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ORIGINAL PAPER

Rheological, physical and sensory characteristics of light ice cream as affected by selected fat replacers

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Abstract

In this study, some rheological, physical and sensory properties of light (5% fat) ice cream in comparison with the control sample (10% fat) were investigated as functions of fat replacer type [guar gum (GG), basil seed gum (BSG) and their mixture (MGB, 50:50)] and concentration (0.35, 0.45, 0.50 and 0.55%). All samples exhibited shear-thinning and thixotropic behaviors. The fat reduction resulted in higher melting rate and lower breakdown coefficient, but a contrary trend was observed by increasing fat replacer concentration. Generally, BSG and MGB represented a more shear-sensitive thixotropic nature and melting resistance than GG samples. Regarding the first dripping time, GG light ice creams started dripping first, followed by MGB, then BSG light samples at the same gum concentration. The existence of synergistic relationship for consistency coefficient and plastic viscosity of light mixes was explored by MGB. A synergistic effect was observed for all rheological properties of MGB control sample, with exception of pseudoplasticity. At lower gum concentrations, there were not any significant differences found between the creaminess of samples at the same concentrations, but at 0.55% gum, BSG sample showed the highest value for this property. BSG was found to decrease coarseness, coldness, and meltdown of light ice creams more effectively than GG. Principal components analysis (PCA) revealed that the sensory properties had an inter-dependent with each other. Moreover, PCA scores divided the samples into three groups: full fat ice creams, light samples with 0.35 and 0.45% BSG and MGB, and light ice creams with 0.5 and 0.55% BSG and MGB.

Keywords Hydrocolloid · Fat replacer · Ice cream · Principal component analysis · Rheology · Texture

Introduction

Nowadays, health-conscious consumers are concerned reduced fat products to prevent fat related diseases. Therefore, finding a trustworthy fat substitute is one of the most challenging issues that food industry has encountered so far. Ice cream is a complex colloidal system containing fat globules, air bubbles and ice crystals dispersed in a highly viscous aqueous phase [1]. "Regular" ice cream usually has a fat content of 10% while "reduced fat" and "light" ice creams contain at least 25 and 50% less total fat than regular ice cream, respectively [2]. Fat as a main component plays important roles in ice cream. Discrete and partially coalesced fat globules present in the matrix, coat some parts of the air bubble surfaces as a binding agent and support the cells lined mainly by proteins. Moreover, interactions between milk fat and other ingredients in ice cream lead to an improvement in the texture, mouth feel, creaminess, flavor and overall sensations of lubricity [3]. For mentioned reasons, to overcome the upcoming problems due to fat reduction, ice cream manufacturers are probing for suitable fat replacers. In this regard, the largest numbers of fat replacers are hydrocolloids in which their functionalities allow them to mimic the properties of fat in food products [4, 5].

Hydrocolloids are capable of interacting with water, develop the texture/viscosity of frozen desserts and increase the stability during storage by maintaining thickness and cryoprotection [1]. Guar gum derived from *Cyamopsis tetragonoloba* seeds, with a mannose:galactose ratio of 1.6:1, was used as a single or combined thickener and stabilizer in ice cream and affected the physical, rheological and organoleptic properties by binding free water [1, 6, 7]. Basil is a pharmaceutical herb of the *Lamiaceae* (*Ocimum basilicum* L.) family and has been widely cultivated in Iran

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as well as Asia, Africa and Central and South America. A viscous and slimy mass can be obtained by soaking the basil seeds in water [8]. From the chemical point of view, basil seed gum (BSG) mainly consists of glucomannan (43%) and (1-4)-linked xylan (24.29%). Due to the relatively high percentage of uronic acids (12.1–19.5%) in *O. basilicum* species, the gum extract shows typical polyelectrolyte behavior [9]. The fat mimetic potential of BSG was found comparable with some commercial hydrocolloids [4, 8, 10]. Several studies on functional properties of BSG in regular ice cream indicated that this gum had satisfactory impacts on apparent viscosity, draw temperature, meltdown behavior, ice crystal growth, colloidal structure and total acceptance [11, 12].

The literature shows that the influence of hydrocolloid-based fat replacers on the rheological properties [13–15], textural and physical characteristics [14–16], and sensory attributes [1, 14, 17, 18] of reduced-fat ice creams (fat content < 10%) have been assessed. However, there is no evidence regarding the utilization of BSG as a fat replacer in light ice cream (fat content < 5%) so far. Therefore, the main objectives of present study were: (i) to investigate the impact of different concentrations of basil seed gum (as a novel hydrocolloid) and guar gum (as a commercial hydrocolloid) and the 50:50 blend of them on the rheological, textural, physical and sensory properties of vanilla light ice creams (5% fat), (ii) to compare these properties with regular ice cream (10% fat) as a blank and (iii) to describe the relationships between samples and their attributes using principal component analysis (PCA).

Materials and methods

Sample preparation

The ice cream mixes had the following formulations: 5% (light) or 10% (control) milk fat (provided as homogenized/pasteurized cream—25% fat by Pegah Dairy industry Com., Mashhad, Iran), 11% milk solids non-fat (skim milk powder, Zarrin Shad Food Industries Com., Esfahan, Iran); 15% sugar and 0.1% vanilla (purchased from local markets), 0.15% emulsifier (E471 mono and diglyceride, Beldem Food Industries Com., Dilbeek, Belgium) and 0.35, 0.45, 0.50, and 0.55% selected gums (guar gum (Rhodia Com, Germany), and basil seed gum (obtained at the optimized conditions [10]) or their mixture (MGB) in the ratio of 50:50). The dry ingredients (the selected fat replacers and sugar) were dispersed into the liquid materials (milk and cream) at 50 °C and agitated using a lab mixer (Model SM-65, Sunny, Germany). The ice cream mixes were pasteurized at 80 °C for 25 s (HTST), homogenized at 23,000 rpm for 2 min (Ultra Turrax T25D IKA, Germany). The pasteurized mixes were cooled and then aged at 5 °C for 12 h. After that, the mixes were gently blended with vanilla extract and frozen for 30 ± 5 min using a batch ice cream maker (Model IC 100, Feller Technologic GmbH, Dusseldorf, Germany). Then, samples were packaged into plastic containers, hardened and stored in a chest freezer (− 18 °C) for about 24 h.

Rheological measurements

The steady shear flow behavior of mixes was measured at an equilibrium temperature of 5 ± 0.5 °C using a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) coupled with a heating circulator (Model F12-MC, Julabo Labortechnik, Seelbach, Germany). Appropriate measuring spindle (C25 cup/bob geometry) was used.

Time-dependent properties

The ice cream mixes were subjected to a constant shear rate (150 s^{-1}) and the evolution of shear stress (τ, Pa) as a function of shearing time (t, min) was recorded until an equilibrium state was achieved. The time dependency of mixes was investigated by fitting the experimental data with two time-dependent rheological models as follows [5]:

Weltman model:

$$\tau = A + B \ln t \tag{1}$$

where A (Pa) and B (Pa) are the initial shear stress and the extent of thixotropy, respectively.

