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Utilization of Monk Fruit Sweetener as A Promising Sugar Substitute in Preparing Sugar Free Syrup for Popular Desserts

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THIS study aimed to produce high quality sugar-free syrup using monk fruit sweetener (MF) alone or in combination with rabaudioside A (RA) and studied their physicochemical and sensory characteristics and the technological application in sweetening of some popular Arabian desserts. Inulin, polydextrose (PD), erythritol and zusto (Z) were added to the sugar-free syrup as thickening agents. The results demonstrated that using MF alone or in a blend with RA at ratio 90:10 or 80:20 MF/RA to produce sugar-free syrup had properties similar to those of sugar syrup. Addition of either PD or Z to the above mentioned syrups gave high scores for the sensory characteristics with texture values closest to that of sugar syrup, in addition to the absence of the unpleasant aftertaste that was observed with those contained inulin or erythritol. Both syrups (MF + Z or MF/RA (80:20) + PD) received the highest sweetness taste score as compared to sucrose syrup. TLC analysis revealed the stability of the above mentioned sugar-free syrups. The absorption rate of the tested syrups by the various desserts (basbousa, kunafah, baklawa, balah el sham, and luqmat el qady) was lower than that of the sugar syrup indicating health benefits. Overall, there were no statistically significant differences in the sensory quality of the mentioned desserts when sweetened with the above mentioned sugar-free-syrups compared to those sweetened with sugar syrup. Therefore, monk fruit sweetener has potential as a natural promising sugar substitute in preparing low-calorie functional foods and sugar-free products for obese and diabetic patients.

Keywords: Monk fruit, Rabaudioside A, Arabian desserts, Zusto and Erythritol.

Introduction

Scientific studies and food manufacturers are increasingly concentrating on natural high-intensity non-nutritive sweeteners to produce low-calorie products to satisfy the demand of health-conscious consumers. As recent studies revealed that, the monk fruit sweetener is a natural high potency non-nutritive sweetener that has drawn both scientific and commercial interest (Thakur et al., 2021). It can be used as a sugar-free food additive in reduced-calorie health products and also as a replacement of sugar in traditional medicine and healthy food for diabetes and obese patients (Fang et al., 2017; Gong et al., 2019; Zhang et al., 2020). In addition, pharmacological studies have demonstrated that monk fruit extract has hypoglycemic, anti-inflammatory, anti-cancer, neuroprotective, antioxidant and antimicrobial activities (Liu et al., 2018; Liu et al., 2019; Luo et al., 2022; Shen et al., 2022).

Natural monk fruit sweetener extracted from the edible luo han guo herbal medicine (*Siraitia grosvenorii*) belonging to cucurbitaceous family originally that was grown in China. The isolated sweetener are mogrosides, and according to chemical composition are cucurbitane-type triterpene glycosides, isolated and identified as mogrosides III, IV, V, and VI, siamenode I, and

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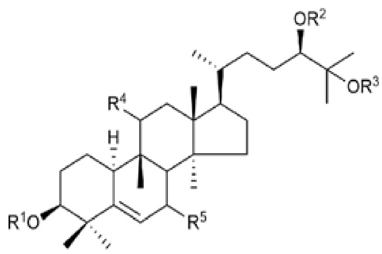
11-oxo-mogroside V that have sweet taste with intensity of sweetness as 195, 300, 378, 125, 456 and 68 times, respectively than sucrose (Fig. 1). These are present at 2.5% in the dried monk fruit (Suzuki et al., 2007). Mogroside V is the predominant triterpene glycosides with a content of 1.5-2% in the dried fruit and a range from 25% to 45% or 55% in monk fruit extract, depending on the production method (Chaturvedula & Prakash, 2011; Pandey & Chauhan, 2019). The sweetness intensity of monk fruit sweetener is depending on the degree of fruits ripe, purity, pH value, and temperature. Monk fruit sweetener has many benefits for human subjects as a dietary supplement. It has a wide range of potential applications in the food and beverage, nutraceutical, and pharmaceutical industries where it is non-calorific, stable at 100 °C, and a more palatable intense sweetener than other intense sweeteners (Kim et al., 2015). Monk fruit extracts are evaluated by the European Food Safety Authority (EFSA), and the Food and Drug Administration (FDA) considering it to be generally recognized as safe (GRAS) and readily available to consumers in countries like Asia, Canada, Australia, and New Zealand (Gardner et al., 2012). According to Marone et al. (2008), the no observed adverse effect level (NOAEL) of mogrosides in the diet was 7.07 and 7.48 g/kg bw/day for male and female rats, respectively.



Compound name	R1	R2	R3	R4	R5
Mogroside III	glc	glc-6-glc	H	a-OH	H_2
Mogroside V	glc-6-glc		H	a-OH	H_2
Mogroside VI	glc-6-glc		H	a-OH	H_2
Siamenoside I	glc		H	a-OH	H_2
11-Oxomogroside V	glc-6-glc		H	O	H_2

Fig. 1. The structures of the cucurbitane triterpene glycosides compounds isolated from monk fruit.

Additionally, it can be combined with low-calorie sweeteners resulting in a synergistic blend that results in better taste and flavour profile. The addition of rebaudioside A and B to a threshold level reduced the bitterness aftertaste and increase the taste acceptance score (Quinlan & Zhou, 2017). Rebaudiosides are a natural non-nutritive sweetener that extracted from the stevia plant and have 350-450 times the sweetness of sucrose.The synergy produced by the blends provides certain sensory properties, improved taste and the sweetness intensity was better than individual compounds, enhance flavors and overcome the undesirable aftertaste, and also can provide advantages in terms of economics and stability (Woodyer et al., 2018). However, researches on functional foods containing monk fruit extract or powder for particular benefits are limited. The other sweeteners are referred to as «bulk sweeteners» such as polyols (erythritol), which are used as fillers in many food products to add bulk, viscosity, and texture, in addition to maintaining the sensory qualities of the products (Souza et al., 2022). Polydextrose and inulin can be used separately or in combination to replace sugar in the production of pectin jelly and have several health promoting effects (Ünal et al., 2022).

