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The effect of two novel hydrocolloids known as Balangu seed gum (BSG) and palmate-tuber salep (PTS) with carboxymethylcellulose (CMC) on the rheological characteristics of a typical soft ice cream was studied. The power law model well described the flow behavior of mixes with a high correlation coefficient (r). The flow behavior index was in the range of 0.450–1.154, while the consistency coefficient varied from 0.051 to 6.822 $Pa\,s^n$. All mixes showed a pseudoplastic behavior except the mix containing 0.3% PTS, which was found to have a slightly dilatant characteristic. An increase in the concentration was accompanied by an increase in the pseudoplasticity and consistency coefficient. The effect of selected gums on some sensory properties of a soft ice cream such as viscosity, coldness, firmness, degree of smoothness (coarseness), liquefying rate, body and texture and total acceptance has also been investigated in this work. The correlation between the apparent viscosity and sensory attributes has been determined because of the importance of viscosity in the quality evaluation of an ice cream. Taking into account the commercial ice cream properties, a 0.4% BSG gum concentration may be recommended.

Key Words: ice cream, flow behavior, stabilizer, sensory quality, Balangu, salep

INTRODUCTION

Lallemantia royleana with the vernacular name of Balangu Shirazi or Balangu is a member of the *Labiate* family, and is widely distributed in different parts of the European and Middle East countries (Zargari, 1980). Balangu seed is conventionally consumed as a stimulant, reconstiuent, diuretic and expectorant, and is used in traditional or industrial applications in a range of products, such as the Tokhme Sharbati beverage in Iran and Turkey (Naghibi et al., 2005; Razavi et al., 2008). This seed is a good source of polysaccharides, fiber, oil and protein (Razavi and Karazhiyan, 2008). It adsorbs water quickly when soaked in it because of its high mucilage content, and produces a sticky, turbid and tasteless liquid, which can be used as a novel hydrocolloid in various food formulations (Razavi et al., 2008).

Salep is produced from the tubers of orchids that grow naturally in various regions of Iran and Turkey. It constitutes the raw material of traditional Iranian (Amin, 2005) and Turkish (Kaya and Tekin, 2001) ice creams. Salep contains approximately 11–44% high polysaccharides, such as, glucomannan. Glucomannan is classified as a hydrocolloid and absorbs 200 mL of water per gram (Tekinsen, 2006). Water-soluble/dispersible polysaccharides, termed as hydrocolloids or gums, are known as viscosity builders (thickener) and gelling agents in aqueous systems. Technologists also call them as stabilizers, since they can improve the long-term stability in systems consisting of water and oil (Garti and Leser, 2001). Salep varieties grown in Iran represent two forms, the one with branched or palmate, and the other, with rounded or unbranched tubers. It is found that the palmate-tuber salep (PTS), at similar concentrations, produces solutions with more consistency than the rounded-tuber salep (Farhoosh and Riazi, 2007).

The rheological properties of gums are particularly important when they are used in the formulation of foods for its effect on the textural and sensory attributes. The rheological behavior of fluid and semi-solid foods should be carefully taken into account for the designing and modeling purposes of different food processes. Furthermore, these characteristics are sometimes measured as an indicator of the product quality (e.g., indication of the total solids or change in the molecular size). Rheological data are required for calculation in any process involving fluid flow (e.g., pumping,

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mixing, filtration) and play an important role in the analyses of the flow conditions in food processes such as pasteurization and aseptic processing (Marcotte et al., 2001).

The quality of an ice cream mainly depends upon the ingredients used in the mix as well as the processing parameters (Minhas et al., 2002). Viscosity is one of the most important factors that influences this quality. The viscosity of an ice cream mix is affected by the composition (mainly fat and stabilizer), kind and quality of ingredients, processing and handling of the mix, concentration (total solid content) and temperature. As the viscosity increases, the resistance to melting and the smoothness of the texture increases but the rate of whipping decreases. So, the desirable viscosity can be assured by controlling the mix composition (Marshall and Arbuckle, 1996).

The effect of different gums on the rheological characteristics of an ice cream mix has been reported earlier (Cotrell et al., 1980; Goff and Davidson, 1992; Kaya and Tekin, 2001; Minhas et al., 2002), but there is no data recorded in literature concerning the effect of the two Iranian sources of hydrocolloids, meaning, PTS and Balangu seed gums (BSG) on the properties of a typical ice cream. Therefore, the aims of this study were: (1) to investigate the flow behavior of ice cream mixes containing BSG and PTS, (2) to compare the rheological characteristics of ice cream mixes which contain PTS and BSG as stabilizers, with carboxymethylcellulose (CMC), that is a well known commercial gum used in ice cream formulation, (3) to study the effect of these hydrocolloids on the sensory quality of a typical soft ice cream.