First order stress decay model, with a non-zero equilibrium stress value:

$$\tau - \tau_e = \left(\tau_0 - \tau_e\right)e^{-kt} \tag{2}$$

where τ_0 (Pa) and τ_e (Pa) are the initial and the equilibrium shear stress, respectively and k (s^{-1}) is the breakdown rate constant.

Time-independent properties

To eliminate the time dependency, samples were sheared at 150 s^{-1} for 2400 s prior to measurement. Afterwards, the time-independent rheological behavior was evaluated by recording the shear stress values when shearing the samples performed at the logarithmically increasing trend from 14.4 to 600 s^{-1} during 17.5 min. The viscous flow behavior data was described by the following models, Power law (3) and Casson (4):

$$\tau = k(\dot{\gamma})^n \tag{3}$$

where τ is the shear stress (Pa), k is the consistency coefficient (Pa s^n), $\dot{\gamma}$ is the shear rate (s^{-1}) and n is the flow behavior index (dimensionless).

$$\sqrt{\tau} = k_{0c} + k_c\sqrt{\dot{\gamma}} \tag{4}$$

where k_{0c} ($Pa^{0.5}$) and k_c ($Pa^{0.5}$ $s^{0.5}$) are the intercept and slop of $(\tau)^{0.5}$ versus $(\dot{\gamma})^{0.5}$, respectively. Therefore, the magnitudes of k_{oc}^2 and k_c^2 have been utilized as the Casson yield stress (τ_{0c}, Pa) and Casson plastic viscosity (μ_c, Pa s), respectively.

Instrumental textural analysis

Instrumental textural characteristics were assessed for ice cream samples stored at − 18 °C for 24 h. Penetration test was performed at room temperature using a texture analyzer (model QTS 25 kg, CNS Farnell, Hertfordshire, UK) equipped with a 6-mm diameter stainless steel cylindrical probe, based on the modified method suggested by BahramParvar et al. [19]. The penetration depth (deformation as a target value) was 15 mm and the test speed set at 2 mm/s. Hardness (the peak compression force (N) during the penetration of the sample) and adhesiveness (the negative surface area (N s) during withdrawing the probe from the sample) were obtained.

Melting rate determination

Ice cream samples (30 g) were placed on a wire mesh (2 mm × 2 mm) and exposed to 25 °C. The melted material dripping through the screen was weighed every minute for a period of 60 min using an electronic digital balance (± 0.01 g, Lutron Measurement System, Lutron GM 1500P, Taiwan). Melting rate (g/min) was determined from the linear portion of plots of the drained mass as a function of time [7].

Overrun measurement

The same volume of ice cream mix and ice cream samples were weighted and the overrun was calculated as follows [20]:

$$\text{Overrun}\,(\%) = [(\text{weight of mix} - \text{weight of ice cream})/(\text{weight of ice cream})] \times 100.$$

Sensory evaluation

The sensory properties (*vanilla flavor*: the intensity of vanilla flavor as it is released during consumption, *milky*: the intensity of a flavor similar to that of fresh dairy milk, *coldness*: a chilling of the tongue and palate soon after the sample is placed in mouth, *hardness*: resistance against scooping a portion of ice cream, *coarseness*: a rough sensation in mouth due to presence of detectable ice crystals which disappears as the ice crystals melt, *creaminess*: combination of a smooth texture, fat-like feeling, uniform melting to thick and homogenous fluid as ice cream melts in mouth, and *meltdown*: the time required for ice cream to turn into liquid) of the ice cream samples were determined using the quantitative descriptive analysis (QDA) method as described by Stone et al. [21]. Through discussion and consensus in three 2 h training sessions, seven panelists (four female and three male of age between 23 and 30 year) described sensory attributes. Each sample (30 g) was scooped into lidded plastic containers, coded using a three-digit random number and kept in a refrigerator at − 18 °C prior to testing. Rating of ice creams was carried out using a 10-cm line scale anchored at its end points with the phrases "lowest" and "highest".

Statistical analysis

The experimental design was a completely randomized design. Statistical analysis of the data was performed with the MSTATC statistical software (version 1.42, MSTATC director, Michigan State University, USA). Except for full-fat samples, data were analyzed with two-way ANOVA, in order to understand the effects of both gum type and concentration on the properties of light ice cream. Duncan's multiple range test was used to assess the statistical difference between means at the significance level of 0.05. The large letters indicate the difference between means of all light samples properties analyzed by two-way ANOVA, while the small letters were related to the comparison between means of light ice creams characteristics containing each gum with those of corresponding controls. Principal component analysis (PCA) was performed using the XLSTAT package (version 2014.1.09, UK) to find the correlation between instrumental and sensory properties. Curves were drawn by Microsoft Excel spreadsheet (version 2003, Microsoft Office, USA). Rheological parameters of fitted models and coefficients of determination were obtained by statistical model fitting software program namely Slide Write version 7.0. The determination coefficient (R^2) and root mean square error (RMSE) indices were used to evaluate the goodness of fit of the rheological models.

Results and discussion

Steady shear rheological properties

Time-dependent properties

Time-dependent rheological properties of food systems are used to determine the relationship between structure and flow, and the correlation of physical properties with sensory characteristics [14]. In this study, mixes were subjected to a long shearing period (at 150 s^{-1}) to destroy the structure of material completely at which the flow behavior is no longer dependent on shearing time. All examined formulations showed thixotropic behavior, meaning that the apparent viscosity decreased with shearing time as a result of structural changes [22]. Usually, colloidal suspensions or concentrated solutions including substances of high molecular weight are thixotropic systems [22]. As the fat content of ice cream mix was reduced to half, the extent of thixotropy (*B*) decreased for mixes containing GG ($P > 0.05$) from 1.13 to 0.64 Pa, BSG ($P < 0.05$) from 4.76 to 2.96 Pa and MGB ($P < 0.05$) from 3.17 to 0.88 Pa (Table 1), whereas it was increased by an increase in the concentration of selected fat replacers. One possible explanation regarding this phenomenon is related to the milk proteins–gums interactions, affecting the structure–property relationships. Tárrega et al. [23] studied the time-dependent flow properties of aqueous and milk dispersions of different cross-linking modified starches. They found that the maize starch samples (6%) showed anti-thixotropy in water while the same samples exhibited thixotropy in milk dispersions. In the other words, water substitution with milk in starch dispersions led to an increase in the extent of thixotropy that was in agreement with our results. Under the same gum concentration, light ice cream mixes containing BSG significantly ($P < 0.05$) exhibited a more shear-sensitive thixotropic nature than mixes with GG and MGB. The reason behind mentioned observation may be owing to the higher static yield stress of BSG than GG as reported by Hosseini-Parvar et al. [8], connected to the multi-fractional structure of BSG. Similar findings have recently been reported by Javidi et al. [14] who investigated the time dependency of low-fat (2.5%) ice cream mixes using second-order structural kinetic model. According to results of Koocheki and Razavi [24], increasing gum concentration also resulted in thixotropy enhancement, but there was no specific trend in the *K* value (Table 1) as stated by Razavi et al. [5]. The initial shear stress values (*A* and τ_0) varied in the range of 33.89–104.03 and 28.66–79.66 Pa, respectively for the Weltman and first-order stress decay with a non-zero equilibrium stress models. While the equilibrium shear stress (τ_{eq}) magnitude ranged between 18.63 and 67–96 Pa. These parameters decreased significantly ($P < 0.05$) by reducing the fat content and increased with increasing gum concentration. Research carried out by Razavi et al. [5] showed that an increase in the concentration of fat replacers led to the higher initial shear stress of low-fat sesame paste. Regarding the type of fat replacer used in our work, a significant difference was observed in the initial shear stress values of all systems containing 0.55% gum ($P < 0.05$).

