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ORIGINAL RESEARCH

Effects of guar gum and arabic gum on the physicochemical, sensory and flow behaviour characteristics of frozen yoghurt

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This study investigated the effect of guar gum and arabic gum on physicochemical, sensory and flow behaviour properties of frozen yoghurt. The results indicated that gums significantly affected the viscosity, overrun and melting rate of frozen yoghurt. The highest overrun value was observed in sample containing 0.5% arabic gum. Frozen yoghurt containing 0.3% guar gum had the highest viscosity. The longest first dripping time was observed in sample containing 0.5% arabic gum. Flow behaviour of samples showed that all frozen yoghurts exhibited shear thinning behaviour. Guar gum at a concentration of 0.2% and arabic gum at a concentration of 0.5% presented the best total acceptability. The results of this study revealed that the frozen yoghurt produced with arabic gum had the better overall sensory and physicochemical characteristics.

Keywords Frozen yoghurt, Guar gum, Arabic gum, Physical properties, Flow behaviour.

INTRODUCTION

Frozen yoghurt is a refreshing and nutritious dessert that combines the flavour and texture of ice cream and yoghurt. The ingredients used for frozen yoghurt production are like those used for ice cream, including hydrocolloids, emulsifiers, sweeteners and solid not fat. The viscosity of an ice cream mix is considered a very important attribute as it affects the body and texture of the finished product. The most important factor in enhancing the viscosity during ice cream processing is the addition of stabilisers (Minhas *et al.* 2002). Stabilisers also improve shape retention and melting behaviour (Soukoulis and Tzia 2008) and prevent the formation of objectionable large ice crystals in frozen desserts. They are used in such small amounts as to have negligible influence on foods' taste (Issariyachaikul 2008). During consumption, stabilisers provide uniform meltdown, mouthfeel and texture. Stabilisers can also contribute to a smoother and more resistant body. Most polysaccharide-based ice cream stabilisers influence the rheological properties of the continuous phase. The amount of stabiliser used varies with its properties, the solid content of the mix, the type of processing and other factors. The amount used in regular ice cream may be in the range of 0–0.5% but is usually 0.2–0.3% (Issariyachaikul 2008).

In the food industry, guar gum is used as a thickening and stabilising agent in a wide variety of foods, usually in amounts less than 1% of food weight (Slavin and Greenberg 2003). Arabic gum is used for its nutritional and surface properties (Sanchez *et al.* 2002). Some studies have been conducted on the effect of some gums on the physicochemical properties of ice cream. Soukoulis and Tzia (2008) studied the effect of some hydrocolloids on the physical and sensory properties of frozen yoghurt. They reported that the addition of hydrocolloids increased viscosity significantly and that the use of xanthan gum improved aeration, leading to the highest overrun. Minhas *et al.* (2002) studied the flow behaviour characteristic of ice cream mix with various stabilisers such as gelatin, arabic gum, guar gum and karaya gum. They concluded that all of the mixes indicated pseudoplastic behaviour.

The determination of rheological properties is essential for design, process and quality control, sensory evaluation, stability and consumer acceptance of a product (Arslan *et al.* 2005). To perform

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a quantitative comparison of materials, the experimental data must generally be fitted to some form of best-fit mathematical equation or model. The model is used to predict the viscosity of a flow as a function of shear stress or shear rate. Some useful flow models have been developed; the ones used in this study for fitting the flow curve of frozen yoghurt were as follows:

1 Power law model (Ostwald-de Waele equation):

$$\tau = k(\gamma)^n \tag{1}$$

where k is the consistency coefficient (Pa.s^n), γ is the shear rate (per second), τ is the shear stress (Pa) and n is the flow behaviour index. For shear-thinning fluids, $n < 1$, and for shear-thickening fluids, $n > 1$.

2 Herschel–Bulkley model (Bourne 1982)

$$\tau = \tau_0 + k(\gamma)^n$$

In this equation, τ is the shear stress, τ_0 the yield stress (Pa), γ the shear rate, k consistency coefficient and n the flow behaviour index.