MATERIALS AND METHODS

Materials

Homogenized and UHT milk (2.5% milk fat), and homogenized and pasteurized cream (30% milk fat) were purchased from Pegah Dairy Industry Co, Mashhad, Iran. Skimmed milk powder was provided by Multi Milk Powder Industry Co, Mashhad, Iran. Sugar and vanilla were obtained from a local confectionary market and CMC was supplied by Sunrose Company, Mashhad, Iran. The dried tuber powder of PTS and crude extract powder of BSG were prepared according to the methods based on the works of Farhoosh and Riazi (2007), and Mohammad Amini and Haddad Khodaparast (2007), respectively.

Methods

Manufacture of the Ice Cream

Mixes were formulated to contain 10% milk fat, 15% sugar, 11% milk solid nonfat (MSNF) and 0.3–0.5% stabilizers. Formulas for all the mixes are summarized in Table 1. The required amount of dry stabilizers were first mixed with sugar. This mixing of the gum with some of the sugar, prior to its addition to the mother mix, was applied using the traditional procedure, mainly to preventthe lumps in the mix (Marshall and Arbuckle, 1996). Liquid ingredients including milk and cream were mixed together and warmed up to 50 °C at which time the pre-weighed were added. Mixing of the dry and liquid ingredients was accomplished by a Moulinex mixer (Model R10, Moulinex, Ecully cedex, France). The mixes were pasteurized at 80 °C for 25 s (HTST), cooled immediately to 5 °C and then stored overnight at 5 °C. After aging, vanilla extract was added and the freezing was carried out in a batch soft ice cream maker (Feller ice cream maker, Model IC 100, Feller Technologic GmbH, Dusseldorf, Germany). Required freezing time for the different mixes was 25 ± 5 min. After drawing, products were collected into 50 mL plastic containers with lids, coded and placed in a chest freezer for 1 h (Electrosteel, Model ES. 453, Mashhad, Iran).

Rheological Measurements

Rheological properties of ice cream mixes were investigated using a rotational viscometer (Visco 88, Bohlin Instruments, Malvern, Worcestershire, UK) equipped with a heating circulator (Model F12-MC, Julabo

Table 1. Ice cream mix formulations used in this study.

Ingredient	Mix 1	Mix 9	Mix 8	Mix 7	Mix 6	Mix 5	Mix 4	Mix 3	Mix 2	Mix 9	Mix 8
Cream	29.66	28.17	28.59	29.66	28.17	28.59	29.66	28.17	28.59	28.17	28.59
Vanilla	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Sugar	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Stabilizer*											
CMC	0.30	–	–	–	–	–	–	0.50	0.40	–	–
BSG	–	–	–	–	0.50	0.40	0.30	–	–	–	–
PTS	–	0.50	0.40	0.30	–	–	–	–	–	0.50	0.40
Skim Milk	5.216	5.20	5.20	5.216	5.20	5.20	5.216	5.20	5.20	5.20	5.20
Milk (2.5% Fat)	49.72	51.03	50.71	49.72	51.03	50.71	49.72	51.03	50.71	51.03	50.71

*CMC: Carboxymethylcellulose, BSG: Balangu seed gum, PTS: palmate-tuber ssalep.

Labortechnik, Seelbach, Germany). Appropriate measuring spindle (C30) was used during viscosity measurements according to the viscosity of the mixes. Samples were loaded into the cup and allowed to equilibrate at the desired temperature (5 ± 0.5 °C) and were subjected to a programmed shear rate logarithmically increasing from 14.2 to $501.7\,s^{-1}$. Rheological analyses were performed in six replications. Furthermore, to compare the sensory and rheological data, apparent viscosity of all the mixes at the shear rate of $51.8\,s^{-1}$ was recorded. It should be mentioned that this shear rate has been reported as an effective oral shear rate (Morris, 1983).

Sensory Evaluation

The ice creams were evaluated for sensory characteristics (viscosity, coldness, firmness, degree of smoothness (coarseness), liquefying rate, body and texture and total acceptance) at the Dairy Laboratory, Department of Food Science and Technology, Ferdowsi University of Mashhad, Iran. All samples were served in 50 mL plastic containers with lids and the evaluation was done at 24 ± 1 °C in plain view under white lights. Panelists were selected from the student population. In order to test panelists in the first training session, three coded samples were given which two of which were alike and one was different. Those who could recognize the different sample were chosen for the sensory evaluation of ice creams. Finally, 10 panelists, eight females and two males, all between the ages of 23 and 30 were selected. Seven 30 min training sessions were held over a period of 1 month. In these sessions, definition of attributes and assessment techniques were introduced and the sample evaluation was done practically. Sensory evaluations of appearance, flavor, body and texture, and total acceptance were performed using the 9-point scale (1 = poor, 5 = average, 9 = excellent). Other attributes were assessed using 9-point scale too, according their definitions. The ballot is shown in Figure 1 (Aime et al., 2001). Four panel sessions were established and two or three samples were assessed in each one. The samples were tempered in a batch freezer for 1 h after production and presented at the same time in a random order. In this study, sensory analyses were performed in 10 replications.