Time-independent properties

The parameters obtained by fitting the experimental data to the time-independent models are available in Table 1. According to the previous studies [13, 15, 16, 25], the values of the flow behavior index (*n*) of all samples were in the range of 0.419–0.618, indicating their pseudoplastic nature. Food systems with a slight deviation from Newtonian behavior tend to a slimy feeling in the mouth, while shear thinning behavior results in easier pumping and desirable texture and mouth feel. We observed that fat reduction had no significant effect on the *n* values, whereas both adding fat replacers and increasing their concentration enhanced the pseudoplasticity of mixes, related to the ability of hydrocolloids to form the compact entanglements sensitive to shear rate [7]. Consistency coefficient (*K*) is considered as an indicator of the viscous nature of food systems. As shown in Table 1, the values of consistency coefficient ranged from 0.85 to 5.44 Pa s^n, was the highest for mixes containing GG, intermediate for MGB and the lowest for BSG. As expected, the fat reduction led to decrease in the *K* value of samples, which was significant for mixes with GG and BSG ($P < 0.05$). Kaya and Tekin [25] investigated the flow behavior of water–salep–sugar compared with milk–salep–sugar as a representative ice cream. At the same salep concentration, they observed higher *K* values in milk–salep–sugar than in water–salep–sugar, due to higher solid content in the former system. This observation demonstrates the impact of milk fat and proteins on the structure and consistency of systems. However, *k* values of examined light samples increased as gum added [14]. The same influence of gum concentration or fat content on the *K* value was also detected by others [1, 4].

The yield point is defined as the stress at which a material begins to cause flow. This parameter, as a quality control tool, is correlated well with texture, body, and scoopability of the ice cream [26]. BSG has been recognized as a functional ingredient having high yield stress and therefore is able to stabilize the food suspensions such as salad dressings and mayonnaise [8]. In this research, the magnitude of the Casson yield stress was decreased by reducing the fat content at a fixed gum level, while higher yield stress values were observed by increasing the fat replacer concentration as a result of the increased intermolecular associations, which is in agreement with other previously published works [4, 7, 23]. In a study, the rheological properties of model systems mimicking ice cream [sucrose solutions without or with milk solids-not-fat (MSNF) and/or, galactomannan] was investigated by Patmore et al. [6]. They observed that the yield stress values of galactomannan/sucrose solutions synergistically increased as a result of adding MSNF. It seems that incompatibly of galactomannans and milk proteins resulted in slightly structured systems.

Concerning the Casson plastic viscosity value, a similar trend was observed by reducing the fat content, adding the selected fat replacers and increasing their concentrations. There was no significant difference between the μ_c values of 0.50B and 0.55B with that of a corresponding control

Table 1 Time-dependent and time-independent rheological properties of full fat and light ice cream mixes

Sample codes	Time-dependent models									Time-independent models							
	Weltman				Stress decay					Power law				Casson			
	A (Pa)	B (Pa)	R^2	RMSE	τ_0 (Pa)	τ_{eq} (Pa)	k (s^{-1})	R^2	RMSE	K (Pa s^n)	n (-)	R^2	RMSE	τ_{0C} (Pa)	μ_C (Pa s)	R^2	RMSE
CG[1]	64.40^{bc}	1.13^{bc}	0.96	0.16	60.51^{bc}	56.64^{b}	0.00406	0.99	0.03	3.27^{c}	0.554^{a}	0.99	1.41	9.90^{c}	0.317^{a}	0.99	2.02
0.35G[2]	39.54^{Fd}	0.64^{Fc}	0.93	0.05	37.94^{Fd}	35.33^{DEc}	0.00597	0.99	0.03	2.09^{FGd}	0.537^{Ca}	0.99	0.49	6.21^{EFd}	0.235^{BCd}	0.99	1.50
0.45G	54.56^{DEc}	1.11^{EFbc}	0.97	0.10	50.88^{DEc}	46.92^{Cb}	0.00384	0.99	0.05	4.63^{BCb}	0.462^{Eb}	0.99	0.40	12.50^{BCbc}	0.251^{ABCc}	0.98	2.18
0.50G	70.99^{Cb}	2.08^{DEab}	0.91	0.39	66.22^{Bb}	56.72^{Bb}	0.00530	0.99	0.14	5.44^{Bb}	0.449^{Eb}	0.99	0.61	14.44^{Bb}	0.257^{ABbc}	0.99	2.23
0.55G	88.04^{Ba}	3.03^{CDa}	0.94	2.02	79.66^{Aa}	67.96^{Aa}	0.00512	0.99	0.70	5.44^{Ab}	0.419^{Fc}	0.99	0.67	19.79^{Aa}	0.268^{Ab}	0.98	2.82
CB[1]	74.08^{b}	4.76^{b}	0.98	0.33	54.06^{b}	36.12^{c}	0.00141	0.99	0.90	1.64^{b}	0.613^{a}	0.99	0.67	5.15^{b}	0.287^{a}	0.99	1.31
0.35B[2]	42.54^{EFc}	2.96^{CDc}	0.99	0.18	28.66^{Gc}	18.63^{Fb}	0.00113	0.99	0.14	0.85^{Hc}	0.618^{Aa}	0.99	0.56	2.71^{Gc}	0.211^{Dc}	0.99	0.43
0.45B	71.16^{Cb}	5.05^{Bb}	0.99	0.68	46.53^{Eb}	29.35^{Ea}	0.00086	0.99	0.25	1.49^{GHbc}	0.574^{Bb}	0.99	0.67	4.60^{FGbc}	0.232^{CDbc}	0.99	0.86
0.50B	99.27^{ABa}	7.05^{Aa}	0.99	1.46	64.76^{BCa}	39.73^{CDa}	0.00079	0.99	0.59	2.76^{EFa}	0.521^{Cc}	0.99	0.64	8.04^{DEa}	0.253^{ABCab}	0.98	2.19
0.55B	104.03^{Aa}	7.58^{Aa}	0.99	1.01	69.59^{Ba}	41.48^{CDa}	0.00101	0.98	0.49	3.02^{EFa}	0.520^{Cc}	0.99	0.98	8.87^{Da}	0.266^{Aab}	0.99	1.88
CM[1]	76.92^{a}	3.17^{bc}	0.97	0.44	63.70^{a}	52.02^{a}	0.00160	0.99	0.33	2.76^{cd}	0.604^{a}	0.99	0.58	8.60^{b}	0.359^{a}	0.99	2.46
0.35M[2]	33.98^{Fb}	0.88^{Fd}	0.98	0.05	30.46^{FGc}	27.64^{Eb}	0.00239	0.99	0.02	1.56^{GHd}	0.585^{Ba}	0.99	0.71	4.89^{FGc}	0.250^{ABCb}	0.99	0.81
0.45M	66.27^{CDa}	2.38^{Dc}	0.99	0.30	55.02^{Db}	41.91^{CDa}	0.00090	0.95	0.42	3.19^{DEbc}	0.523^{Cb}	0.99	0.54	8.07^{DEbc}	0.255^{ABCb}	0.99	1.56
0.50M	72.84^{Ca}	3.90^{BCb}	0.98	0.75	55.98^{Db}	42.88^{CDa}	0.00074	0.99	0.43	4.09^{CDab}	0.497^{Dbc}	0.99	0.59	11.30^{Cab}	0.271^{Ab}	0.99	2.03
0.55M	75.25^{Ca}	4.97^{Bb}	0.91	0.64	57.28^{CDab}	44.36^{CDa}	0.00061	0.92	0.79	4.46^{Ca}	0.484^{Dc}	0.99	0.97	12.51^{BCa}	0.273^{Ab}	0.99	1.79