Traditional Middle Eastern dessert is one of the oldest and most popular desserts consumed in Egypt, especially during the fasting month of Ramadan. These desserts contain traditional syrups like sucrose, maple and corn syrup which raise calorie intake of consumer and increase the risk of diabetes, obesity, and overweight. Obesity and overweight in people are associated with various risk factors for cardiovascular disease, heart diseases, and certain type of cancers. Nowadays, artificial sugar substitutes and sugar alcohols are used to produce sugar-free syrups, but they frequently have an unpleasant taste and quality attributes as well as the possibility of certain health problems from consuming these types of artificial sweeteners (Witkowski et al., 2023). Our study focuses on finding the added value of a natural monk fruit sweetener that is currently underutilized due to the lack of knowledge. Therefore, the study was conducted to produce sugar-free syrup using monk fruit sweetener (MF) alone or in combination rabaudioside A (RA) and studying its physicochemical and sensory characteristics. Also, investigate the effect of its addition on the sensory properties of some popular Arabic sweets.

Materials and Methods

Materials

Monk fruit sweetener (made in China for Sohkar LLC, Dubal, UAE) and erythritol (Now Food, Bloomingdale, IL60108, USA) were procured from Amson Global Inc., Richmond Hill, ON, L4E0B9, rebaudioside A-99% was procured from Stevia World Agrotech Pvt, Ltd. Bangalore, Inulin (Frutafit® TEX), of long average chain length ≥ 23 monomers (Sensus, Brenntag Química, Spain) were imported by AWA for Food Additives Co. Alexandria, Egypt. Polydextrose and zusto which consists of polydextrose, soluble maize fibers, inulin, isomalt and erythritol were imported by El-Bawadi Company (New Borg El Arab, Alexandria, Egypt). Sugar, flour, butter, corn oil, eggs, milk, baking powder, vanilla and salt were all bought from local Alexandria markets, Egypt. Luqmat el Kady mix was purchased from Dream Mashreque Food Company (New Borg El Arab, Alexandria, Egypt).

Methods

Evaluation of sweetness intensity

Staff members aged 25 to 50 years from the Department of Food Science and Technology, Faculty of Agriculture, Alexandria University were selected for the sweetness intensity study after introducing them to a variety of sweetener prior to the study as described by Wiet & Beyts (1992). Trained panelists were asked to perform magnitude estimation for the concentrations of 5, 7, 10, 15, and 20% sucrose solutions. Samples of monk fruit (MF) and rebaudioside A (RA) were prepared fresh on the day of testing and administered to each panelist in coded plastic cups at room temperature (22 °C) .

Syrup preparation

Several formulas of the sugar-free syrup were prepared by replacing the 100% sugar with MF alone or in combination with RA at ratio 90:10 and 80:20 in the presence of the different thickening agents (inulin, poly dextrose, zusto and erythritol). The amount of MF and RA were calculated according to its expected sweetness equivalence to 10% sucrose. First, sugar syrup was made by combining 100 g of sugar with 100g of water in a stainless steel vessel, and then heated at 80 °C for 15 min with stirring to get the final TSS of the mixture to 67%. Preliminary experiments were conducted to determine the optimum concentration of the selected thickening agents (inulin, polydextrose, zusto or erythritol). Based on the results, the thickening solutions were prepared using 20 g of inulin, polydextrose, zusto or erythritol in 100g water in a bowl and dissolve the mixture by raising the temperature to 80 ˚C for 15 min with stirring to obtain a viscosity close to that of the standard sugar syrup. Subsequently, the MF or MF blended with RA (MF/RA) was added to a 100 mL of this solution with continuous stirring and the mixture was heated for 2-3 min. The prepared syrup was stored in glass jars and kept on room temperature for analysis. Sensory profile of syrups was evaluated using trained panelists to determine the best formula to obtain low calorie syrup that has comparable characteristic to the original sugar syrup used on a commercial scale for traditional Arabian desserts. The residual aftertaste attributes was measured about 20 sec after swallowing.

Physico-chemical measurements of syrup

Total soluble solids (TSS%) were determined using a hand refractometer at room temperature, titratable acidity was determined according to the AOAC (2000), pH was measured using Beckman pH meter, viscosity was measured by DVII -PRO Viscometer (USA) using a SC4-15 spindle at 35°C temperature according to Rangana (1977). Heat stability of sweeteners in syrup was examined by TLC as described by Hong et al. (2022). The visible spectra (380-770 nm) data were used to determine the colour of all syrups using a Hunter Lab Ultra Scan VIS model colorimeter. The lightness (L*), redness (a*), yellowness (b*), total colour difference (Δ E) and chroma (C) values were calculated using the software CromaLab (Gordillo et al., 2015).

Preparation of popular desserts

Basbousa

Ingredients included: 325 g of semolina, 75 g of flour, 90 g of coconut, 200 g each of sugar, butter, and yoghurt, as well as a little of milk. The ingredients were combined to make a thick batter in a bowl poured onto a baking sheet and baked for 35 to 40 minutes at 190 °C. Syrup was poured over the basbousa evenly as soon as it comes out from the oven (Abd-ELmoteleb, 1995).

kunafah

500 g of kunafah strands were covered with 200 g of milted butter. The kunafah was baked in a baking tray for about 30 minutes in a 200 °C oven. After taking it from of the oven, the kunafah was inverted onto a serving plate and drizzle with syrup.