Statistical Analysis

The experimental design was a completely randomized design, performed in triplicates on separate days. Data were analyzed with the MSTATC statistical software (version 1.42, MSTATC director, Michigan State University, USA). Means were compared using least significant differences (LSD) test and results were considered significant for $p < 0.05$. Curves fitting was done by Microsoft excel spreadsheet and SigmaStat software.

RESULTS AND DISCUSSION

Rheological Properties

Flow Behavior

Typical rheograms for ice cream mixes evaluated at 5 ± 0.5 °C are shown in Figures 2–4. It can be seen that all ice cream mixes had a non-Newtonian behavior. The apparent viscosity of all ice cream mixes decreased with increasing the shear rate that confirm that all ice cream mixes had pseudoplastic behavior, except for the mix containing 0.3% PTS (Figure 4), which was slightly dilatant (Rao, 1999). The decrease in viscosity with an increase in the shear rate has been related to the increased alignment of the constituent molecules of the tested system (Rha, 1975). It was commonly reported that ice cream mixes exhibit non-Newtonian flow characteristics (Goff and Davidson, 1992), which is in agreement with the results of this study. This trend has been also observed for the ice cream mixes containing natural gums (Cotrell et al., 1980; Goff and Davidson, 1994; Kaya and Tekin, 2001) and many hydrocolloid solutions (Cancela et al., 2005; Kayacier and Dogan, 2006; Farhoosh and Riazi, 2007; Yasar et al., 2007).

Rheological Modeling and Parameters

There are many different models to describe the rheology of non-Newtonian fluids. The power law model is perhaps the most widely employed model for non-Newtonian liquids (Barnes et al., 1989). We decided to use this model (Equation (1)) due to the fact that its two parameters – consistency coefficient and flow behavior index – showed excellent representation of the data for all ranges of the shear rates used in this work:

$$\tau = k\dot{\gamma}^n, \qquad (1)$$

where τ is the shear stress in Pa, k is the consistency coefficient in Pa s^n, $\dot{\gamma}$ is the shear rate expressed in s^{-1} and n is the flow behavior index (dimensionless). The parameters obtained for the power law model are summarized in Table 2. It is seen that the correlation coefficients (r) obtained between experimental data and predicted values were high, which confirm the power law model to be adequately suitable for describing the flow behavior of ice cream mixes. In this research, n-values ranged from 1.154 to 0.450 and were statistically different ($p < 0.05$) among the samples. The flow behavior index is reported to be around 0.7 for the ice cream mixes (Goff and Davidson, 1994). Cotrell et al. (1980) showed the n-value of the ice cream mix to be in the range of 0.98–0.68 and 0.88–0.48 for the guar gum and locust bean gum used in the range of 0.05–0.40%, respectively. Kaya and Tekin (2001) obtained the

Name: Time and date: Sample code:

For each attribute, take a level teaspoon of ice cream from the center of the sample cup. If necessary, level the ice cream off using the side of the container to ensure that a consistent amount of sample is taken. Place a vertical line across the horizontal line at the point that best describes the intensity of each attribute.

1. Intensity of coldness:

Placed sample in the mouth and manipulate in your mouth. Judge coldness is defined as the cooling effect which precedes meltdown of the sample. Extreme coldness occurs when a very sharp cooling effected during manipulation of the sample. Slight coldness reflects a low degree of cooling.

Slight coldness ... Extreme coldness

1 2 3 4 5 6 7 8 9

2. Firmness:

Place sample in the mouth and press against the upper palate. Judge firmness is defined as the amount of force required by your tongue to flatten the ice cream. Ice cream that is soft provides very little resistance to flattening whereas firm ice cream requires considerable force to flatten.

Soft ... Firm

1 2 3 4 5 6 7 8 9

3. Viscosity:

Place 1/2 teaspoon of sample in the mouth. Gently manipulate the sample by slowly rotating the sample between the tongue and palate. During the melting process and immediately after the sample has liquefied, assess the ease of movement within the mouth. High viscosity means the sample does not move easily within the mouth and may feel sticky on the palate offering resistance to movement. Low viscosity means that the sample offers very little resistance to movement, and may be perceived as watery immediately after the sample has liquefied.

Low viscosity ... High viscosity

1 2 3 4 5 6 7 8 9

4. Degree of smoothness:

Spread the sample onto the upper palate with the tongue and assess the degree of smoothness. Ice cream that is not smooth perceived as a coarse or rough texture. A high degree of smoothness means the sample has a smooth and uniform spread onto the palate and no coarse or rough texture is detectable.

Smooth ... Coarse

1 2 3 4 5 6 7 8 9

5. Liquefying rate:

Place sample in the mouth and press between tongue and the upper palate and determine the liquefying rate.