3 Casson model (Casson 1959)

$$\tau^{0.5} = k_{0c}^{0.5} + k_c(\gamma^{0.5})$$

where τ, k_{0c} and k_c are shear stress, intercept of the plot of ($\tau^{0.5}$–$\gamma^{0.5}$) and slop of plot, respectively. In this equation ,$k_c^2 = \mu_c$ and $k_{0c}^2 = \tau_{0c}$ that are Casson viscosity (Pa.s) and Casson yield stress (Pa), respectively.

There is little information about the effect of gums on the physical properties and flow behaviour of frozen yoghurt. In this study, we aimed to produce frozen yoghurts containing guar gum and arabic gum at different concentrations and to investigate their physicochemical, sensory and flow behaviour properties.

MATERIALS AND METHODS

Preparation of yoghurt

Milk containing 2.5% fat and 8.25% Solid Not Fat (SNF) was standardised to 11% SNF according to the Iranian standard for yoghurt (ISIRI, NO: 695, 4th revision) using skim milk powder. Milk was heated at 85 °C for 30 min and cooled to 42 °C. Commercial yoghurt starter culture (YC-X11; CHR-Hansen, Horsholm, Denmark) was inoculated at a concentration of 0.2% in milk followed by incubation at 42 °C. When acidity reached 80 dornic, the yoghurt was cooled to refrigerator temperature (approximately 7 °C).

Preparation of frozen yoghurt

Sugar (16%) and skim milk powder (to adjust total solid to 30%) were thoroughly mixed and dissolved in skim milk and pasteurised at 85 °C for 30 min. This mix was cooled to refrigerator temperature and then thoroughly blended with yoghurt to produce the final frozen yoghurt mix. The mix was refrigerated at 7 °C for 15 h. The aged frozen yoghurt mix was frozen using a laboratory batch home ice cream maker (Guda *et al.* 1993). The same procedure was used to produce frozen yoghurt containing different levels of guar and arabic gums. After freezing, the samples were distributed among plastic cups (approximately 50 mL) and hardened at −18 °C.

pH measurement

The pH of frozen yoghurt mix was measured with a Methrom-827 pH meter (Methrom, Herisau, Switzerland) after ageing.

Viscosity and flow behaviour

The viscosity of the aged frozen yoghurt mix was measured using a viscometer (RV-DV II Brookfield, Middleboro, MA, USA). Samples were tested at 5 °C using spindle No.6. Shear rate and shear stress values were calculated using the viscosity data according to Mitchka's equations (Mitschka 1982). Plots of shear stress vs shear rate were created for each frozen yoghurt sample at speeds of 10–200 rpm. Flow behaviour index (n) and consistency coefficient (K) values were calculated for each sample. To select the most appropriate model of the samples' behaviour, the correlation coefficient (R^2) was used, with coefficients closer to 1 showing a better correspondence between the values predicted by the model and numerical values derived from experiments.

Overrun

Overrun measurement was carried out by comparing the weight of frozen yoghurt mix and frozen yoghurt in a container of a known volume. Overrun was calculated according to the following equation:

$$\text{Overrun} = \frac{\text{weight of unit mix} - \text{weight of equal volume of frozen yoghurt} \times 100}{\text{weight of equal volume of frozen yoghurt}}$$

Melting rate

The melting properties of frozen yoghurt were studied through the examination of two parameters: melting rate and first dripping time. A piece of frozen yoghurt (30 ± 1 g) was placed on a sieve (mesh: 0.5 mm) on top of a beaker at 25 °C and allowed to melt. The percentage of melted frozen yoghurt after 60 min was determined. The time required for first dripping of frozen yoghurt was recorded (Akalin and Erisir 2008).

Sensory analysis

Sensory analysis of the samples was conducted by seven expert panel members who evaluated flavour, colour, texture and total acceptability on a 5-point scale (1 = unpleasant, 5 = pleasant). Flavour was evaluated by the sample's closeness to an acceptable standard and intensity of refreshing yoghurt flavour and its relative freedom from any cooked or whey aroma. The colour of the frozen yoghurt was evaluated as either white or clear. Some attributes of texture (uniform and without gummy, sandy and icy defect) were evaluated. Overall acceptability was also evaluated, based on characteristics including colour, texture and flavour.