Baklawa

The phyllo pastry layers was placed in the oiled pan, drizzled with butter between layers and cut into diamond-shaped pieces then baked in the oven until golden. After baking, the baklawa was sweetened with syrup (Güldemir, 2022).

Balah el sham (Tulumba)

5 g of sugar and 30 mL of oil were added to 150 mL of boiling water 2 g of salt was added to a 100 g of the flour then add to the previous mixture, and stir vigorously until the mixture is smooth. After allowing the batter to cool, eggs (60 mL) was added gradually until the batter is smooth and soft, dough was allowed to rest for 10 minutes. Dough fingers was formulated using a dressing cones and dropped in moderately hot oil until they turn golden, then submerge in syrup for few minuts (Elwardany and Sheteewy, 2018).

luqmat el qady

A commercially available instant mixed was used to prepare the dough by mixing the mix was water according to the instructions on the container and let the dough rise for 1 h. The dough was formed into balls and fried in sunflower oil at about 150 °C and then submerged in the prepared syrup for few minutes.

Absorption of syrups by dessert

The absorption values of syrups by the selected desserts were determined from the difference of mass of dessert before and after adding the syrups which were expressed as g of syrup absorb per g of dessert.

Sensory evaluation of desserts

The prepared desserts were subjected for sensory evaluation, using untrained judges in, Faculty of Agriculture, Alexandria University. A standard hedonic rating scale from 9 (like) to 1 (dislike) was used to score the colour, flavour, taste, texture, and overall acceptability of the products (Kramer & Twigg, 1973).

Statistical analysis

Data were analyzed using Co-Stat Software (2004) computer program. The level of significant difference was determined at $P \leq 0.05$.

Results and Discussion

Sweetness equivalency and potency of MF and RA

The sweetness equivalency values of MF and RA are shown in Table 1 and Fig. 2 (a & b) as evaluated by the trained panelists. The panelists noticed that the aqueous solution of MF was equi-sweet at 0.025, 0.047, 0.059, 0.098 and 0.114% as sucrose at 5, 7, 10, 15 and 20 %, respectively. Meanwhile, an aqueous solution of RA at 0.016, 0.023, 0.033, 0.05 and 0.072 % promoted the same level of sweetness as sucrose syrup at 2.0, 5.0, 10.0 and 20.0%, respectively. The 0.025% MF (equivalence to 5% sucrose) exhibited 200 times more potent than sucrose. Meanwhile, sweetness of 0.114 % of MF was 175.44 times more potent than 20% sucrose solution. RA at 0.072% was equal to the sweetness of 20 % sucrose solution, but exhibits black liquorice taste attributes. These results were consistent with those reported previously by Kinghorn and Compadre (2011) & Suri et al. (2021). The authors reported that sweetness potency values for MF decreased slightly as the concentration increased compared to 5% to 20% w/v sucrose, also, as the concentration of RA increased; the sweetness intensity slightly decreased and exhibited an aftertaste of black licorice. According to the chemical composition of the sweeteners, the sweetness of mogrosides I and II was found to be equal to that of sugar, whereas the sweetness of mogrosides IV and V ranged from 250 to 450 sweetness of sugar (Kinghorn & Compadre, 2011; Suri et al., 2021). Furthermore, the composition of the food system influences sweetness potency (Massoud et al., 2005; Prakash et al., 2014). The concentration of MF at 0.059% had equal sweetness to a 10% sucrose solution which acts 169.5 times more potent than sucrose. Meanwhile, the 0.033% of RA was equivalent to 10% sucrose, indicating 303.0 times more potency than sucrose (Fig. 2b).

Effect of thickener agents on physico-chemical characteristics of aqueous solutions

Results in Table 2 indicate differences in the physico-chemical characteristics among the prepared thickening solutions. The TSS values ranged from 60 to 66% while the viscosity value of the aqueous solutions changed with the different thickening agents. Viscosity values was 58.33 cP for the sugar syrup, while viscosity values were 65, 75 and 141.67 cP for polydextrose, zusto and inulin solutions, respectively, while it decreased to 41.66 for the erythritol solution. This can be attributed to the molecular weight and different structures of the tested thickening agents. Positive effects of inulin and polydextrose were observed by increasing the viscosity of the final solution due to the binding of water by the high molecular weight carbohydrates. However, at higher concentrations of the thickening agent a negative effect was observed (ropy and slimy characteristic), similar results were observed by Pinto and Dharaiya (2014) when using polydextrose, and maltodextrin in the manufacture of low fat frozen dessert. Erythritol (monosaccharides), according to Carocho et al. (2017), is frequently used by the food industry as a natural bulk sweetener because it gives the mixtures bulk, viscosity, and texture. The results of the pH values showed that erythritol-containing syrup had the lowest pH value (3.88) while polydextrose-containing syrup had the highest pH value (4.33) and was statistically similar to sugar and inulin syrups. An increase in titratable acidity was observed concurrently with a decrease in pH.

As presented in Table 2, the colour values (Hunter L*, a* & b*) of the investigated solutions were different than those of the sugar syrup. The data indicated that the type of thicker agent had an influence on lightness (L*), redness (a*), yellowness (b*), and chroma. It was obvious that the lightness and redness values of all the prepared solutions were lower than the sugar syrup. Inulin and erythritol reduced the b* value while polydextrose and zusto increased the b* value compared with sugar syrup. The observed changes in solution colour may be due to changes in lightness where negative Δ L value indicated that the samples were darker than the colour of the sugar sample. However, Δ 'a*' value of the inulin sample was 'a*' negative, indicating that the sample colour is green with less red. Positive Δ 'b*' values in the polydextrose and zusto containing solutions showed that the sample is yellow with less blue. Changes in chroma, which affects colour intensity, had a similar pattern to those of parameter b*. Different hue angle value was found in the inulin sample. The (ΔE) values were higher than 3 which was distinguished by human eye ($2 < \Delta E < 5$) and the panelists observed difference in colour compared with sugar sample. The caloric value of inulin, polydextrose, zusto and erythritol are 1.39, 2, 0.958 and .02 kcal/g (Kaur & Gupta, 2002; Auerbach & Dedman, 2012; Riedel et al., 2015).