Low ... High

1 2 3 4 5 6 7 8 9

6. Body & Texture:

Evaluate the ice cream in the term of overall body and texture.

Poor ... Excellent

1 2 3 4 5 6 7 8 9

7. Total acceptance:

Note your overall acceptability of ice cream.

Poor ... Excellent

1 2 3 4 5 6 7 8 9

Figure 1. Ice cream ballot for determination of sensory properties.

n-values of 0.96–0.77 for the ice cream mixes containing 0.4–1% salep. Minhas et al. (2002) mentioned that the flow behavior index of the ice cream mixes made with different stabilizers was between 0.74 and 0.93.

The smaller the *n*-values the greater the departure from Newtonian behavior and hence greater the pseudoplasticity (Chinnan et al., 1985). Comparatively, the magnitude of the flow behavior index was the lowest for ice cream mixes containing BSG and the highest for mixes with PTS within the range of concentration levels studied, while CMC produced intermediate values (Table 2). An increase in the gum concentration was

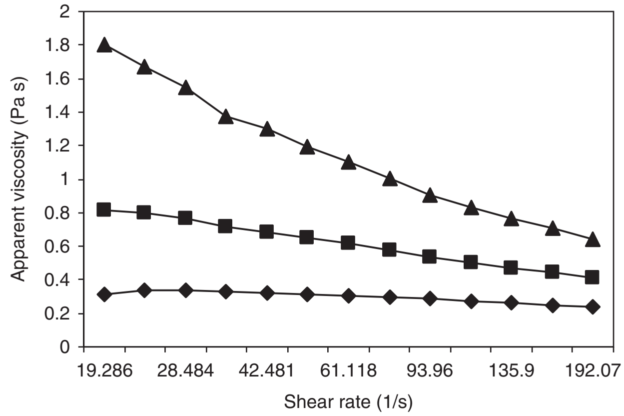

Figure 2. Apparent viscosity vs. shear rate for ice cream mixes produced using CMC at: 5 ± 0.5 °C (◆) 0.30%, (■) 0.40%, (▲) 0.50%.

Table 2. The power law model parameters for different ice cream mixes containing CMC, BSG and PTS.

Gum/Concentration	*n* (–)	*k* (Pa s^n)	*r*
CMC			
0.3%	0.744 cd	0.933 c	0.999
0.4%	0.649 de	2.597 b	0.999
0.5%	0.549 efg	6.822 a	0.999
BSG			
0.3%	0.586 ef	1.114 c	0.996
0.4%	0.520 fg	2.522 b	0.998
0.5%	0.450 g	6.542 a	0.998
PTS			
0.3%	1.154 a	0.051 c	0.996
0.4%	0.933 b	0.123 c	0.997
0.5%	0.776 c	0.700 c	0.998

CMC: Carboxymethylcellulose, BSG: Balangu seed gum, PTS: palmate-tuber salep.
Values followed by different letters are significantly different ($p < 0.05$).

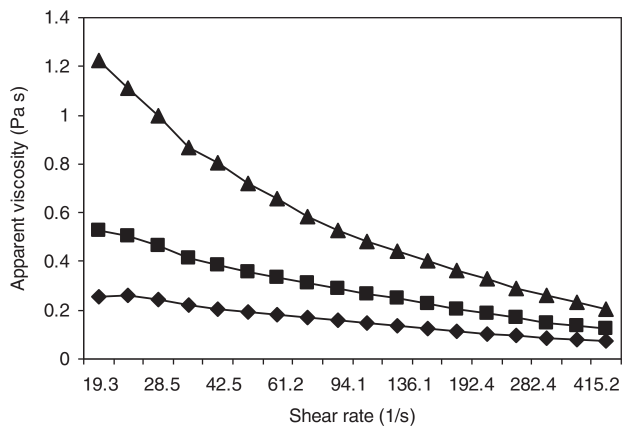

Figure 3. Apparent viscosity vs. shear rate for ice cream mixes produced using BSG at: 5 ± 0.5 °C (◆) 0.30%, (■) 0.40%, (▲) 0.50%.

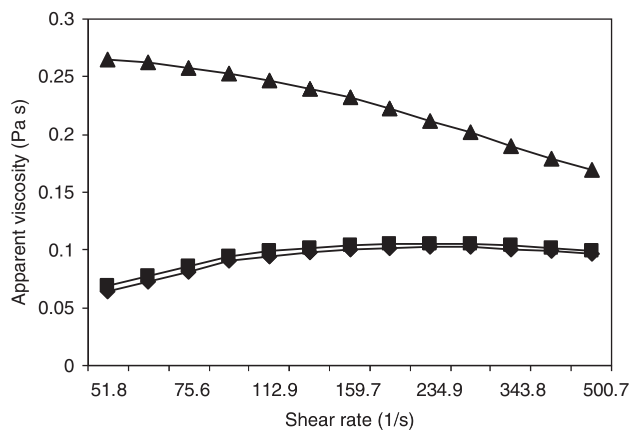

Figure 4. Apparent viscosity vs. shear rate for ice cream mixes produced using PTS at: 5 ± 0.5 °C (◆) 0.30%, (■) 0.40%, (▲) 0.50%.