Statistical analysis

Statistical analysis of the data was performed using SAS software (version 9.1, SAS Institute Inc., Cary, NC, USA). Each experiment was replicated three times. Analysis of variance was conducted as a completely randomised design, and Duncan's multiple range test at $P = 0.05$ was used to compare means when the effect was significant.

RESULTS AND DISCUSSION

pH

Neither guar nor arabic gum had any significant effect on the pH of the frozen yoghurt samples (Table 1), which ranged from 5.05 to 5.017.

Viscosity

Table 1 presents the effect of different gums on the viscosity of frozen yoghurt. The viscosity of samples containing guar and arabic gums was significantly higher than that of the control sample ($P < 0.05$). It was also found that increasing the levels of both gums increased the viscosity. The lowest value for viscosity belonged to the control sample (1522 cp) and the highest to the sample containing 0.3% guar gum (3305 cp). There was no significant difference between guar gum at concentrations of 0.1% and 0.2%, but a concentration of 0.3% increased viscosity significantly. The viscosity of samples containing different levels of arabic gum differed significantly from each other ($P < 0.05$). Viscosity is an important characteristic in that a specific viscosity amount is required for achieving desirable whipping ability and retaining of air bubbles (Tarkashvand 2005). Stabilisers have a high water-holding capacity and can influence the rheological properties of ice cream mix; in other words, an increase in concentration of stabilisers in ice cream causes an increase in viscosity (Moeenfard and Mazaheri Tehrani 2008). Higher viscosity in sample containing gums can be explained by the interaction of gums and liquid part of ice cream mix (Akalin and Erisir 2008). Similarly, Soukoulis and Tzia (2008) showed that hydrocolloids such as carboxymethylcellulose, xanthan and guar could increase the viscosity of ice cream mixes.

Flow behaviour

Figures 1 and 2 show curves for shear stress–shear rate and viscosity–shear rate, respectively, in frozen yoghurts containing guar gum. It could be seen that the shear rate–shear stress relation in all of guar-containing samples was not linear. Results showed that the viscosity decreased when the shear rate increased (Figure 2). The decrease in viscosity was initially sharpened and slowed gradually. An initial reduction in viscosity in the control sample was slower than that in the guar-containing samples, showing stronger shear-thinning behaviour in samples that contained guar gum. The flow behaviour index of these samples also was below 1, indicating non-Newtonian behaviour. Increase in the concentration of guar gum resulted in decrease in the flow behaviour index and increase in the consistency coefficient (Table 2).

The relationship between shear rate and shear stress in frozen yoghurt containing arabic gum was similar to that of frozen yoghurt containing guar gum (Figure 3). The increase in shear rate was not linear with respect to shear stress. Arabic gum at concentrations of 0.1% and 0.3% was not noticeably different from the control, but arabic gum at a concentration of 0.5% resulted in a different shear rate and shear stress from the other samples. Figure 4 shows the effect of shear rate on viscosity in frozen yoghurt containing arabic gum. The flow behaviour index in these samples was below 1, and it was enhanced with increases in gum concentration. Viscosity reduction in these

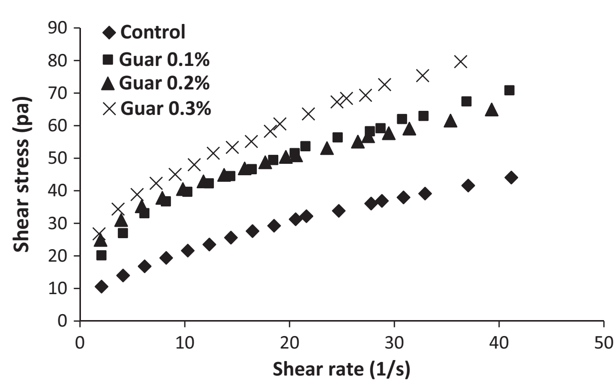

Figure 1 Flow curve of frozen yoghurts containing guar gum.