TABLE 1. Equi-sweet concentrations (%) of monk fruit (MF) and rebaudioside A (RA) relative to sucrose equivalent sweetness.

Sweetener (%)	Equi-sweet concentrations (%)				
Sucrose	5	7	10	15	20
Monk fruit	0.025	0.047	0.059	0.098	0.114
RebaudiosideA	0.016	0.023	0.033	0.05	0.072

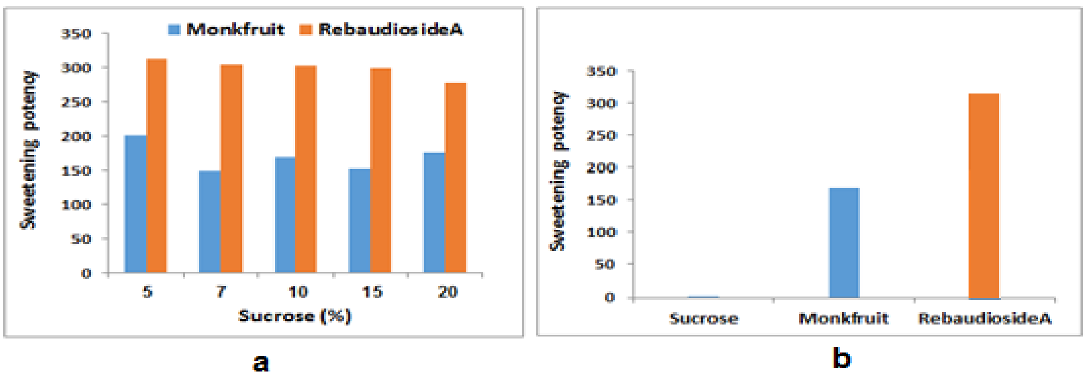


Fig. 2 a. Sweetness equivalency and potency of MF and RA
b. Potency of MF and RA equivalent to the concentration of 10% sucrose solution.

TABLE 2. Physico-chemical properties of thickener agents in aqueous solutions.

Properties*	Sugar syrup	Thickener agent -based aqueous solutions ***			
		Inulin	Polydextrose	Zusto	Erythritol
T. S. S. (%)	$66.0^{c}\pm0.57$	$64.0^{b}\pm0.64$	$60.7^{a}\pm0.21$	$60.0^{a}\pm0.33$	$66.0^{c}\pm0.57$
Viscosity (cP)	$58.3^{c}\pm0.38$	$141.7^{e}\pm0.93$	$65.3^{b}\pm0.66$	$75.0^{d}\pm0.61$	$41.7^{a}\pm0.57$
pH	$4.2^{a}\pm0.02$	$4.3^{a}\pm0.05$	$4.3^{a}\pm0.07$	$4.1^{ab}\pm0.02$	$3.9^{b}\pm0.01$
Titratable acidity (%)	$0.13^{a}\pm0.22$	$0.14^{a}\pm0.16$	$0.18^{b}\pm0.45$	$0.21^{c}\pm0.37$	$0.4^{d}\pm0.18$
Colour values					
lightness (L*)	$34.9^{d}\pm0.87$	$26.7^{a}\pm0.54$	$31.3^{c}\pm0.56$	$31.5^{c}\pm0.73$	$29.6^{b}\pm0.77$
ΔL*	-	-8.22	-3.60	-3.39	-5.26
Redness (a*)	$7.5^{d}\pm0.69$	$0.15^{a}\pm0.05$	$1.\ 7^{c}\pm0.14$	$0.18^{a}\pm0.05$	$0.51^{b}\pm0.18$
Δ a*	-	-0.04	1.78	0.29	0.62
Yellowness (b*)	$7.5^{c}\pm0.22$	$0.34^{a}\pm0.08$	$9.4^{d}\pm0.52$	$7.7^{c}\pm0.19$	$5.9^{b}\pm0.26$
Δ b*	-	-7.2	1.86	0.16	-1.67
Chroma (C*)	$7.5^{c}\pm0.14$	$0.37^{a}\pm0.25$	$9.5^{d}\pm0.19$	$7.7^{c}\pm0.28$	$5.\ 9^{b}\pm0.33$
ΔC*	-	-7.17	2.00	0.16	-1.65
Hue(h*)	$90.9^{d}\pm0.98$	$114.0^{e}\pm1.36$	$79.9^{a}\pm1.04$	$88.6^{c}\pm0.87$	$85.0^{b}\pm1.34$
ΔE**	-	$7.\ 8^{c}\pm0.23$	$3.8^{a}\pm0.12$	$3.4^{a}\pm0.09$	$5.1^{b}\pm0.43$
Calorie value	800.0	27.8	40.0	19.6	4.0

*Data as mean ± SD. Means in the same row sharing the same letters are not significantly different at P≤0.05 level.
**$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$
*** Thickener agent concentration were 20g of each dissolved in 100g of water

The sensory attributes of syrups were evaluated as shown (Fig. 3). As noticed from these results, adding zusto and polydextrose as thickener agents, gave high scores for all the sensory parameters tested with texture values closest to that of sugar syrup while inulin or erythreitol did not receive favourable scores in any of the sensory parameters tested. Consumer preferences for colour and consistency were lower in erythritol-containing solution due to its crystallization and cloudy appearance. Farias et al. (2019) reported that erythritol have limited potential because of its negative impact on the texture, colour, and viscosity of products but it can be used alone in small amounts and in combination with other polyols (Souza et al., 2022). Based on the aforementioned findings, zusto and polydextrose were the ideal thickening agents to produce high quality natural monk fruit syrup, which scored higher than the inulin and erythritol-containing samples in terms of colour, appearance, texture, and acceptability.