accompanied with a decrease in the flow behavior index. The results of this study agreed with former researches (Cotrell et al., 1980; Kaya and Tekin, 2001). It has been reported that, for a given gum type, the value of the flow behavior index and its change with concentration are highly dependent on the molecular size (Marcotte et al., 2001). It has also been shown that gum solutions with a high value of *n* tend to feel slimy in the mouth. While high viscosity and a good mouth feel characteristics are desirable, the choice should be a gum system having a low *n*-value (Szczesniak and Farkas, 1962).

The consistency coefficient, which is considered as being a measure of the viscous nature of food (Sopade and Kassum, 1992), was observed to increase with the stabilizer concentration (Table 2). There was significant difference among the consistency coefficient of the mixes ($p < 0.05$), which varied from 0.051 to 6.822 Pa s^n (Table 2). CMC made the highest *k*-values in ice cream mixes and the difference between BSG and CMC was not significant ($p > 0.05$) at the same concentration level. However, mixes containing PTS had the least *k*-values and this decrease was significantly important ($p < 0.05$). Aime et al. (2001) reported the consistency coefficient of their ice creams between 0.0733 and 1.260 Pa s^n. In Muse and Hartel's research (2004), the consistency coefficient varied from 0.145 to 0.211 Pa s^n. Minhas et al. (2002) concluded that the consistency coefficient of the ice cream mixes ranged between 0.29 and 1.19 Pa s^n.

Apparent Viscosity

The effect of the type and concentration of selected stabilizers on the apparent viscosity of the ice cream mixes is shown in Figure 5. The values that were significantly different ($p < 0.05$) ranged from 0.064 to 1.147 Pa s at the shear rate 51.8 s^{-1}. It can be seen that the apparent viscosity enhanced as the concentration of

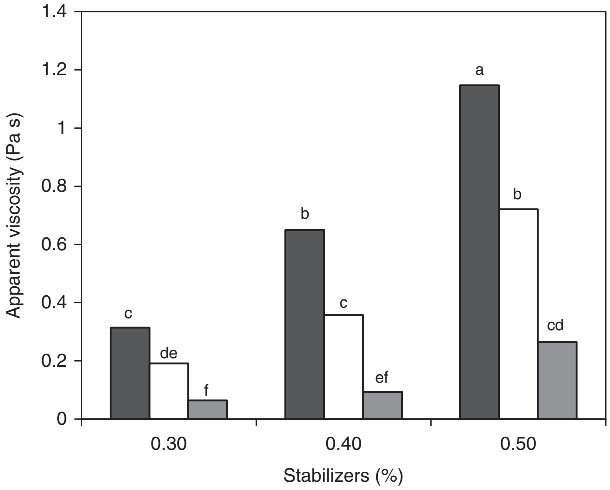

Figure 5. Effect of selected stabilizers on the apparent viscosity of ice cream mix at the shear rate $51.8\,s^{-1}$ and 5 ± 0.5 °C. (■) CMC, (□) BSG, (grey square) PTS.

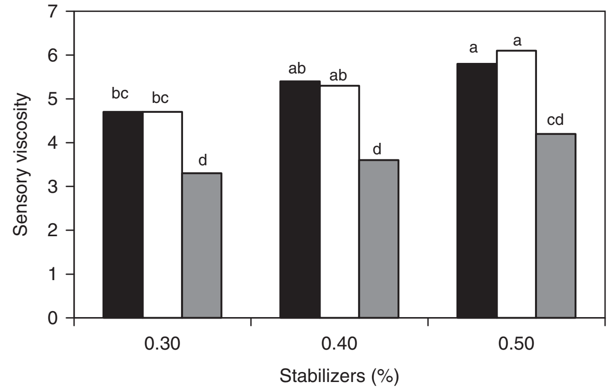

Figure 6. Effect of selected stabilizers on the sensory viscosity of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

the selected hydrocolloids increased. At all concentrations, mixes with CMC and PTS had the most and the least viscosity values, respectively. Our findings were similar to the results of the former studies. Guven et al. (2003) reported that the ice cream produced using only the salep extract had a significantly ($p < 0.05$) lower viscosity value than the mixes containing other stabilizers. According to Aime et al.'s published data (2001), the apparent viscosity of ice creams ranged from 0.018 to 0.149 Pa s. Hagiwara and Hartel (1996) showed that the range of apparent viscosity at shear rate $115\,s^{-1}$ and temperature of 5 °C was approximately 0.023 to 0.058 Pa s for unstabilized mixes and 0.579 to 0.687 Pa s for stabilized ice cream mixes. In another research work, the apparent viscosity of ice cream mixes made with different sweeteners at 20 rpm was obtained between 0.584 and 0.935 Pa s (Muse and Hartel, 2004).