Table 1 Effect of guar and arabic gum on physicochemical properties of frozen yoghurt

Frozen yoghurt	*Concentration of gum (%)*	*pH*	*Overrun (%)*	*Viscosity (cp)*	*First dripping time (s)*	*Melting rate (%)*
Control	0	5.17 ± 0.04[a]	22.37 ± 0.9[c]	1522 ± 13[e]	1032 ± 161[d]	96.4 ± 1[a]
	0.1	5.15 ± 0.05[a]	32.39 ± 1[b]	2729 ± 58[b]	1744 ± 40[b]	84.51 ± 6[ab]
Guar	0.2	5.07 ± 0.01[a]	35.34 ± 1[ab]	2828 ± 33[b]	1788 ± 152[b]	75.66 ± 4[b]
	0.3	5.07 ± 0.003[a]	38.22 ± 0.5[a]	3305 ± 295[a]	1945 ± 112[b]	74.72 ± 3[b]
Arabic	0.1	5.14 ± 0.02[a]	30.19 ± 0.8[b]	1828 ± 148[d]	1402 ± 220[c]	77.62 ± 1[b]
	0.3	5.05 ± 0.04[a]	30.56 ± 2[b]	2257 ± 33[c]	1893 ± 163[b]	75.94 ± 4[b]
	0.5	5.07 ± 0.1[a]	39.38 ± 0.2[a]	3278 ± 53[a]	2363 ± 102[a]	72.03 ± 4[b]

Means in the same column followed by different letters were significantly different ($P < 0.05$).

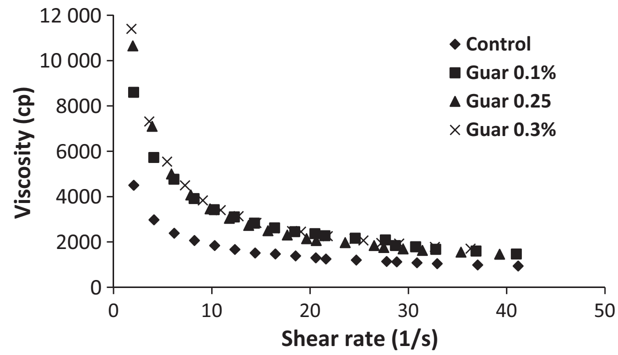

Figure 2 Effect of shear rate on apparent viscosity of frozen yoghurts containing guar gum.

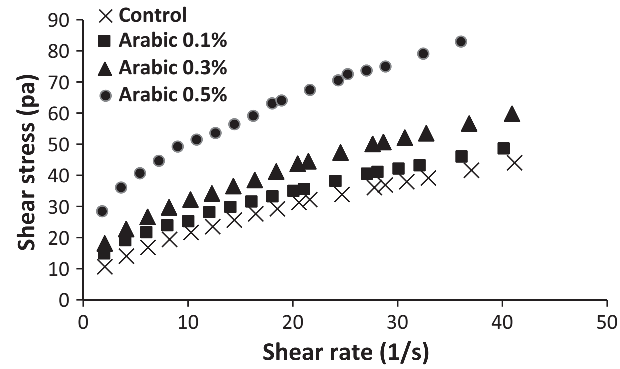

Figure 3 Flow curve of frozen yoghurts containing arabic gum.

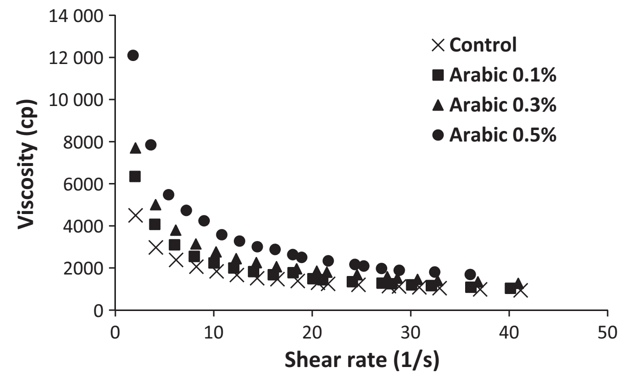

Figure 4 Effect of shear rate on apparent viscosity of frozen yoghurts containing arabic gum.

