inulin. Similar results have been reported regarding the effect of inulin on enhancing the sensory characteristics of other dairy products (El-Kholy *et al.*, 2023). Ahmadian *et al.* (2023) found that the use of ME in the formulation of Cantaloupe dairy dessert drinks not only did not have a negative effect on the sensory characteristics but also improved their sensory acceptance. The disparity between these results and the present study's findings is likely due to differences in the type of desserts. In their research, cantaloupe juice, which has a naturally green color, was used in the base formulation, and this fruit juice demonstrated a masking effect on the taste of the ME.

Table 4. Sensory characteristics of dairy desserts treatments containing moringa extract (ME) and inulin (In).

Treatments	Color	Flavor	Texture	Mouthfeel	Overall acceptability
Control	8.50 ± 0.33 [a]	8.20 ± 0.23 [a]	7.00 ± 0.00 [c]	7.00 ± 0.00 [c]	7.40 ± 0.28 [bc]
ME1In7	7.70 ± 0.33 [b]	7.40 ± 0.28 [b]	7.50 ± 0.18 [b]	7.60 ± 0.28 [b]	7.30 ± 0.18 [bc]
ME2In7	6.90 ± 0.23 [cd]	6.50 ± 0.21 [c]	7.50 ± 0.11 [b]	7.60 ± 0.11 [b]	6.30 ± 0.23 [d]
ME3In7	6.10 ± 0.16 [e]	5.90 ± 0.23 [d]	7.60 ± 0.28 [b]	7.50 ± 0.38 [b]	5.60 ± 0.28 [e]
ME1In5	8.00 ± 0.00 [b]	7.50 ± 0.33 [b]	8.30 ± 0.31 [a]	8.30 ± 0.31 [a]	8.30 ± 0.23 [a]
ME2In5	7.30 ± 0.21 [bc]	6.80 ± 0.23 [c]	8.40 ± 0.28 [a]	8.30 ± 0.31 [a]	7.70 ± 0.28 [b]
ME3In5	6.50 ± 0.28 [de]	6.10 ± 0.16 [d]	8.30 ± 0.21 [a]	8.40 ± 0.28 [a]	6.90 ± 0.28 [c]

The results are reported as mean ± standard deviation. Different letters in the columns indicate significant differences ($P<0.05$).

4. Conclusion

The results of this study indicated that different physicochemical and sensory characteristics of dairy desserts were affected by the addition of ME and inulin combination. A positive relationship was observed between the ME level and the antioxidant capacity of the desserts, and this functional property of the treatments showed a significant increase with the increase in the level of the extract. Inulin in the formulation of desserts was able to reduce syneresis, increase viscosity and improve the sensory acceptance of prepared products compared to the low-calorie control. These results generally demonstrated that by using inulin and ME, functional low-caloric dairy desserts can be produced to improve the health of consumers.

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