Application of simplex-centroid mixture design to optimize stabilizer combinations for ice cream manufacture

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Abstract This study aimed to obtain the optimum formulation for stabilizers in ice cream that could contest with blends presented nowadays. Thus, different mixtures of three stabilizers, i.e. basil seed gum, carboxymethyl cellulose, and guar gum, at two concentrations (0.15 % & 0.35 %) were studied using mixture design methodology. The influence of these mixtures on some properties of ice cream and the regression models for them were also determined. Generally, high ratios of basil seed gum in mixture developed the apparent viscosity of ice cream mixes and decreased the melting rate. Increasing proportion of this stabilizer as well as guar gum in the mixtures at concentration of 0.15 % enhanced the overrun of samples. Based on the optimization criteria, the most excellent combination was 84.43 % basil seed gum and 15.57 % guar gum at concentration of 0.15 %. This research proved the capability of basil seed gum as a novel stabilizer in ice cream stabilization.

Keywords Frozen dessert · Hydrocolloid · Reyhan · Response surface methodology · Viscosity

Introduction

Stabilizers, despite the low level in ice cream formulation, impart specific and important functions such as increase in viscosity of ice cream mix, aeration improvement, cryo-protection, and control of meltdown (Marshall et al. 2003). These functions as well as type of stabilizers and limitations on excessive use of them have been reviewed by BahramParvar and Mazaheri (2011).

A variety of substances, including both commercial and local ones, have been used as stabilizers in ice cream formulations. Guar gum (GG), locust bean gum (LBG), sodium carboxymethyl cellulose (CMC), xanthan, and carrageenan are the most common ones (BahramParvar and Mazaheri 2011). In addition, some endemic non-commercial gums also have been shown to act suitable as ice cream stabilizers (BahramParvar and Mazaheri 2011). For example, BahramParvar et al. (2009) concluded that *Lallemantia royleana* (Balangu) seed gum could apply as a proper stabilizer and not producing significant difference ($P>0.05$) in most characteristics of ice cream, compared to CMC.

At present, because of specific characteristics of each stabilizer, and to gain synergism in function, individual stabilizers are usually mixed. This mixture, which is more effective, can be used in lower amounts and reduces the overall cost of the stabilizer system (BahramParvar and Mazaheri 2011). There are some valuable studies about the application of multiple stabilizers in ice cream formulation (Guen et al. 2003; Rincon et al. 2006; BahramParvar et al. 2008; Soukoulis et al. 2008).

Investigating the conditions that produce the best output is general target in any optimization. Traditionally, optimization has been carried out on the study of each variable separately; but its major weakness is that it is time consuming and that there is a risk of misinterpreting the results if important interactions between studied factors are present. Thus, procedures for optimization of factors by multivariate techniques such as mixture design, Box–Behnken design, and central composite design have been encouraged, as they are faster, more economical and convenient, and let more than one variable be optimized simultaneously (Araujo and Brereton 1996; Santos et al. 2009).

Generally, simplex centroid mixture design is used to study relationships among proportions of different variables and responses (Chen et al. 2010). It can not only establish the surface model of continuous variables, estimating every

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element in the mixture and their interactions, but can also optimize the component elements in accordance with the target to determine the best ratio of ingredients (Jian-Zhong et al. 2007). Nowadays, this method is extensively used for the formulation in food industries (Iop et al. 1999; Yang and Vickers 2004; Laneuville et al. 2005; Dutcosky et al. 2006; Didier et al. 2007; Jian-Zhong et al. 2007; Garcia et al. 2009; Ghorbel et al. 2010; Mastromatteo et al. 2009; Santos et al. 2009; Ryland et al. 2010; Safaraile et al. 2010).

This work aimed to optimize the multiple ice cream stabilizers formulation using two common stabilizers (CMC and GG) and a novel source of gum (basil seed gum: BSG). *Ocimum basilicum* L. with vernacular name of basil (or Reyhan or Reihan) is one of the endemic plants in Iran and is mainly used as a pharmaceutical plant (Naghbi et al. 2005). Its seed, when soaked in water, swells into a gelatinous mass which has reasonable amounts of gum. It has been reported that the polysaccharide extracted from basil seed comprise of two major fractions of glucomannan (43 %) and (1→4)-linked xylan (24.29 %) and a minor fraction of glucan (2.31 %). Presence of highly branched arabinogalactan in addition to glucomannan and (1→4)-linked xylan has also been shown (Hosseini-Parvar et al. 2010). This gum showed good functional properties, which was comparable to some commercial food stabilizers (Razavi et al. 2009). Hosseini-Parvar et al. (2010), in a study on steady shear flow behavior of BSG, concluded that the existence of yield stress, high viscosity at low shear rates, shear thinning behavior, and heat resistant nature of basil seed gum make it a good stabilizer in some food formulations such as mayonnaise and salad dressing. Although mixed stabilizers have been used in ice cream industry, but, to our knowledge, there is not recorded data concerning the application of mixture design in optimization the formulation for ice cream stabilizers. It is also the first time that basil seed gum has been used as an ice cream stabilizer.