Sensory Characteristics

Viscosity

A physical property of ice cream that has a major influence on the sensory quality in general, and texture assessment, in particular, is viscosity. Sensory viscosity in the partially melted state is an important factor because it influences how a sample of ice cream reacts within a person's mouth. The resistance of an ice cream to the mechanical forces imparted by the tongue, upper palate and teeth will dictate the overall perception of ice cream texture (Akoh, 1998).

In all soft ice creams, the sensory viscosity increased with the stabilizer concentration (Figure 6). Panelists found significant differences ($p < 0.05$) among the samples. Sensory judges perceived ice creams containing PTS to have the least viscosity and their differences were significantly important ($p < 0.05$). If the effect of the gum type in the viscosity production was considered, it could be seen that BSG produced the highest value of sensory viscosity, but its difference with CMC was not significant ($p > 0.05$). PTS produced the lowest viscosity in ice creams ($p < 0.05$).

It was observed that there is a good correlation between the results of the sensory viscosity and instrumental viscosity (apparent viscosity at a constant shear rate of $51.8\,s^{-1}$). Regression equation between them for three levels of three stabilizers was fitted as follows:

$$\eta_s = 2.2841\eta_a + 3.8242 \quad (R^2 = 0.706), \qquad (2)$$

where η_a and η_s were the apparent and the sensory viscosities, respectively.

It was compared the sensory ratings provided by a panel of personnel with the shear rate – shear stress data and concluded that the stimulus associated with the oral evaluation of the viscosity was the shear stress developed in the mouth at a constant shear rate of $50\,s^{-1}$ (Rao, 1999).

Coldness

As melting occurs within the mouth, large ice particles are momentarily left behind creating the distinct sensation of coldness (Bodyfelt et al., 1988). Coldness scores ranged from 4.9 to 6.1, but this variation was not important statistically ($p > 0.05$, Figure 7). CMC and PTS produced the least and highest coldness in ice cream, respectively. This is probably due to the role of viscosity. Stabilizers bind water and reduce the ice crystal growth and retard the coldness sensation (Marshall and Arbuckle, 1996). Therefore, CMC with the highest viscosity gained the lowest coldness score.

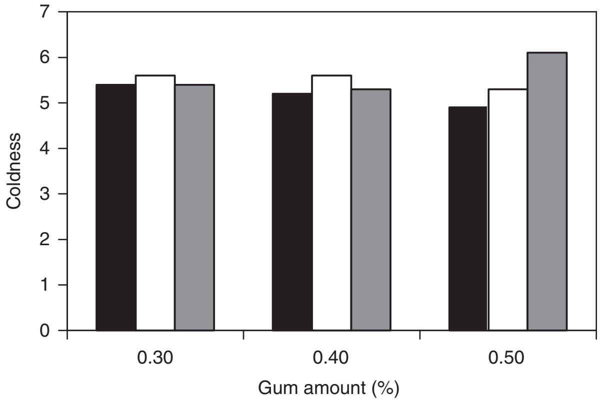

Figure 7. Effect of selected stabilizers on the coldness of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

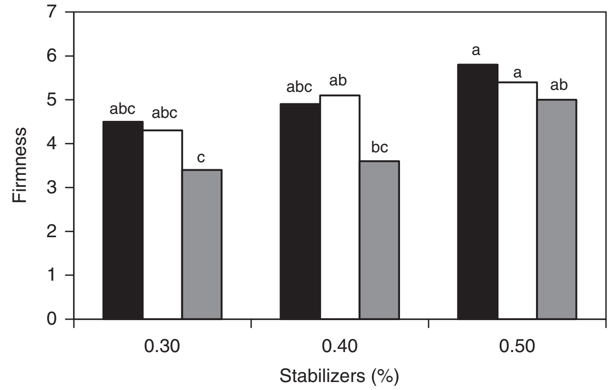

Figure 8. Effect of selected stabilizers on the firmness of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

Firmness

The firmness of ice cream is related to its structure. The air cells of ice cream structure are essentially spherical, although there is some distortion due to the formation of fat and ice crystals. The material surrounding these air cells is a non-Newtonian fluid containing clumps of fat (up to 80%) and small ice crystals (Aime et al., 2001). Significant differences in firmness were detected among samples ($p < 0.05$), which varied between 3.4 and 5.8 (Figure 8). In all the samples, firmness was increased as the gum concentration increased. PTS and CMC produced the lowest and highest firmness in the final products, respectively. These findings were predictable due to their viscosity. It was seen that the stabilizers bind water, increase the viscosity and enhanced the firmness of ice creams.