[1]CG, CB, and CM are full fat ice cream mixes (controls) containing 0.35% guar gum, basil seed gum and a mixture of them (50:50), respectively

[2]G, B, and M are light ice cream mixes containing different levels of guar gum, basil seed gum and mixture of them (50:50), respectively

[a–d, A–H]Means of two replicates in the same row with same superscripts do not differ significantly ($P > 0.05$)

sample, indicating the ability of BSG to mimic the plastic viscosity of full-fat ice cream in light samples. Emadzadeh et al. [4] also explained that increasing the xanthan concentration was accompanied by an increase in Bingham plastic viscosity of low-calorie pistachio butter.

At the same concentration of gum, except 0.35M, there were significant differences between consistency coefficient and yield stress values of light mixes containing different types of fat replacers ($P < 0.05$). The highest and lowest values of these rheological properties were observed in light samples with GG and BSG, respectively. However, the consistency coefficient of mixes containing BSG and MGB enhanced more than that of GG samples with increasing gum concentration. This observation may be connected to stronger anionic nature of BSG in comparison to GG that results in more expansion of BSG molecular chains and higher consistency coefficient.

Rheological interaction between guar gum and basil seed gum

Synergistic interactions between hydrocolloids maybe lead to food quality improving and particular food applications extending due to enhanced functional properties. It could also have a commercial potential for cost reduction. The synergy comes from the association or non-association of different hydrocolloid molecules, influenced by several factors such as the source of hydrocolloids, their ratio and total polymer concentration in the system [27, 28]. In this research, the positive or negative interactions were observed between the rheological parameters of selected gums mixture (50:50). Under the same gum concentration and fat content, the expected value ($EV_{mixture}$) of any characteristic was calculated by the following equation:

$$EV_{mixture} = \left(V_G + V_B\right)/2 \tag{6}$$

where V_G and V_B are the value of rheological parameter determined for samples containing GG and BSG, respectively. As shown in Table 2, the difference between this magnitude and the observed value of each rheological parameter of selected gums mixture was calculated as positive or negative interaction:

$$Interaction\,(\%) = \frac{Observed\ value - Expected\ value}{Expected\ value} \times 100 \tag{7}$$

In general, the positive interaction of Casson yield stress, as well as Casson plastic viscosity, were found for ice cream mixes. The breakdown coefficient values of all formulations, with the exception of the full fat sample, were less than calculated magnitudes. The mixed gums generally led to a reduction in the initial stress values of the time-dependent models. But, a progressive trend was observed in the equilibrium stress value of samples containing 0.35 and 0.45% selected gums. In addition, the samples containing a mixture of selected fat replacers were less pseudoplastic than either of formulations with GG and BSG. The increase in *k* values were 4.16–16.10%, however, the consistency coefficient of 0.5M was slightly lower than the expected magnitude. The rheological properties of different ratios of GG, CMC, and BSG at two concentrations (0.15 and 0.35%) were investigated by BahramParvar and Razavi [29]. They reported that viscosity increased by 67, 38 and 21% in blends including 0.15% GG–CMC mixture in the ratio of 50:50, 0.35% GG–CMC mixture in the ratio of 50:50 and sample containing a blend of 66.67% GG–16.67% CMC–16.67% BSG at a concentration of 0.35% gum, respectively. But there was a viscosity reduction for some formulations containing a mixture of BSG and CMC.

Table 2 The positive or negative rheological interactions between guar and basil seed gums

Attribute	CM[1]	0.35M[2]	0.45M[2]	0.5M[2]	0.55M[2]
A (Pa)	+9.94	−17.20	+5.14	−14.43	−21.64
B (Pa)	+7.10	−51.11	−22.72	−14.57	−6.31
τ_0 (Pa)	+10.07	−8.53	+11.48	−14.52	−23.24
τ_{eq} (Pa)	+10.84	+2.39	+9.01	−11.08	−18.93
K (Pa s^n)	+10.9	+6.07	+4.16	−0.24	+16.10
n (-)	−3.48	−1.37	−0.96	−2.41	−3.10
τ_{0C} (Pa)	+12.55	+8.81	−5.60	+0.52	−12.71
μ_C (Pa s)	+15.88	+10.80	+5.29	+5.90	+2.20

[1]CM is full fat ice cream mix (control) containing 0.35% mixture of guar gum and basil seed gum

[2]M is light ice cream mixes containing different levels of the mixture of guar gum and basil seed gum (50:50)

Regarding the full fat sample, a synergistic relationship was found in all rheological properties apart from pseudoplasticity when GG was combined with BSG. Therefore, it can be deduced that fat content has an important role in synergistic interactions of GG and BSG.