samples is attributable to the disruption of molecular entanglements of the polysaccharide by the applied shear (Santipanichwong and Suphantharika 2009). At a concentration of 0.5% arabic gum, viscosity reduction at initial shear rate was greater than for concentrations of 0.1% and 0.3%. Although the slope of curve in control sample was less than that of frozen yoghurt containing arabic gum, shear thinning behaviour could be seen. Table 2 shows the results of fitting of data with rheological models. Our results showed Power law model satisfactorily fitted the experimental data for each sample with a good correlation coefficient when compared to other models. Minhas *et al.* (2002) studied the flow behaviour of ice cream mixes containing various stabilisers and reported that ice cream mixes having arabic gum exhibited shear-thinning behaviour.

Overrun

The overrun value of frozen yoghurt in this study ranged from 22.37% to 39.38%. The low overrun may be due to using a batch-type household ice cream maker. Akalin *et al.* (2008) and Issariyachaikul (2008) also reported low overrun values when using batch freezers. In the current study, the addition of gums had a significant effect on the overrun of frozen yoghurt samples ($P < 0.05$) (Table 1). Moreover, increasing concentrations of different gums improved the overrun of samples. Frozen yoghurts containing 0.5% arabic gum and 0.3% guar gum had higher overrun values than other samples. The lowest value for overrun belonged to the control frozen yoghurt. The difference between overrun for guar gum at concentrations of 0.1% and 0.2% was not significant. Protein, fat and hydrocolloids are important for air incorporation (Marshall *et al.* 2003). Frozen yoghurt with high concentration of hydrocolloids and therefore

Table 2 Values of power law, Herschel–Bulkley and Casson model parameter for frozen yoghurt containing guar and arabic gum

		Models									
		Power law			*Herschel–Bulkley*				*Casson*		
Treatment	*Concentration of gum (%)*	*n*	*k*	R^2	*n*	*k*	τ_0	R^2	K_c^2	τ_{0c}	R^2
Control	0	0.51	6.51	0.998	0.83	1.49	12.04	0.992	0.36	7.77	0.995
Guar	0.1	0.4	15.45	0.996	0.76	3.18	19.56	0.98	0.48	16.05	0.993
	0.2	0.31	20	0.997	0.74	3.04	21.5	0.956	0.34	19.72	0.988
	0.3	0.36	20.92	0.992	0.79	3.53	22.38	0.96	0.58	19.04	0.995
Arabic	0.1	0.44	9.14	0.997	0.72	2.53	12.51	0.997	0.36	10.25	0.997
	0.3	0.43	11.75	0.997	0.88	1.58	14.6	0.994	0.43	12.67	0.997
	0.5	0.35	22.36	0.995	0.79	3.82	24.14	0.968	0.61	20.53	0.992

n, flow behaviour index (dimensionless); *k*, consistency coefficient ($Pa.s^n$); R^2, correlation coefficient; τ_0, yield stress (Pa); τ_{0c}, Casson yield stress (Pa); K_c^2, Casson viscosity (Pa.s).

high viscosity could trap air cells better than low-viscosity mixes that could not trap enough air. Soukoulis *et al.* (2008) and Soukoulis and Tzia (2008) also reported that increasing levels of guar gum increased the overrun of vanilla ice cream and frozen yoghurt.