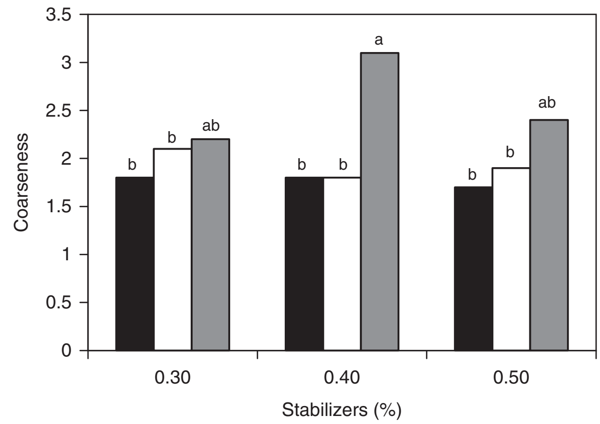

Figure 9. Effect of selected stabilizers on the coarseness of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

Degree of Smoothness (Coarseness)

As it is shown in Figure 9, panelists found significant difference for the degree of smoothness among the samples ($p < 0.05$). The coarseness scores ranged from 1.7 to 3.1. PTS produced the highest coarseness among the stabilizers used. All the samples had a desirable smoothness, which confirm that selected hydrocolloids act as suitable stabilizers in term of smoothness. A smooth texture is an indicator of uniform small ice crystals and air cells and no detectable crystals (Abdullah et al., 2003). Marshall and Arbuckle (1996) stated that one of the primary purposes of using stabilizers in ice cream is to produce smoothness in the body and texture.

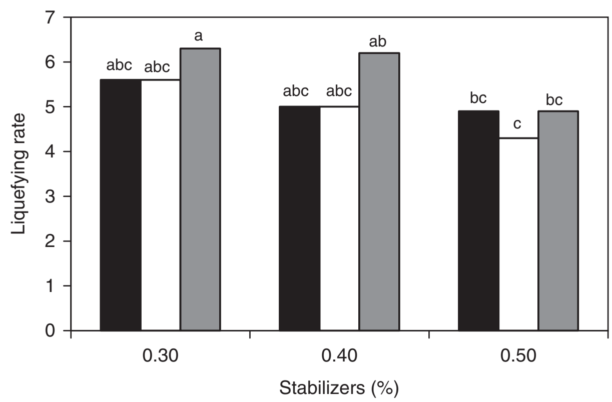

Figure 10. Effect of selected stabilizers on the liquefying rate of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

Liquefying Rate

The liquefying rate scores, which varied from 4.3 to 6.3, were significantly different ($p < 0.05$). In this article, the liquefying or melting rate was evaluated as intermediate that is acceptable (Figure 10). If the product melts too fast, a messy situation ensues. A fast-melting product is undesirable as it tends to heat readily. However, a slow rate of melting can also be indicative of a defective ice cream (Marshall and Arbuckle, 1996). In all the

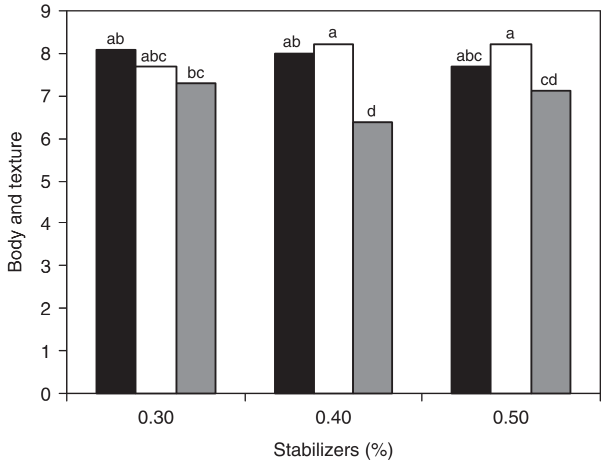

Figure 11. Effect of selected stabilizers on the body and texture of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

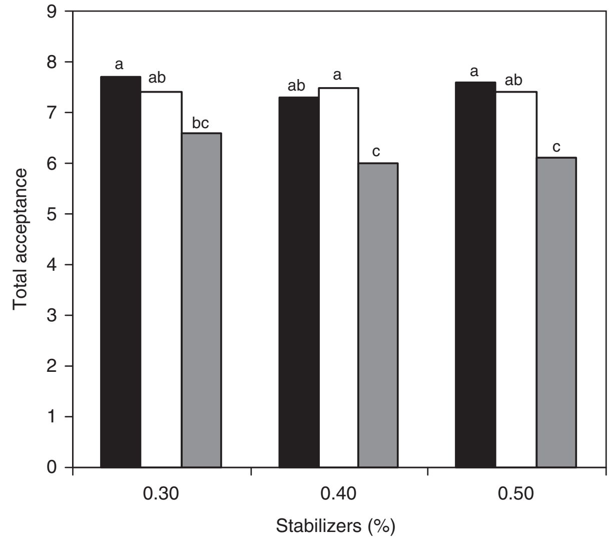

Figure 12. Effect of selected stabilizers on the total acceptance of typical soft ice cream. (■) CMC, (□) BSG, (grey square) PTS.

cases, the liquefying rate decreased when the stabilizers concentration increased (Figure 10). Melting resistance or slow liquefying rate is one of the effects of stabilizers (Marshall and Arbuckle, 1996). Ice creams containing PTS and BSG had the highest and lowest liquefying rate, respectively, which were attributed to their viscosities. The difference between ice creams stabilized with PTS and BSG were significant ($p < 0.05$), while samples containing CMC had no significant variation with them ($p > 0.05$).