Instrumental textural attributes

Hardness is measured as the resistance of ice cream to deformation when an external force is applied. Some factors such as ice crystal size, ice phase volume and the amount of air dispersed in ice cream matrix have an influence on the hardness of ice creams [16, 30], which may be altered due to change in type and amount of ingredients used in the formulation. From data in Table 3, it can be understood that ice cream hardness increased with a decrease in the fat content. The reason for this finding can be attributed to added ice phase volume as reported by others [17, 30]. Guinard et al. [31] indicated that the hardness in medium fat ice cream (14.99% fat and 43.95% total solids) was three times greater than that of the high fat

Table 3 Instrumental textural properties, melting characteristics and overrun of full fat and light ice creams

Sample codes	Instrumental textural attributes		Melting characteristics		Overrun (%)
	Hardness (N)	Adhesiveness (N s)	Melting rate (g/min)	First dripping time (min)	
CG[1]	1.3 ± 0.14^{d}	$0.7^{b} \pm 0.08^{b}$	0.83 ± 0.01^{bc}	19.5 ± 0.71^{ab}	29 ± 1.12^{d}
0.35G[2]	3.9 ± 0.50^{Gc}	0.9 ± 0.36^{Db}	1.00 ± 0.04^{Ba}	15.5 ± 2.12^{Ec}	40.1 ± 0.49^{Ba}
0.45G	4.6 ± 0.88^{Gc}	1.0 ± 0.26^{Db}	0.95 ± 0.02^{Cab}	17.0 ± 1.41^{DEbc}	36.4 ± 1.55^{CDb}
0.50G	7.2 ± 1.66^{DEFb}	1.7 ± 0.27^{CDb}	0.95 ± 0.01^{Cab}	19.0 ± 1.41^{CDEabc}	35.5 ± 0.07^{Db}
0.55G	18.7 ± 2.19^{Aa}	4.4 ± 1.37^{ABa}	0.89 ± 0.02^{Db}	21.5 ± 0.70^{CDa}	32.1 ± 0.25^{Ec}
CB[1]	$2.7^{c} \pm 0.23$	$1.3^{c} \pm 0.25$	0.41 ± 0.01^{b}	19.0 ± 0.00^{c}	13.9 ± 0.09^{c}
0.35B[2]	4.2 ± 0.69^{Gbc}	1.4 ± 0.12^{CDc}	0.55 ± 0.02^{Fa}	17.0 ± 1.41^{DEc}	31.1 ± 1.13^{Ea}
0.45B	5.4 ± 1.23^{FGb}	2.4 ± 0.36^{Cb}	0.34 ± 0.01^{Gb}	27.5 ± 2.12^{Bb}	27.8 ± 1.34^{Fa}
0.50B	12.9 ± 0.92^{Ca}	4.7 ± 0.47^{Aa}	0.10 ± 0.01^{Hc}	37.0 ± 4.24^{Aa}	23.2 ± 1.62^{Gb}
0.55B	14.6 ± 1.96^{BCa}	5.0 ± 1.01^{Aa}	0.06 ± 0.01^{Ic}	40.5 ± 3.53^{Aa}	23.7 ± 1.69^{Gb}
CM[1]	$5.0^{c} \pm 1.01$	$1.0^{c} \pm 0.16$	0.77 ± 0.02^{d}	17.0 ± 1.41^{b}	29.2 ± 0.85^{c}
0.35M[2]	5.7 ± 0.73^{EFGc}	1.3 ± 0.28^{CDc}	1.10 ± 0.01^{Aa}	15.5 ± 0.71^{Eb}	44.5 ± 0.99^{Aa}
0.45M	8.0 ± 1.19^{DEb}	1.5 ± 0.42^{CDbc}	0.98 ± 0.02^{Cb}	17.5 ± 0.71^{BCDb}	39.0 ± 0.99^{BCb}
0.50M	9.4 ± 0.46^{Db}	2.0 ± 0.24^{CDb}	0.88 ± 0.03^{Dc}	22.5 ± 3.53^{BCDa}	32.4 ± 3.00^{Ec}
0.55M	15.3 ± 2.08^{Ba}	3.5 ± 0.47^{Ba}	0.79 ± 0.01^{Ed}	24.5 ± 2.12^{BCa}	29.3 ± 0.64^{EFc}

[1]CG, CB, and CM are full fat ice cream mixes (controls) containing 0.35% guar gum, basil seed gum and a mixture of them (50:50), respectively

[2]G, B, and M are light ice cream mixes containing different levels of guar gum, basil seed gum and mixture of them (50:50), respectively

[a–d, A–I]Means of two replicates in the same row with same superscripts do not differ significantly ($P > 0.05$)

sample (19.30% fat and 53.16% total solid). In another study, the hardness of ice creams increased during storage time that the observation was related to ice recrystallization phenomena [1]. Muse and Hartel [30] stated that the rheological properties, especially viscosity are one of the most important parameters affecting the hardness, so that the lower the hardness, the softer the sample. This explanation may be the reason of why increasing the fat replacer concentration increased the hardness of light ice creams (Table 3).

Adhesiveness is defined as the work necessary to overcome the attractive forces between the surface of the food product and the surface of other materials with which it comes in contact. As seen in Table 3, the effect of fat content and gum concentration on the adhesiveness of samples was found parallel to the results of the hardness that may be due to change in ice phase volume, viscosity, and texture. The similar trend for these parameters was reported by other researchers [13, 16, 19].

On the other hand, hardness was generally more influenced by MGB in comparison with individual gums. The lowest hardness was observed in the formulations including GG, except for 0.55G which had the highest hardness value, while BSG samples showed the highest adhesiveness and those containing GG had the lowest values of this property. At 0.55% level of gum, there was no significant difference between adhesiveness of ice creams with GG and BSG ($P > 0.05$), but the addition of the gums mixture resulted in a significant reduction in adhesiveness ($P < 0.05$), that may be owing to the fact that hydrocolloids interaction could produce a new functionality.

Melting rate

It is found that a couple of factors can mainly impact on melting behavior of ice cream, including the mix ingredients, the consistency coefficient of the mix, the amount of dispersed air, the volume and structure of the ice crystals and the network of fat globules [13, 17, 30, 31]. The ice cream melting process is controlled by the heat and mass transfer phenomena [7], in which water has higher thermal conductivity than fat. As shown in Table 3, the first dripping time was decreased by reducing fat content that was significant for GG sample. The melting rate of ice creams contained 0.35% gum also accelerated with the decrease in fat content ($P < 0.05$). The observation was in accordance with Roland et al. [17], but Specter and Setser [32] observed no significant differences between the meltdown of reduced calorie and control frozen desserts. In another research, some physical properties of regular (10%), reduced fat (6%) and low fat (3%) ice creams containing 4% fat replacer [whey protein isolate (WPI) or inulin] were evaluated [13]. The authors found that, unlike WPI, reduced fat and low-fat samples with inulin melted faster than regular ice cream ($P < 0.05$). Adding GG, BSG and MGB reinforced the melting resistance and increased the first dripping time. The reason for this result may be connected to the complex network of polysaccharides and their water holding capacity, resulting in micro-viscosity enhancement and foam stabilization. In contrast of GG, increasing BSG and MGB levels generally had a significant impact on the melting rate of light ice creams, which is probably related to the fact that the effect of increasing BSG and MGB level on *k* values was more than that of GG, as mentioned earlier. Akalin et al. [13] also reported an inverse relationship between melting rate and consistency coefficient of reduced fat ice creams. In addition, the significant decreasing influence ($P < 0.05$) of κ-carrageenan on the first dripping time of the ice creams has been stated [7, 19].

The melting resistance of light ice creams containing BSG was significantly ($P < 0.05$) higher than samples including GG and MGB, at the same concentration of gum. There were no significant differences between first dripping times of two gum systems (GG and MGB) at the same concentrations ($P > 0.05$). But, at 0.50 and 0.55% gum, BSG samples showed the highest value of this melting characteristic ($P < 0.05$).