CMC, a chemically modified natural gum, is a linear, long chain, water-soluble, and anionic polysaccharide. This polymer chain composed of two repeating anhydroglucose units joined through 1,4 glucosidic linkages (Murray 2000). Electrostatic repulsion between its molecules mainly accounts for the stability and high viscosity of CMC aqueous solution. This stabilizer forms weak gels by itself, but gels well in combination with carrageenan, locust bean gum or guar gum (BahramParvar and Mazaheri 2011). CMC has found various applications in different foods such as frozen products, instant products, sauces and dressings, soft drinks and bakery products (Murray 2000). Guar gum is a non-ionic polysaccharide produced from the seeds of annual plants, *Cyamopsis tetragonalobus* and *psoraleoides*. This galactomannan are composed of linear (1→4)-β-D-mannan chains with varying amounts of single D-galactose substituent linked to the main

backbone by (1→6)-α-glycosidic bonds (Wielinga and Maehall 2000). It readily disperses and does not cause excessive viscosity in ice cream mix. This inexpensive hydrocolloid is considered to be a strong stabilizer (BahramParvar and Razavi 2012).

Considering the above, the objectives of this research were: (1) to introduce a new source of hydrocolloid means basil seed gum as ice cream stabilizer, (2) to study the physical characteristics of ice cream containing different combinations and levels of three stabilizers (BSG, GG, and CMC), and (3) to optimize the formulation for ice cream stabilizers using mixture design methodology.

Materials and methods

Materials

Homogenized-UHT milk (3 % fat) and homogenized-pasteurized cream (30 % fat) were obtained from Pegah Dairy Industry Co, Mashhad, Iran. Skim milk powder was purchased from Multi Milk Powder Industry Co, Mashhad, Iran. Sugar and vanilla (vanillin 100 %, Polar Bear Brand, China) were purchased from local confectionary market. CMC and GG were supplied by Sunrose (Mashhad, Iran) and Rhodia (Germany) companies, respectively. BSG was prepared according to the work done by Razavi et al. (2009).

Ice cream preparation

Target composition of ice cream was 10 % milk fat, 11 % nonfat milk solids, 15 % sucrose, 0.1 % vanilla, and 0.15 or 0.35 % stabilizer. Two batches of each ice cream sample were made and some experiments were done twice per each. Results were recorded as the mean of measurements in order to reduce the error. The ice cream formulations were calculated by algebraic mass balance method (Marshall et al. 2003). Liquid ingredients were warmed up to 50 °C. Pre-blended dry ingredients were then added and mixed using Moulinex mixer (Model R10, Moulinex, France). The ice cream mix was pasteurized at 81 °C for 25 s (HTST) and homogenized with a laboratory rotor—stator homogenizer (Ultra Turax T-25, IKA Instruments, Germany) at a required speed (17000–22000 rpm) for 1 min to reduce the fat globule size. These mixes were immediately cooled and aged at 4 °C overnight. Ice cream mixes were frozen for 30 min using a batch ice cream maker (Feller ice cream maker, Model IC 100, Feller Technologic GmbH, Germany), then collected into 50 mL lidded plastic containers.

Mixture design and statistical analysis

The simplex-centroid mixture design method, provided by Minitab statistical software (version 13.20, Minitab Inc., State College, PA), was used to determine the optimum proportions and levels of selected stabilizers. The selected stabilizers (BSG, GG, and CMC) were included as the independent variables. Stabilizer concentration, 0.15 or 0.35 % that are common in ice cream formulations, was considered as process variable. The feasible space for a mixture experiment with three components is a triangle called a simplex. The composition of each mixture varies depending on its position on the simplex region; for example, the vertices of the simplex correspond to pure blends made up of 100 % in weight of a single ingredient (Laneuville et al. 2005). All the mixtures in the simplex must have the same final weight (BSG+GG+CMC=100). The final experimental design is shown in Table 1. The studied responses were apparent viscosity, draw temperature, overrun, and melting rate.