Sensory characteristics of low calorie monk fruit sweetener (MF) syrups

The sensory properties of low-calorie syrups made from monk fruit sweetener alone and blended with rebaudioside A (RA) using polydextrose (PD) or zusto (Z) as bulking agents are displayed in Table 3. It was evident that there was no significant ($P \leq 0.05$) difference between all syrups and sucrose syrup in regards to their, flavour or texture attributes. Monk fruit sweetener syrup showed higher intensities of negative attributes like bitterness and a prolonged aftertaste, which is an unpleasant sensory quality of sweeteners. Meanwhile, the presence of RA with MF reduced the bitter taste and bitter aftertaste in the syrup compared to that when MF was used alone. Syrup sweetness potency varied depending on the amount of sweetener used. The syrup made of the MF/RA (80:20) + PD or MF + Z received the highest sweetness taste score. On the other hand, the syrup made with MF/RA+ Z had the lowest sweetness taste score. This finding could be due to the interactions and synergistic effects between zusto and high-potency sweeteners, which have different physico-chemical properties from bulk agents (Ruiz-Aceitun et al., 2018). According to Antenucci and Hayes (2015), high-potency sweeteners can activate sweet-taste receptors at very low concentrations, but as their concentration increases their sweetness potency decreases. This is probably due to increased bitterness and the saturation of amino acid residues in sweet-taste receptors. As noticed from Table 3, blending MF sweetener with RA reduced the unpleasant residual aftertaste (bitterness) that results from using MF alone. Recent research (Pandey and Chauhan, 2019) has shown that the presence of some mogrosides in monk fruit extract is what causes its unpleasant flavour and/or undesirable sensory profile. However, Quinlan and Zhou (2017) stated that stevia rebaudiana, specifically its sweet steviol glycosides known as rebaudiosides A and B, can improve the taste and reduce the aftertaste. The addition of allulose to monk fruit extract provides 70% of the sweetness and improved sensory profile (Woodyer et al., 2018). Based on these findings, two syrups were chosen, one made of MF/ RA (80:20) + PD and the other were made of MF + Z, to be used in sweetening Arabian desserts (Fig. 4).

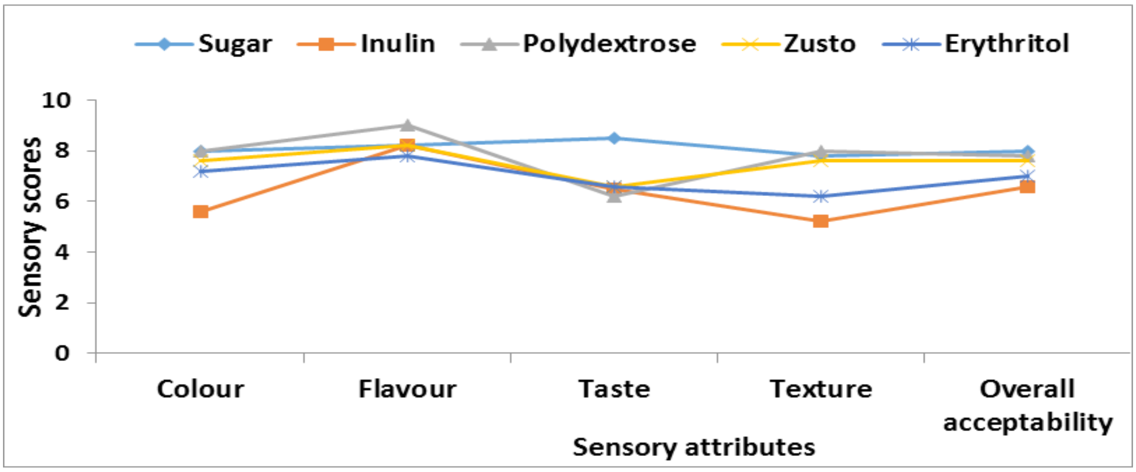


Fig. 3. The sensory attributes of thickener agents aqueous solutions.

TABLE 3. Sensory characteristics of low calorie syrup prepared from monk fruit sweetener (MF) along or with rebaudioside A (RA) using bulking agents*.

Sweetener in syrup**	Bulking agents	Colour	Flavour	Taste profile				Texture
				Sweetness	Bitterness	The residual aftertaste		
						Sweetness	Other taste	
Sugar	-	7.3^{a}±0.63	8.5^{a}±0.56	8.4^{bc}±0.52	0.0^{a}±0.00	0.55^{a}±0.12	0.0^{a}±0.00	7.80^{a}±0.28
MF extract	-	8.37^{a}±0.67	7.25^{a}±0.37	7.9^{abc}±0.45	2.7^{b}±0.12	1.05^{ab}±0.18	2.25^{c}±0.22	7.0^{a}±0.45
MF (100%)	Polydextrose (PD)	7.7^{a}±0.45	7.3^{a}±0.63	7.5^{abc}±0.88	1.3^{a}±0.23	1.25^{abc}±0.24	1.27^{bc}±0.43	7.1^{a}±0.72
MF+RA(90:10)		7.6^{a}±0.33	7.5^{a}±0.95	8.0^{bc}±0.44	0.3^{a}±0.30	1.92^{bc}±0.33	0.55^{abc}±0.46	7.3^{a}±0.70
MF+RA(80:20)		7.9^{a}±0.49	8.3^{a}±0.52	8.5^{bc}±0.67	0.2^{a}±0.17	1.7^{bc}±0.26	0.90^{abc}±0.77	7.7^{a}±0.41
MF (100%)	Zusto	7.5^{a}±0.78	8.4^{a}±0.65	8.7^{c}±0.63	0.5^{a}±0.25	1.63^{bc}±0.22	0.35^{ab}±0.35	7.5^{a}±0.75
MF+RA(90:10)		7.9^{a}±0.48	7.9^{a}±0.78	7.3^{ab}±0.96	0.96^{a}±0.19	1.12^{ab}±0.28	0.68^{abc}±0.29	7.3^{a}±0.88
MF+RA(80:20)		7.4^{a}±0.54	7.4^{a}±0.19	6.7^{a}±0.87	1.2^{a}±0.17	0.77^{a}±0.14	1.33^{bc}±0.70	7.3^{a}±0.93

*Data as mean ± SD.