Melting properties

Meltdown of ice cream involves both heat and mass transfer. Heat gradually penetrates from the exterior to the interior of ice cream owing to the melting of ice crystals. The water of melted ice crystals diffuses into a concentrated serum phase (Soukoulis *et al.* 2008). In this study, samples with high consistency coefficients had more resistance to flow and thus melted more slowly (Muse and Hartel 2004). The first dripping time of frozen yoghurt increased with the addition of both gums (Table 1). However, there was no significant difference between the dripping times of samples containing different levels of guar gum. While guar gum at a concentration of 0.1% showed no significant difference from the control sample, concentrations of 0.2% and 0.3% could slow the melting rate significantly ($P < 0.05$). Levels of arabic gum had a significant effect on first dripping time. The longest time was obtained for the sample containing 0.5% arabic gum ($P < 0.05$). Arabic gum also decreased the rate of melting compared with the control sample, but there was no considerable difference between the three concentrations of this gum. Stabilisers can form sticky network in yog-ice cream that results in more resistance to melting (El-Nagar *et al.* 2002). Furthermore, it has been previously showed that ice creams with higher overrun melt more slowly (Sofjan and Hartel 2004). Our results confirmed the same for frozen yoghurt. Increase in the time of melting might be attributed to the lower heat transfer rate of air trapped in the mixture (Moeenfard and Mazaheri Tehrani 2008). Sofjan and Hartel (2004) also found that air acted as a good insulator, slowing the rate of heat transfer in ice cream and thus decreasing melting rate.

Sensory properties

Figures 5 and 6 show the mean scores for the samples' colour, texture and flavour. Result showed that the addition of arabic gum and guar gum had no significant effect on the colour of frozen yoghurt samples. Guar gum and arabic gum had significant effect on flavour, texture and total acceptability. Addition of gums decreased the formation of ice crystals, improving texture. Similar results have been reported by Moeenfard and Mazaheri Tehrani (2008) who found that increases in concentration of stabilisers result in increase in score of texture. El-Sayed *et al.* (2002) reported that the addition of xanthan gum had no adverse effect on flavour of yoghurt, whereas it did affect texture and body.

CONCLUSION

This study investigated the effects of guar gum and arabic gum on physical and flow behaviour characteristics of frozen yoghurt.

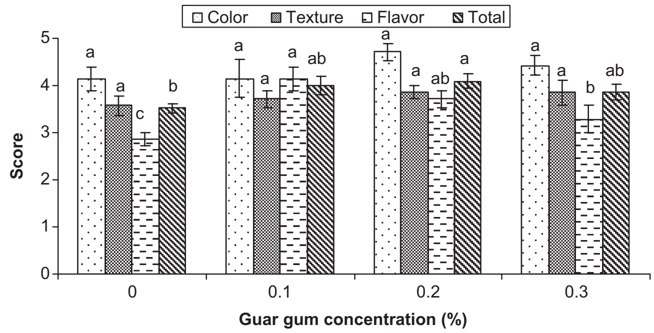

Figure 5 Effect of guar gum on sensory properties of frozen yoghurt.

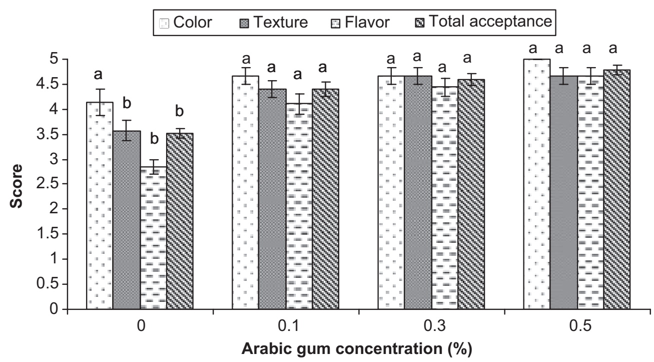

Figure 6 Effect of arabic gum on sensory properties of frozen yoghurt.

The results showed that both gums had significant effects on the properties of frozen yoghurt. Increasing the concentration of gums led to greater overrun, viscosity and melting resistance. The greatest improvements in these physicochemical properties were obtained in frozen yoghurt containing 0.3% guar gum and 0.5% arabic gum. Results for flow behaviour showed that the flow behaviour index of all samples was below one, in other words, that they were non-Newtonian. We observed shear-thinning behaviour in all frozen yoghurt, and the addition of gums enhanced this property. The power law was the best model to predict the flow behaviour of frozen yoghurt samples containing gums. Guar gum at a concentration of 0.2% and arabic gum at a concentration of 0.5% resulted in the most favourable sensory evaluations. In conclusion, frozen yoghurt with arabic gum could be recommended for better physicochemical and sensory properties as well as its lower cost.