Analytical methods

Viscosity The ice cream mixes after aging at 4 °C were subjected to different shear rates ranging from 14.2 to 512 s⁻¹ using a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) equipped with a heating/cooling circulator (Julabo, Model F12-MC, Julabo Labortechnik, Germany). Temperature was controlled at 5±0.5 °C using the circulator. Apparent viscosity calculated at shear rate of 117 s⁻¹ was chosen for comparison.

Draw temperature Draw temperatures (°C) of ice creams was recorded using a digital thermometer (French cooking, Biotemp, Alla France, France).

Overrun Overrun of samples was calculated as follows (Marshall et al. 2003):

$$\% \text{ overrun} = ((\text{weight of unit volume of mix} - \text{weight of unit volume of foam}) / \text{weight of unit volume foam}) \times 100.$$

Table 1 Mixture design with 3 components (basil seed gum: BSG, carboxymethyl cellulose: CMC, guar gum: GG) and 1 process variables (gum concentration) as well as experimental responses

Formulation code	BSG	CMC	GG	Gum concentration (%)	Apparent viscosity (Pa.s)	Draw temperature (°C)	Overrun (%)	Melting rate (g/min)
1	100	0	0	0.15	0.170	-6.2	42.995	0.569
2	0	100	0	0.15	0.123	-4.85	50.765	0.802
3	0	0	100	0.15	0.160	-4.45	65.220	0.642
4	50	50	0	0.15	0.190	-4.15	30.732	0.541
5	50	0	50	0.15	0.123	-4.55	52.468	0.577
6	0	50	50	0.15	0.140	-4.75	44.628	0.626
7	33.33	33.33	33.33	0.15	0.113	-5.3	42.580	0.643
8	66.67	16.67	16.67	0.15	0.570	-4.85	49.885	0.321
9	16.67	66.67	16.67	0.15	0.117	-4.85	45.875	0.622
10	16.67	16.67	66.67	0.15	0.147	-4.5	51.725	0.615
11	100	0	0	0.35	0.857	-5.6	55.715	0.059
12	0	100	0	0.35	0.413	-4.6	56.815	0.658
13	0	0	100	0.35	0.480	-4.35	46.930	0.660
14	50	50	0	0.35	0.577	-3.9	30.600	0.102
15	50	0	50	0.35	0.773	-4.45	54.638	0.700
16	0	50	50	0.35	0.407	-4.95	61.460	0.632
17	33.33	33.33	33.33	0.35	0.553	-5.3	59.082	0.470
18	66.67	16.67	16.67	0.35	0.710	-4.2	33.192	0.216
19	16.67	66.67	16.67	0.35	0.407	-4.25	52.387	0.552
20	16.67	16.67	66.67	0.35	0.347	-3.95	51.800	0.658

Table 2 Predicted model for physicochemical data of ice cream formulations containing different ratios and levels of three stabilizers

Attribute	Predicted model	R^2	R^2 (adj)
Apparent viscosity	$Y = 0.535BSG + 0.236CMC + 0.336GG - 2.646(BSG \times GG) + 0.319(BSG \times X_1) + 0.148(CMC \times X_1) + 0.148(GG \times X_1)$	90.92 %	85.62 %
Draw temperature	$Y = -5.90BSG - 4.72CMC - 4.40GG + 5.13(BSG \times CMC) + 2.57(BSG \times GG) - 1.17(CMC \times GG) - 82.22(BSG \times CMC^2 \times GG) - 26.44(BSG \times CMC) - 31.84(CMC \times GG) + 0.30(A \times X_1) + 0.12(CMC \times X_1) - 0.32(BSG \times CMC \times X_1) - 0.47(BSG \times GG) - 0.72(CMC \times GG \times X_1) - 1.63(BSG \times GG \times X_1) - 8.30(BSG \times GG \times X_1) - 20.82(BSG \times GG \times X_1)$	99.98 %	99.84 %
Overrun	$Y = 49.6BSG + 53.8CMC + 56.4GG - 84.3(BSG \times CMC) + 216.4(BSG \times GG) + 6.4(BSG \times X_1) + 3.0(CMC \times X_1) - 9.1(GG \times X_1) - 19.0(BSG \times CMC \times X_1) + 45.9(CMC \times GG \times X_1) + 92.2(BSG \times G \times X_1) + 330.9(BSG \times CMC \times GG \times GG \times X_1) + 556.4(BSG \times GG \times X_1)$	99.93 %	99.36 %
Melting rate	$Y = 0.303BSG + 0.719CMC + 0.657GG - 0.829(BSG \times CMC) + 0.630(BSG \times GG) + 1.648(BSG \times CMC) - 0.262(BSG \times X_1) - 0.070(CMC \times X_1) + 0.756(BSG \times GG \times X_1)$	95.30 %	91.07 %