**MF: monk fruit sweetener; RA: rebaudioside A.

Means in the same column sharing the same letters are not significantly different at $P \leq 0.05$ level.

Fig. 4. General appearance of syrups (MF: monk fruit sweetener; RA:rebaudiosideA;PD: polydextrose and Z: zusto).

Stability of MF and RA in the syrup

Thin-Layer Chromatography was used to investigate the stability of MF and RA in the syrup (TLC). The MF and RA demonstrated good stability, with neither MF sweetener nor RA decomposing at the temperature used to produce the syrup (100 °C for 10 minutes) (Fig. 5). Zhou and Zhu (2014) found that monk fruit extract remains stable above 150°C, which is the processing temperature. The monk fruit extract, which has about 30% mogroside V, was stable for 4 h at 100-150 °C temperature (Younes et al., 2019). Rebaudiodide A, according to Chaturvedula and Prakash (2013), has excellent heat stability up to 60 °C for 137 h in acidic solutions.

Utilization of the syrups in popular Arabian desserts

The selected syrups were prepared MF/ RA (80:20) + PD and MF + Z and sugar syrup was used as control syrup. The different syrups were used to sweeten the different baked or fried desserts (basbousa, kunafah, baklawa, balah el sham and luqmat el qady) using the required amounts for each dessert.

The absorption values of syrups by dessert

The absorption rate of the tested syrups by the various desserts under study is presented in Fig. 6. Sugar syrup showed the highest absorption rate (0.407, 0.552, 0.663, 0.325 and 0.25 g/g) followed by MF/RA+PD (0.288, 0.552, 0.611, 0.166 and 0.171 g/g) then MF+ zusto (0.223, 0.55, 0.44, 0.136, and 0.163 g/g) syrups for basbousa, kunafah, baklawa, balah el sham and luqmat el qady, respectively. Different factors, such as temperature, viscosity, and syrup concentrations, as well as the ingredients of desserts, influence the rate of absorption. The high viscosity of MF + Z syrup (75 cP) (Table 2) resulted in the lowest absorption rate by all products. Because of its high viscosity, syrup cannot penetrate the product's outer surface, which results in a lower syrup absorption, which could be a positive feature from the health point of view. As presented in Table 4, the panelists seem to have approved desserts sweetened using sugar-free syrups. Monk fruit mogroside extract is a new low-calorie, non-sugar sweetener that offers higher sweetness (>300 times) than sucrose, so it can be used in a wide range of foods, beverages, and other products as an additive, or to prepare sugar-free foods (Yang et al., 2016 and Pandey & Chauhan, 2019). However, there are very few studies on functional foods containing monk fruit extract or powder for specific benefits (Pandey and Chauhan, 2019).

Sensory evaluation of dessert products with sugar free syrups

The mean scores for all sensorial characteristics provided by panelists are shown in Table 4. Statistical analysis showed that there were no statistically significant differences between samples sweetened with sugar syrup and those with MF + Z or MF/ RA + PD syrups in any of the sensorial characteristics (Table 4 and Fig. 7). Taste is an important consideration when evaluating the sensory characteristic of food products. It can be observed that the products made with MF+ Z syrup had a high score for the sweetness taste quality compared to other products. Thus, it was clear that basbousa, and baklawa with sugar-free syrups scored higher for texture than products with the control sugar syrup.

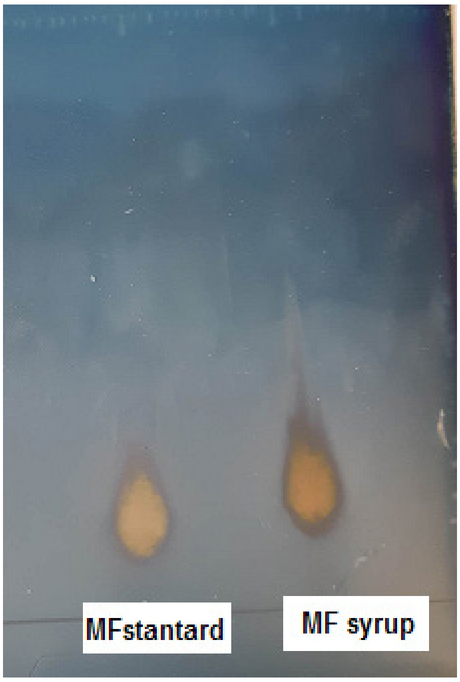


Fig. 5. TLC analysis for investigate the stability of monk fruit sweetener (MF) in syrup.