Overrun

A certain value of viscosity is needed to have a proper air content (overrun). If the liquid is viscous enough, it is efficiently able to entrap air bubbles, while in low viscosity ice cream mix, the air bubbles collapse rapidly [33]. In this study, the overrun values ranged between 13.9 and 44.5%, depending on the composition (Table 3). The fat reduction led to a significant increase in the overrun of ice creams with 0.35% of each gum. It has been demonstrated that the material surrounding air cells of ice cream is composed of fat globules and ice crystals. Thus, fat content was found to have an effect on air cells stability. In addition, hydrocolloids are able to reduce the kinetics of ice recrystallization phenomena due to water-holding and microviscosity enhancement, cryogel formation and phase separation of them. Such inhibitory effects of hydrocolloids on ice crystal growth as well as their ability to increase the viscosity of mixes have important influences on air incorporation in the foam systems. The overrun of MGB mixes was greater than other two gum systems at the concentrations of 0.35 and 0.45%. Also, there was no significant difference between 0.55M and 0.55G (Table 3), indicating a synergistic interaction between GG and BSG. As presented in Table 3, an increase in the hydrocolloid concentration generally caused a decrease in the overrun value. In this regard, it should be considered that the vigorous agitation of high viscose mix would be faced with difficulty and then air incorporation decreases [19]. All GG and BSG light ice creams and 0.35M and 0.45M had significantly higher air content than their counterpart control samples (Table 3).

Sensory attributes

Effect of fat content

Milk fat has been known as an important factor for perceived textural quality e.g. enhancement of creaminess, mouthcoating and flavor perception [1]. Vanilla is used as the primary flavor in ice creams varying in fat content. By reducing the fat content, vanilla flavor and milky attributes decreased (Table 4). Similar results have been reported by Roland et al. [1, 17]. Fat has the apolar substrate that enables it to dissolve the lipophilic flavor components e.g. vanillin and control the flavor release. As seen in Table 4, fat reduction increased coldness ($P < 0.05$), hardness ($P > 0.05$), coarseness ($P < 0.05$) and meltdown ($P < 0.05$). During the melting of ice cream in the mouth, larger ice crystals are momentarily left behind and afterward the cold sensation would be felt. As the fat level in ice cream decreases, the water content increases such that more water is available to form more volume and larger crystals of ice phase. The contribution of fat to the structural characteristics of ice cream as well as its low heat conductivity can also explain the meltdown findings. In addition, the panelists perceived more creaminess in full fat ice cream compared to light samples with 0.35% gum. Creaminess, as a highly complex perception, encompasses both creamy flavor and creamy texture sensation [33]. It was reported that adding dairy flavors to milk model systems enhanced creaminess perception [34]. Soukoulis et al. [1] also found that increase of milk fat content was accompanied by a significant increase of creamy attribute and decrease of hardness and coarseness. But no significant differences were reported between creamy, smooth texture and melting rate attributes of reduced fat (6%) and full fat (9%) ice creams by Prindiville et al. [18].

Effect of fat replacer

As depicted in Table 4, the panelists did not perceive significant differences in both vanilla flavor and milky attributes among light ice creams ($P > 0.05$) as affected by selected fat replacer type and concentration. But, the coldness and coarseness attributes of light samples containing 0.35% gum were improved by the addition of GG, BSG, and MGB as a fat replacer. At 0.45 and 0.50% gum concentrations, coarseness was respectively lowest for ice cream with BSG and MGB. Also, the coldness of 0.55G was significantly higher than 0.55B and 0.55M. These results indicate that BSG and MGB are able to improve these sensory attributes of light ice creams. Adding fat replacers led to the reduction of meltdown, which BSG and MGB were more effective than GG. It seems that ice crystallization and melting phenomena could be

Table 4 Sensory characteristics of full fat and light ice creams

Sample code	Vanilla flavor	Milky	Coldness	Hardness	Coarseness	Creaminess	Meltdown
CG[1]	6.9 ± 0.4^{a}	7.8 ± 0.3^{a}	4.5 ± 0.8^{b}	4.0 ± 0.8^{c}	3.5 ± 0.5^{b}	4.8 ± 0.3^{bc}	4.3 ± 0.6^{b}
0.35G[2]	5.2 ± 0.7^{Aab}	5.7 ± 0.7^{Aab}	6.5 ± 0.5^{ABa}	5.1 ± 0.6^{BCbc}	5.1 ± 0.2^{Aa}	4.2 ± 0.7^{FGc}	6.5 ± 0.5^{Aa}
0.45G	5.1 ± 0.3^{Aab}	4.9 ± 0.8^{Ab}	5.5 ± 1.1^{BCDab}	3.9 ± 0.5^{Cc}	5.8 ± 0.3^{Aa}	5.6 ± 0.6^{DEb}	5.0 ± 0.4^{CDEb}
0.50G	4.8 ± 1.7^{Ab}	6.0 ± 0.5^{Aab}	4.2 ± 0.7^{DEFb}	6.0 ± 0.4^{Bb}	3.0 ± 0.5^{CDbc}	7.5 ± 0.5^{ABa}	5.0 ± 0.5^{CDEb}
0.55G	5.0 ± 0.7^{Aab}	5.4 ± 1.2^{Ab}	5.0 ± 0.5^{CDab}	7.3 ± 0.7^{Aa}	2.5 ± 0.7^{Dc}	7.3 ± 0.4^{ABCa}	4.9 ± 0.5^{CDEb}
CB[1]	6.5 ± 0.5^{a}	7.5 ± 0.2^{a}	4.5 ± 0.6^{b}	4.8 ± 0.7^{c}	2.7 ± 0.7^{c}	5.3 ± 0.4^{b}	3.7 ± 0.6^{c}
0.35B[2]	4.0 ± 1.0^{Ab}	6.3 ± 0.5^{Aab}	6.9 ± 0.3^{Aa}	5.0 ± 1.0^{BCc}	5.0 ± 0.4^{Aa}	3.5 ± 0.9^{Gc}	5.5 ± 0.5^{BCa}
0.45B	4.7 ± 0.8^{Ab}	5.3 ± 0.7^{Abc}	4.8 ± 0.3^{CDEb}	5.9 ± 0.4^{Bbc}	4.0 ± 0.2^{Bb}	5.3 ± 0.7^{DEb}	4.1 ± 0.3^{EFGbc}
0.50B	5.1 ± 0.9^{Aab}	4.4 ± 0.9^{Ac}	5.0 ± 0.4^{CDb}	7.0 ± 0.2^{Aab}	2.7 ± 0.7^{Dc}	6.3 ± 0.6^{CDb}	4.9 ± 0.2^{CDEab}
0.55B	4.0 ± 0.4^{Ab}	6.0 ± 0.9^{Ab}	3.2 ± 0.7^{Fc}	7.9 ± 0.3^{Aa}	3.0 ± 0.5^{CDbc}	8.2 ± 0.2^{Aa}	2.8 ± 0.2^{Hd}
CM[1]	6.5 ± 0.9^{a}	8.3 ± 1.1^{a}	4.1 ± 0.3^{b}	3.7 ± 0.8^{c}	3.9 ± 0.3^{b}	4.9 ± 0.7^{b}	4.0 ± 0.5^{b}
0.35M[2]	4.4 ± 0.8^{Ab}	5.3 ± 0.6^{Ab}	6.1 ± 0.3^{ABCa}	4.1 ± 0.3^{Cc}	5.8 ± 0.2^{Aa}	3.7 ± 0.5^{Gc}	6.0 ± 0.5^{ABa}
0.45M	3.7 ± 0.3^{Ab}	4.5 ± 0.6^{Ab}	5.0 ± 0.9^{CDab}	5.5 ± 1.0^{Bb}	4.0 ± 0.5^{Bb}	4.9 ± 0.6^{EFb}	5.2 ± 0.8^{BCDa}
0.50M	4.3 ± 0.8^{Ab}	5.4 ± 0.7^{Ab}	5.0 ± 1.1^{CDab}	7.1 ± 0.4^{Aa}	3.7 ± 0.7^{BCb}	5.0 ± 0.5^{EFb}	3.7 ± 0.3^{FGHb}
0.55M	4.5 ± 0.4^{Ab}	5.8 ± 0.8^{Ab}	3.6 ± 0.5^{EFb}	7.6 ± 0.6^{Aa}	2.7 ± 0.5^{Dc}	7.0 ± 0.6^{BCa}	3.5 ± 0.5^{GHb}