BSG, CMC, GG, and X1 mean basil seed gum, carboxymethyl cellulose, and gum concentration, respectively

Melting rate Melting rate of ice creams was determined by carefully cutting the hardened ice cream (50 ± 0.5 g) as a cube, placing the ice cream onto wire sieve over a beaker, and weighing the amount of ice cream drained in the beaker at 22 ± 1 °C every 5 min. The weight of material passing through the screen was recorded as a function of time. Melting rate (g/min) was calculated from the linear portion of each melting curve (Soukoulis et al. 2008; Karaca et al. 2009).

Sensory evaluation Sensory evaluation of optimum formulation was done to assess acceptability of the sample for consumers. Fifty-one untrained panelists, twenty-two male and twenty-nine female, with age between 20 and 45 years, were selected among students, faculty, and staff at Ferdowsi University of Mashhad. They used a hedonic scale (i.e., 9 = like extremely, 5 = neither like nor dislike, and 1 = dislike extremely) to evaluate the sample on sensory characteristics of

Table 3 Analysis of variance for the different models fitted to responses of Table 1

	Apparent viscosity			Draw temperature			Overrun			Melting rate		
Variation source	df	Seq SS	P	df	Seq SS	P	df	Seq SS	P	df	Seq SS	P
Regression	7	1.01795	0.000	17	6.18895	0.001	17	1732.00	0.006	9	0.731954	0.000
Component only		-	-									
Linear	2	0.21157	0.007	2	1.14181	0.000	2	364.39	0.022	2	0.351614	0.000
Quadratic	-	-	-	3	2.47485	0.001	2	539.89	0.002	3	0.107768	0.002
Special cubic	-	-	-	-	-	-	1	68.76	0.131	-	-	-
Full cubic	1	0.07203	0.013	-	-	-	-	-	-	1	0.027445	0.020
Special quartic	-	-	-	1	0.80736	0.000	1	38.99	0.095	-	-	-
Full quartic	-	-	-	2	0.95040	0.001	1	12.80	0.042	-	-	-
Component × concentration												
Linear	3	0.72172	0.000	3	0.52481	0.007	3	149.57	0.006	2	0.167074	0.000
Quadratic	1	0.01263	0.246	3	0.01250	0.021	3	287.24	0.007	1	0.078080	0.001
Special cubic	-	-	-	1	0.00960	0.029	-	-	-	-	-	-
Full cubic	-	-	-	-	-	-	1	94.10	0.013	-	-	-
Special quartic	-	-	-	-	-	-	1	2.42	0.027	-	-	-
Full quartic	-	-	-	2	0.26763	0.004	2	173.85	0.007	-	-	-
Residual error	12	0.10170		2	0.00105		2	1.16		10	0.036086	
Total	19	1.11965		19	6.19000		19	1733.16		19	0.768040	

appearance, flavor, body & texture, color, and total acceptance. All samples were served in 50 mL lidded plastic containers and evaluation was done in plain view under white lights.

Results and discussion

Model establishment

The responses data in Table 1 were subjected to mixture design analysis and predicted equation was developed for each attribute. The polynomial models describing the correlation between responses and variables are given in Table 2. Quadratic models were chosen for analysis the apparent viscosity and melting rate data, while draw temperature and overrun were analyzed with full quartic models. Only significant sources with P values of ≤ 0.05 were included in the regression model. Coefficient of determination (R^2) and R^2 -adjusted values indicate that the selected models had a good fit with the data (Table 2). In general, a positive sign for the coefficient in the fitted model indicates the ability of the variable to increase the response, while the negative sign shows the ability of a variable to decrease the response.

Analysis of variance (ANOVA) results for the responses have been summarized in Table 3. The associated P-value was used to indicate statistical significance.