Coating material: Silica Gel G Merck type 60.
Developing solvent: n butanol: ethanol:water: aacetic acid (7:1:1:0.2 v/v)
Visualization: 10% sulfuric acid in ethanolic solution

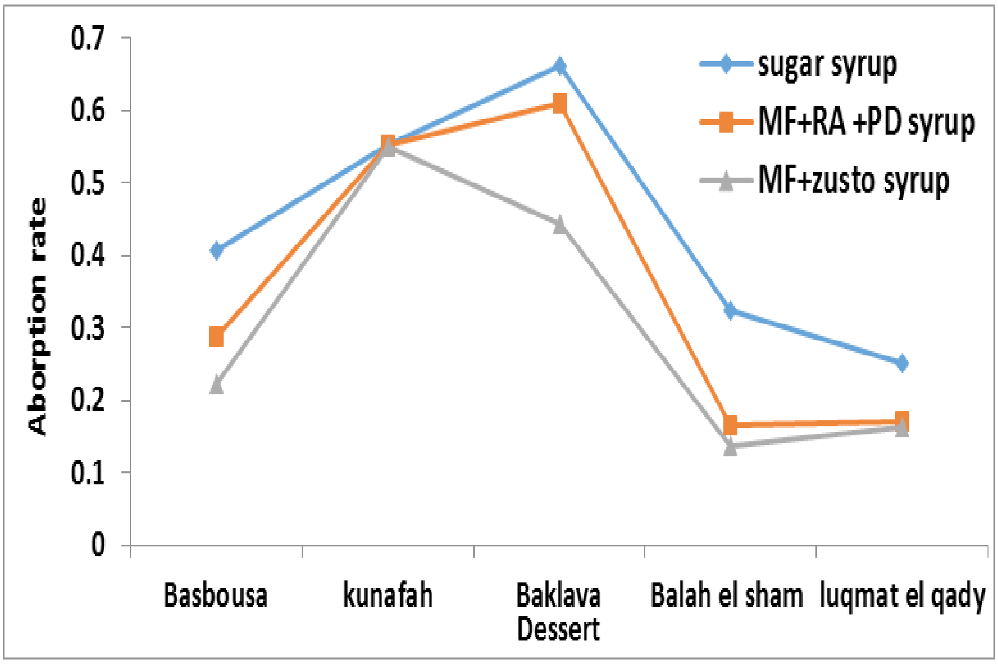


Fig. 6. The absorption rate of sugar syrup and monk fruit sweetener syrups by Arabian desserts.

TABLE 4. Effect of sugar- free syrups on sensory characteristics of the various desserts .

Type of syrup*	Sensory analysis**				
	Colour	Flavour	Taste (sweetness)	Texture	Overall acceptability
			Basbousa		
Control (sugar)	$7.9^{a}\pm0.63$	$7.8^{a}\pm0.65$	$7.9^{a}\pm0.08$	$7.6^{a}\pm0.24$	$7.9^{a}\pm0.33$
MF+RA+PD	$8.0^{a}\pm0.27$	$7.6^{a}\pm0.47$	$7.3^{a}\pm0.45$	$7.8^{a}\pm0.57$	$7.5^{a}\pm0.49$
MF+Z	$8.1^{a}\pm0.52$	$7.9^{a}\pm0.86$	$8.1^{a}\pm1.05$	$7.9^{a}\pm0.10$	$8.1^{a}\pm0.52$
			Kunafah		
Control	$8.33^{a}\pm0.32$	$8.33^{a}\pm0.48$	$8.22^{a}\pm0.60$	$7.78^{a}\pm0.27$	$8.17^{a}\pm0.37$
MF+RA+PD	$8.0^{a}\pm0.18$	$7.62^{a}\pm0.42$	$7.81^{a}\pm0.58$	$8.06^{a}\pm0.44$	$7.94^{a}\pm0.31$
MF+Z	$8.06^{a}\pm0.95$	$7.55^{a}\pm0.78$	$8.37^{a}\pm0.37$	$7.5^{a}\pm0.67$	$7.75^{a}\pm0.22$
			Baklawa		
Control	$8.0^{a}\pm0.51$	$8.33^{a}\pm0.69$	$8.22^{a}\pm0.87$	$7.67^{a}\pm0.97$	$8.28^{a}\pm0.51$
MF+RA+PD	$8.14^{a}\pm0.48$	$8.0^{a}\pm0.16$	$7.71^{a}\pm0.20$	$7.86^{a}\pm0.83$	$8.00^{a}\pm0.37$
MF+Z	$8.43^{a}\pm0.42$	$8.29^{a}\pm0.81$	$8.28^{a}\pm0.73$	$7.86^{a}\pm0.63$	$8.35^{a}\pm1.04$
			Balah el sham		
Control	$8.7^{a}\pm0.48$	$8.3^{a}\pm0.43$	$8.1^{a}\pm0.99$	$8.0^{a}\pm0.67$	$8.4^{a}\pm0.74$
MF+RA+PD	$8.3^{a}\pm0.92$	$7.6^{a}\pm0.22$	$7.9^{a}\pm0.83$	$7.6^{a}\pm0.44$	$7.8^{a}\pm0.67$
MF+Z	$8.3^{a}\pm0.63$	$8^{a}\pm0.32$	$8.2^{a}\pm0.42$	$7.9^{a}\pm0.39$	$8.3^{a}\pm0.84$
			luqmat el qady		
Control	$8.50^{a}\pm0.53$	$8.30^{a}\pm0.48$	$8.2^{a}\pm0.62$	$8.0^{a}\pm0.61$	$8.2^{a}\pm0.70$
MF+RA+PD	$8.40^{a}\pm0.74$	$8.50^{a}\pm0.82$	$7.95^{a}\pm1.03$	$7.6^{a}\pm0.82$	$7.8^{a}\pm0.22$
MF+Z	$8.50^{a}\pm0.53$	$8.40^{a}\pm0.34$	$8.30^{a}\pm0.79$	$7.6^{a}\pm0.70$	$8.15^{a}\pm0.94$

*MF: monk fruit sweetener; RA: rebaudioside A; PD: polydextrose; Z: zusto.
**Data as mean ± SD.
Means in the same column sharing the same letters are not significantly different at $P \leq 0.05$ level.