[1]CG, CB, and CM are full fat ice cream mixes (controls) containing 0.35% guar gum, basil seed gum and a mixture of them (50:50), respectively

[2]G, B, and M are light ice cream mixes containing different levels of guar gum, basil seed gum and mixture of them (50:50), respectively

[a–d, A–H]Means of two replicates in the same row with same superscripts do not differ significantly ($P > 0.05$)

controlled through stabilization, high water retention and viscosity enhancement abilities of hydrocolloids [1, 33]. BahramParvar and Goff [12] studied the ice recrystallization in ice creams stabilized with different hydrocolloids. They observed a considerable ability of BSG to reduce the rate of ice crystal growth compared to carboxymethylcellulose/guar gum blend. In another research, an improvement in melting quality of ice creams was obtained as a result of xanthan gum addition [1]. Also, the coldness and meltability scores of non-fat ice creams with carbohydrate- and protein-based fat replacers were found significantly higher than non-fat samples without fat replacer [17]. Considering the impact of gum concentration on creaminess, the addition of 0.45% GG, BSG, and MGB to light ice creams was adequate to simulate creaminess of control samples (Table 4), which indicate the ability of these hydrocolloids to mimic the creaminess of full-fat ice cream in light samples. On the other hand, adding fat replacers generally caused an increase in sensory hardness. As the hardness scores of light samples containing 0.50 and 0.55% GG, BSG and MGB were significantly more than those of counterpart full fat ice creams. The reason for such an effect could be attributed to viscosity enhancement ability of the hydrocolloids [35]. It was also reported that sago was able to act as fat replacer from the texture point of view. So that the texture of low-fat mango ice cream was comparable to that of corresponding control sample [36].

Correlation of instrumental and sensory properties

Pearson correlation coefficients (Table 5) show a significant correlation in some cases ($P < 0.05$). For instance, creaminess had a high positive correlation with hardness, adhesiveness, consistency coefficient, Casson yield stress, initial shear stress, the extent of thixotropy, equilibrium shear stress and sensory hardness, but coldness and coarseness had a negative correlation with creaminess. In addition, the correlation coefficients of sensory hardness with hardness and adhesiveness were 0.866 and 0.872, respectively.

Principal component analysis (PCA) is a multidimensional statistical technique that "bundles" groups of correlated measurements and substitutes a new variable (a factor or principal component) in place of the original variables. In this research, PCA was performed to describe relationships between 18 variables of ice cream. The first principal component (F1) and the second principal component (F2) accounted for 71.17% of the total variation in the data. Interpreting the PCA loading (Fig. 1a), the sensory evaluation data had an inter-dependent with each other; creaminess and hardness were plotted on the positive dimension of the horizontal line PC1 and the remaining were plotted on negative dimension.

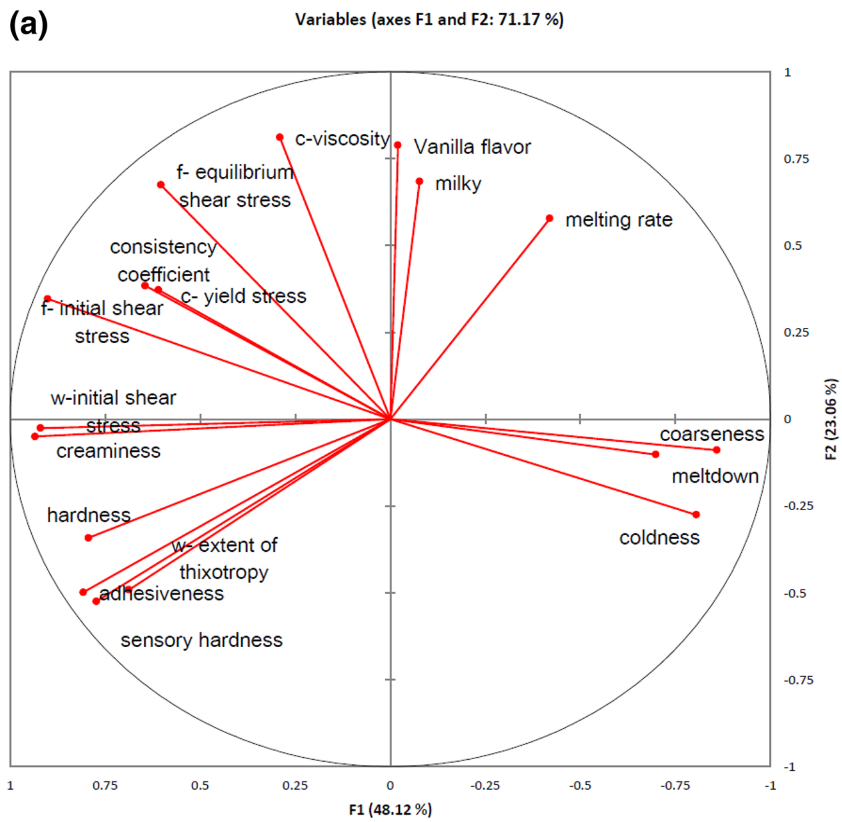
Regardless of 0.45G, 0.50G and 0.55G, it can be seen that the scores are divided into three groups (Fig. 1b); the first one includes full fat ice creams, that shows higher vanilla flavor and milky, which can be described by fat content. The second one contains light ice creams with