Effect of mixture components on the responses

Mean values for various attributes of different ratios of selected stabilizers are given in Table 1. In addition, the mixture triangular contour plots of the responses are depicted in Figs. 1, 2, 3 and 4 to present more detailed interaction related to the regression models on apparent viscosity, draw temperature, overrun, and melting rate, respectively.

The viscosity of an ice cream mix is considered a key attribute as it affects the body and texture of the finished product (Stanley et al. 1996). This response that varied between 0.113 and 0.857 Pa.s, was related to formulations containing equal ratios of selected gums at concentration of 0.15 % (F7) and 100 % BSG at concentration of 0.35 % (F11), respectively. Similar values for apparent viscosity of ice cream mixes have been reported by other researchers (Hagiwara and Hartel 1996; Prindiville et al. 1999; Aime et al. 2001; Kaya and Tekin 2001; Alvarez et al. 2005; BahramParvar et al. 2008; Soukoulis et al. 2008; BahramParvar et al. 2009, 2010). For example, Hagiwara and Hartel (1996) found the apparent viscosity of 0.579–0.687 Pa.s (at shear rate of 115 s^{-1}) for ice cream mixes containing 12 % milk fat, 11 % milk solid non fat, 16.5 % sweetener, 0.1 % emulsifier, and

Fig. 1 Contour plots for the effect of different combinations of basil seed gum (BSG), guar gum (GG), and carboxymethyl cellulose (CMC) on apparent viscosity at two concentrations of 0.15 and 0.35 %

0.3 % commercial stabilizer (blend of 80 % locust bean gum and 20 % carrageenan). Apparent viscosity of ice creams containing 0.3 % commercial stabilizer—emulsifier blend ranged between 0.019 and 0.149 Pa.s in different levels of fat (Aime et al. 2001). BahramParvar et al. (2010) showed that the apparent viscosity of ice cream mixes ranged between 0.064 and 1.147 Pa.s at shear rate of 51.8 s^{-1} . Giving an overall curvilinear effect, an increased proportion of BSG showed a positive relationship with apparent viscosity. Therefore, combination of CMC and GG with BSG could improve their viscosities (Fig. 1). High viscosities of model solutions containing high ratios of BSG and GG in the mixture of selected gums have been recently proved (BahramParvar and Razavi 2012). Suitable functionality of another domestic seed gum

Fig. 2 Contour plots for the effect of different combinations of basil seed gum (BSG), guar gum (GG), and carboxymethyl cellulose (CMC) on draw temperature at two concentrations of 0.15 and 0.35 %

with seed origin, Balangu seed gum, in ice cream formulation has been reported (BahramParvar et al. 2009, 2010).

Draw temperature as a measure of heat removal in the freezer is dependent on conditions of freezing, type of freezer, and characteristics of the ice cream mix (Hartel 1996). Ice cream containing 0.15 % BSG had the lowest draw temperature (-6.20°C), while the sample with 50 % BSG and 50 % CMC at concentration of 0.35 % gained the highest one (-3.90°C). Increasing portions of BSG decreased the draw temperatures at 0.15 %. In contrast, high ratios of CMC in the mixtures elevated draw temperatures. Such ordered trends were not observed in the case of GG at 0.15 % as well as all selected gums at 0.35 %. Such that, draw temperature decreased to some levels then increased. Generally, high ratios of BSG and also mixture of three selected gums at equal proportions produced low draw temperatures (Fig. 2). As

draw temperature decrease, smaller ice crystals are produced in the product (Baer et al. 1999). A reason is that at lower draw temperatures, more ice crystals can be produced immediately in the form of many small nuclei, and the less of equilibrium ice-phase volume is generated during the hardening period. The result is an extremely smooth ice cream, with many small crystals, which is more stable to recrystallization during storage (Hartel 1996). Therefore, function of BSG in reduction of draw temperature at concentration of 0.35 % could help manufacturer to improve ice creams quality.

Overrun values ranged between 30.60 (sample with 50 % BSG and 50 % CMC at concentration of 0.35 %) and 65.22 % (sample with 0.15 % GG). Muse and Hartel (2004) reported values of about 40 to 70 % overrun for ice cream produced by a batch freezer. Increase in proportion of BSG as well as GG in

Fig. 3 Contour plots for the effect of different combinations of basil seed gum (BSG), guar gum (GG), and carboxymethyl cellulose (CMC) on overrun at two concentrations of 0.15 and 0.35 %

Fig. 4 Contour plots for the effect of different combinations of basil seed gum (BSG), guar gum (GG), and carboxymethyl cellulose (CMC) on melting rate at two concentrations of 0.15 and 0.35 %

the mixtures at concentration of 0.15 % enhanced the overrun of samples. However, BSG decreased the overrun at 0.35 % (Fig. 3) that could be related to high viscosity and disability of batch ice cream maker in entrapment of air.