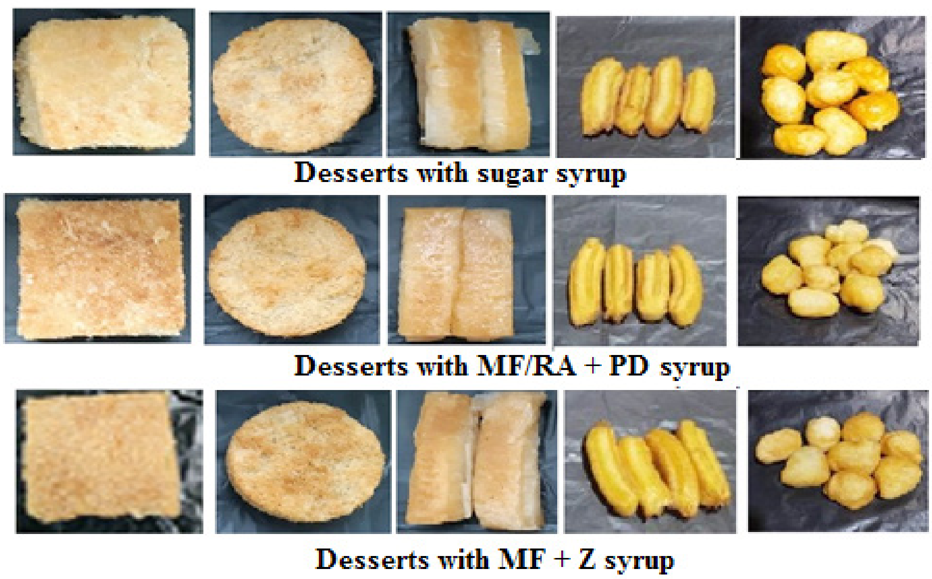


Fig. 7. General appearance of basbousa, kunafah, baklawa, balah el sham and luqmat el qady with sugar syrup and monk fruit sweetener syrups (MF: monk fruit sweetener; RA: rebaudioside A; PD: polydextrose and Z: zusto).

Texture attributes of food is a key quality parameter in consumer acceptance and market value (Kadam et al., 2015). The addition of texturizing agent could enhance the textural properties and mouth feel of products (Abd El-Razek et al., 2013 Ansari et al., 2021). On the other hand, it is worth mentioning that when the crunchy texture is required for the product (as in the case of balah el sham and luqmat el qady), the panelists preferred the texture of these products when sugar syrup was used compared to those with sugar-free syrups (Table 4). Polydextrose stimulates desserts in preservation their creaminess and adds smoothness, suitable texture, and mouthfeel (Jana et al., 1994; Ünal, & Arslan, 2022). Ansari et al. (2021) demonstrated, inulin and polydextrose, or resistant starch can be added to products as a prebiotic component to improve sensory characteristics with extending the product shelf life. It was clear that the panelists accepted all the aforementioned products, and they described their overall acceptability as "like very much" and "like moderately. For the overall acceptability, desserts with MF + zusto syrup received the highest scores for overall acceptability, followed by MF/RA + PD with similar sensory properties to the control products, which could be suitable for diabetics due to their low sugar and calories. Pandey & Chauhan (2019) reported significant reduction in glycemic index of monk fruit sweetener.

Conclusion

In the light of the data presented here, monk fruit sweetener can be utilized when blended with rebaudioside A, and or with thickening agents / bulk sweeteners such as polydextrose and zusto in the production of functional low-calorie food and drinks for obese and diabetic people.

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الإستفادة من مُحلي فاكهة الراهب كبديل واعد للسكر فى إعداد شراب خالي من السكر للحلويات الشعبية

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هدفت هذه الدراسة إلى إنتاج شراب عالي الجودة خالي من السكر باستخدام محلي فاكهة الراهب (MF) فى الصورة الفردية أو بالخلط مع رابوديوسيد ا (RA) و دراسة خواصه الكيموطبيعية والحسية و التطبيق التكنولوجي للشراب الناتج فى تحلية بعض الحلويات العربية الشعبية. تم إضافة الإنيولين و بولى ديكستروز (PD) و الإريثريتول و زاستو (Z) فى إعداد الشراب الخالى من السكر كمحاكاه للقوام. فأوضحت النتائج أن الشراب الخالى من السكر المحلى MF بمفرده أو بالخلط مع محلى RA بنسبة 90 : 10 و80 : 20 (RA/ MF) له خواص تشابه نظيراتها فى الشراب المحلى بالسكر . وقد حاز الشراب على أعلى درجة فى قيم الخواص العضوية الحسية و خاصية القوام وكذلك غياب صفة المذاق الغير مرغوب المتبقى بعد التذوق عند إضافة PD أو Z مقارنة بالإنيولين و الإريثريتول. كذلك حصل كل من MF+ Z أو PD+ (80: 20) RA/MF على أعلى درجة حلاوة من قبل المحكمين مقارنة بشراب السكر. أظهرت نتائج تحليل TLC ثبات المحليات فى الشراب الخالي من السكر . كما تبين ان معدل امتصاص الحلويات الشعبية (البسبوسة، الكنافة، البقلاوة، بلح الشام، ولقمة القاضي) أقل في الشراب الخالى من السكر مقارنة بشراب السكر مما يدل على فوائده الصحية. بشكل عام أوضحت النتائج عدم وجود فروق معنوية في الجودة الحسية للحلوى المذكورة عند تحليتها بالشراب الخالى من السكر مقارنة بنظيراتها المحلاه بشراب السكر. لذلك، يمكن إستخدام محلي فاكهة الراهب كبديل طبيعى واعد للسكر فى إنتاج الأغذية الوظيفية منخفضة السعرات الحرارية والمنتجات الغذائية الخالية من السكر لمرضى السمنة ومرضى السكري.

الكلمات المفتاحية: محلي فاكهة الراهب ، ريبوديوسيد أ ،الحلويات العربية ، زاستو و إريثريتول.