Body and Texture

Texture is directly related to the structure. Structure depends on the size, number and arrangement of air cells, ice crystals and fat clumps (Abdullah et al., 2003). The body and texture values ranged from 6.4 to 8.2 and were significantly different ($p < 0.05$). Samples with BSG acquired the best body and texture scores (Figure 11), although the difference between CMC and BSG was not significant ($p > 0.05$). On the contrary, PTS declined the body and texture scores of ice creams significantly ($p < 0.05$). This can be related to the low viscosity of ice creams containing salep. In this study, all the ice creams obtained body and texture scores better than average. The desired texture of an ice cream is smooth, creamy and homogeneous but the desired body should be firm with substantial feeling of solid matter within the foam (Marshall and Arbuckle, 1996).

Total Acceptance

The total acceptance of soft ice creams were assessed between 6 and 7.7, where the most acceptable ice cream was the sample containing 0.3% CMC (Figure 12). Total acceptance scores of all the samples were higher than the average value (5) in a 9-point scale. Panelists found no differences ($p > 0.05$) between CMC and BSG in terms of the total acceptance, although significant differences were observed between the samples containing CMC and PTS. Salep decreased the overall acceptability of an ice cream at all the concentrations studied. This result is similar to that reported by Guven et al. (2003).

Table 3. Pearson coefficients indicating relationship among apparent viscosity, sensory viscosity° and sensory attributes of ice cream.

Variable	Apparent viscosity	*p*-value	Sensory viscosity	*p*-value
Apparent viscosity	1.000	0.000	0.840	0.004
Sensory viscosity	0.840	0.004	1.000	0.000
Coldness	−0.615	0.078	−0.381	0.312
Firmness	0.853	0.003	0.895	0.001
Coarseness	−0.622	0.074	−0.733	0.025
Liquefying rate	−0.713	0.031	−0.873	0.002
Liquefying rate	0.473	0.198	0.766	0.0161
Total acceptance	0.559	0.117	0.752	0.019

Relationship Between Apparent Viscosity and Sensory Attributes

Because of the stabilizer's viscosity role in the textural quality of an ice cream, correlation between the instrumental viscosity, sensory viscosity and other sensory characteristics were investigated. The data in Table 3 included Pearson correlation coefficients. Nine points (three gums at three contents) were used for determining the correlation. The total acceptance ($r = 0.752$, $p < 0.05$) and the body and texture ($r = 0.766$, $p < 0.05$) were highly correlated with the sensory viscosity, where their correlations with the apparent viscosity were good ($r = 0.559$, $p > 0.05$) and relatively poor ($r = 0.473$, $p > 0.05$), respectively. Firmness had a highly significant positive correlation with the sensory ($r = 0.895$, $p < 0.05$) and instrumental ($r = 0.853$, $p < 0.05$) viscosities. Coldness had poor ($r = -0.381$) and good ($r = -0.615$) correlations with the sensory and instrumental viscosities, respectively. However, none of the relationships were significant ($p > 0.05$). Correlations between coarseness and both the types of viscosities were high. Pearson coefficients were -0.733 ($p < 0.05$) and -0.622 ($p > 0.05$) for the sensory and apparent viscosities, respectively. These negative correlations meant that coarseness was decreased with a viscosity increase. Liquefying rate was highly correlated with the sensory ($r = -0.873$, $p < 0.05$) and instrumental viscosity ($r = -0.713$, $p < 0.05$).

CONCLUSION

It is found that the all ice cream mixes containing BSG, PTS and CMC behave as non-Newtonian and shear thinning (except for 0.3% PTS) fluids at temperatures of 5 ± 0.5 °C. The viscosity and the consistency coefficient increased with the stabilizers concentration, while the flow behavior index decreased. When the selected gums were used in the formulation of a soft ice cream, CMC and BSG gave a totally better quality than PTS. It is also concluded that in most sensory characteristics, there was a good correlation between viscosity and those attributes. Results of this study introduced the BSG as a very suitable ice cream stabilizer, which is comparable with CMC as a well-known commercial stabilizer. PTS acted properly in many attributes, but for obtaining better results in this extract, more content should be proposed.

The results of this study are useful in the designing of processing operation, evaluation and modeling, modifying textural attributes and assessment of product quality. Due to the good results obtained in functionality, further research is necessary to take advantage of these Iranian gums in other conditions and products.

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