REFERENCES

Akalin A S and Erisir D (2008) Effect of inulin and oligofructose on the rheological characteristics and probiotic culture survival in low fat probiotic ice cream. *Journal of food science* **73** 184–188.

Akalin A S, Karagozlu C and Unal G (2008) Rheological properties of reduced-fat and low-fat ice cream containing whey protein isolate and inulin. *European Food Research Technology* **227** 889–895.

Arslan E, Yener M E and Esin A (2005) Rheological characterization of tahin/pekmez (sesame paste/concentrated grape juice) blends. *Journal of Food Engineering* **69** 167–172.

Bourne M C (1982) *Food Texture and Viscosity*. New York: Academic Press.

Casson N (1959) A flow equation for pigment-oil suspensions of the printing oil type. In *Rheology of Dispersed Systems*, pp 82–104. Mill C C, ed. New York: Pergamon Press.

El-Nagar G, Clowes G, Tudorica C M, Kuri V and Brennan C S (2002) Rheological quality and stability of yog-ice cream with added inulin. *International Journal of Dairy Technology* **55** 89–93.

El-Sayed E M, Abd El-Gawad I A, Murad H A and Salah S H (2002) Utilization of laboratory-produced xanthan gum in the manufacture of yoghurt and soy yoghurt. *European Food Research and Technology* **215** 298–304.

Guda E, Attia I A, Salem S A and Kamar M S (1993) Studies on frozen yoghurt: manufacturing method. *Egyptian Journal of Food Science* **21** 57–66.

Issariyachaikul K (2008) Development of modified fat ice cream products using inulin as a fat replacer. Mahidol, p. 87.

Marshall R T, Goff H D and Hartel R W (2003) *Ice Cream*. New York: Aspen Publishers.

Minhas K S, Sidhu J S, Mudahar G S and Singh A K (2002) Flow behavior characteristics of ice cream mix made with buffalo milk and various stabilizers. *Plant Foods for Human Nutrition* **57** 25–40.

Mitschka P (1982) Simple conversion of Brookfield R.V.T. readings into viscosity functions. *Rheologica Acta* **21** 207–209.

Moeenfard M and Mazaheri Tehrani M (2008) Effect of some stabilizers on the physicochemical and sensory properties of ice cream type frozen yoghurt. *American-Eurasian Journal of Agriculture & Environment Science* **4** 584–589.

Muse M R and Hartel R W (2004) Ice cream structural elements that affect melting rate and hardness. *Journal of Dairy Science* **87** 1–10.

Sanchez C, Renard D, Robert P, Schmiitt C and Lefebvre J (2002) Structure and rheological properties of acacia gum dispersions. *Food Hydrocolloids* **16** 257–267.

Santipanichwong R and Suphantharika M (2009) Influence of different b-glucans on the physical and rheological properties of egg yolk stabilized oil-in-water emulsions. *Food Hydrocolloids* **23** 1279–1287.

Slavin J L and Greenberg N A (2003) Partially hydrolyzed guar gum: clinical nutrition uses. *Nutrition* **19** 549–552.

Sofjan R P and Hartel R W (2004) Effects of overrun on structural and physical characteristics of ice cream. *International Dairy Journal* **14** 255–262.

Soukoulis C and Tzia C (2008) Impact of the acidification process, hydrocolloids and protein fortifiers on the physical and sensory properties of frozen yoghurt. *International Journal of Dairy Technology* **61** 170–177.

Soukoulis C, Chandrinos I and Tzia C (2008) Study of the functionality of selected hydrocolloids and their blends with [kappa]-carrageenan on storage quality of vanilla ice cream. *LWT-Food Science and Technology* **41** 1816–1827.

Tarkashvand Y (2005) *Ice Cream*. First print. Tehran: Ata publisher (in Persian).