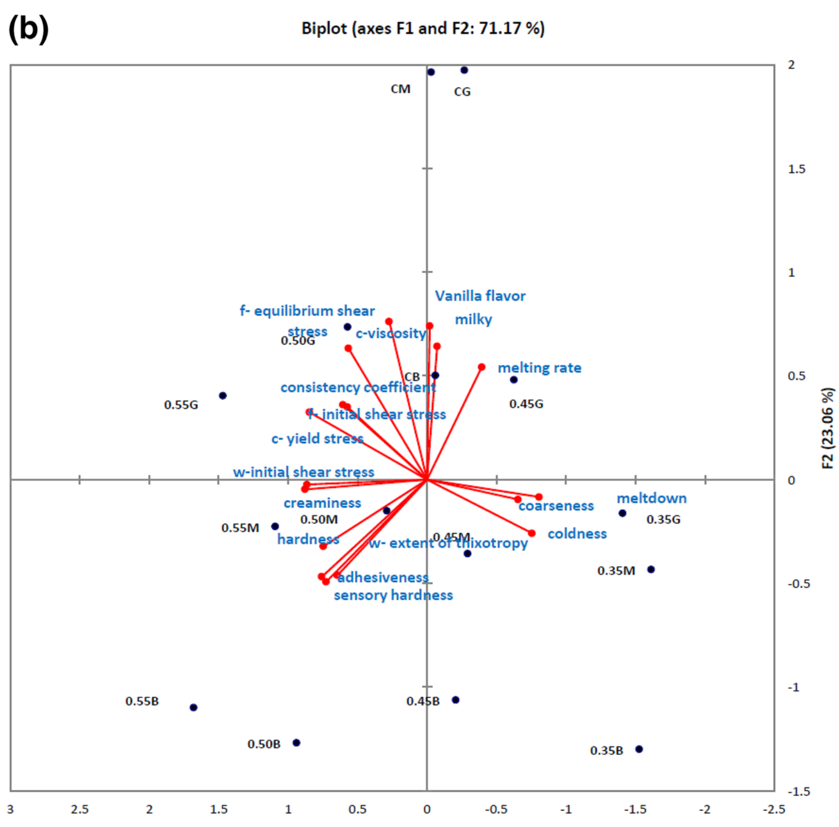
Table 5 Correlation coefficients between rheological, physical and sensory data of full fat and light ice creams

Variables	Hardness	Adhesiveness	Consistency coefficient	c-Yield stress	c-Viscosity	w-Initial shear stress	w-Extent of thixotropy	f-Initial shear stress	f-Equilibrium shear stress	Vanilla flavor	Milky	Coldness	Sensory hardness	Coarseness	Creaminess	Meltdown	Melting rate
Hardness	**1**	**0.900**	**0.524**	**0.604**	−0.076	**0.656**	**0.546**	**0.603**	0.371	−0.429	−0.449	−0.404	**0.866**	**−0.566**	**0.731**	−0.322	−0.257
Adhesiveness		**1**	0.274	0.358	−0.143	**0.781**	**0.784**	**0.569**	0.187	−0.353	−0.400	−0.438	**0.872**	**−0.617**	**0.744**	−0.418	**−0.624**
Consistency coefficient			**1**	**0.961**	0.220	0.378	−0.086	**0.707**	**0.845**	−0.011	−0.198	−0.441	0.375	−0.393	**0.678**	−0.201	0.343
c-Yield stress				**1**	0.251	0.416	−0.068	**0.756**	**0.893**	0.057	−0.144	−0.396	0.398	−0.443	**0.677**	−0.187	0.315
c-Viscosity					**1**	0.338	0.007	0.512	**0.573**	**0.723**	**0.713**	**−0.574**	−0.256	−0.341	0.117	−0.475	0.215
w-Initial shear stress						**1**	**0.810**	**0.861**	0.465	0.067	−0.017	**−0.768**	**0.668**	**−0.834**	**0.798**	**−0.723**	**−0.607**
w-Extent of thixotropy							**1**	0.410	−0.120	−0.183	−0.105	**−0.556**	**0.698**	**−0.640**	**0.549**	**−0.697**	**−0.882**
f-Initial shear stress								**1**	**0.846**	0.248	0.081	**−0.748**	0.490	**−0.791**	**0.822**	**−0.554**	−0.173
f-Equilibrium shear stress									**1**	0.401	0.170	−0.513	0.156	−0.504	**0.589**	−0.238	0.332
Vanilla flavor										**1**	**0.748**	−0.199	−0.508	−0.192	−0.100	−0.151	0.111
Milky											**1**	−0.273	−0.452	−0.158	−0.153	−0.329	0.082
Coldness												**1**	−0.424	**0.723**	**−0.757**	**0.842**	0.288
Sensory Hardness													**1**	**−0.654**	**0.709**	−0.441	−0.478
Coarseness														**1**	**−0.719**	**0.636**	0.436
Creaminess															**1**	**−0.547**	−0.358
Meltdown																**1**	0.480
Melting rate																	**1**

Values in bold are different from 0 with a significance level alpha = 0.05

Fig. 1 Correlation loading plot from PCA on rheological, physical and sensory data of full fat and light ice creams (**a**), principal components analysis of rheological, physical and sensory data of ice creams with different fat contents and gum concentrations (**b**)





0.35 and 0.45% gum; the increased scores of coldness, coarseness, and meltdown are due to the highest ice phase volume. Furthermore, light ice creams comprising 5% fat and 0.50–0.55% gum classified in the third group; which increase of gum concentration resulted in higher values of the extent of thixotropy, hardness, adhesiveness, creaminess, and sensory hardness.

Conclusion

It was found that all ice cream mixes had shear thinning and thixotropic behaviors. In general, the rheological parameters decreased as a result of the fat reduction, but a contrary effect was observed by using selected fat replacers and enhancing their concentrations. A synergistic relationship was found in all rheological properties of full fat sample apart from flow behavior index when GG was mixed with BSG in ratio 50:50. Light ice creams also showed positive rheological interactions in some cases, for example, consistency coefficient and Casson plastic viscosity. Both fat reduction and fat replacer addition increased the hardness and adhesiveness of samples, although no significant differences were found at low concentrations of gums in comparison with control. The reduction of fat content led to increasing the melting rate, first dripping time and overrun values of light samples including 0.35% gum, but a decrease in these properties was observed by increasing the gum level. It was shown that some sensory properties (coarseness, coldness, creaminess, and meltdown) of full-fat ice cream could be simulated as a result of fat replacer addition. The analysis on the basis of PCA showed that fat content and type and concentration of selected gums have important effects on different properties of ice cream. Compare to GG, mixes containing BSG and MGB showed the higher extent of thixotropy. The consistency coefficient of BSG samples increased more than ice cream mixes containing GG with the concentration, owing to the anionic nature of BSG. In some case, the addition of MGB to ice cream was found to have higher overrun value compared with GG samples. In addition, sensory properties of light ice creams with BSG and MGB were comparable with single GG. It is concluded that this novel hydrocolloid (BSG) and BSG–GG blends can be utilized in light ice cream as fat replacer to mimic some sensory characteristics of the full-fat ice cream, which is comparable with single GG as a well-known commercial gum. The present interactions between GG and BSG not only make the wide-ranging products to supply the consumer demand but also reduce the production costs. Thus, further research is worth to assess BSG and other native gums individually, together or in combination with other commercial hydrocolloids in other food formulations.

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