Melting rate of ice cream is of special importance to the consumer when the product is being eaten from a cone or stick.

If the product melts too fast, a messy situation often develops. A fast-melting product also tends to become heat shocked readily (Marshall et al. 2003). Pure mixtures of 100 % BSG and CMC at concentrations of 0.35 and 0.15 % (F11 and F2), respectively gained the lowest (0.059 g/min) and the highest (0.802 g/min) values of melting rate (Table 1). Range of melting rate in our study was in agreement with other researches. Karaca et al. (2009) reported the melting rate of 1.17–1.91 g/min for ice creams containing various fat replacers. Melting rate of ice creams containing different levels and types of emulsifier varied between 0.1 and 1.0 % min⁻¹ (Bolliger et al. 2000). Melting rate values increased with increasing ratios of CMC and GG in the mixture; in contrast, BSG reduced the melting rate (Fig. 4). Intense melting resistance in samples containing high ratios of BSG is due to their high viscosity and role of viscosity in reduction of melting rate (Marshall et al. 2003). The viscosity of the unfrozen phase (serum) in the ice cream promotes with increasing the viscosity of ice cream mix. As the ice crystals melt, the water must diffuse into this serum phase. Ice creams with high viscosities have a greater resistance to flow and will not drip through the screen fast (Muse and Hartel 2004). Rincon et al. (2006) also found that the mixture of local Venezuelan gums, by reduction the rate of meltdown, provided desirable melting characteristics in ice cream.

Formulations optimization

A response optimizer was applied to generate the optimum proportion to meet the expectations of all responses were set in Table 4. Ice creams with higher viscosity, overrun, and melting rate and lower draw temperatures were preferred. The optimum proportions were 84.43 % BSG and 15.57 % GG at concentration of 0.15 %. The finding that lower concentration of gum could produce desirable properties is useful for food industry by lowering the amount of additives and cost. This promising result also could introduce BSG as a very capable stabilizer to ice cream and related products industries; such that, this gum formed the most part of optimized formulation and could act better than the commercial stabilizers. The predicted responses for apparent viscosity, draw temperature, overrun, and melting rate were 0.45 Pa.s, −5.93 °C, 65.32 %, and 0.56 g/min, respectively.

Table 4 The desirable ranges for each response for optimization of stabilizers formulation

Parameters	Goal	Lower	Target	Upper	Weight	Importance
Apparent viscosity	Maximum	0.113	0.8567	0.8567	1	1
Draw temperature	Minimum	−6.20	−6.20	−3.90	1	1
Overrun	Maximum	30.600	65.220	65.220	1	1
Melting rate	Minimum	0.0587	0.0587	0.8017	1	1

Verification of model

An experiment with the optimized stabilizer formulation was conducted in order to confirm the optimum formulation is really true. Mean observed values for apparent viscosity, draw temperature, overrun, and melting rate were 0.40 ± 0.012 Pa.s, -5.65 ± 0.212 °C, 62.38 ± 3.246 %, and 0.57 ± 0.007 g/min, respectively. It was found that there is no significant difference between predicted and observed responses ($P > 0.05$), indicating the adequacy of optimization process.

Hedonic sensory scores of appearance, flavor, body & texture, color, and total acceptance of ice cream containing optimum stabilizers blend were 7.02, 7.32, 6.92, 7.21, and 7.51 respectively. These results showed that all characteristics scored good or excellent and were acceptable for consumers. This means that optimum stabilizer formulation not only produce desirable physical properties in ice cream, but also help to create pleasing sensory attributes in the product.

Conclusions

Simplex centroid mixture design was used to optimize the three hydrocolloids, i.e. basil seed gum, guar gum, and carboxymethyl cellulose, proportions and their concentration in ice cream formulation. Regression models for apparent viscosity, draw temperature, overrun, and melting rate were established and triangular contour diagrams indicated the effect of variables on responses. The combination of 84.43 % BSG and 15.57 % GG at level of 0.15 % were proposed as optimized formulation that satisfied all expectations. The optimized formulation produced in practice and results demonstrated that the experimental data were in a good agreement with the predicted values using mixture; thus confirming the validity and adequacy of the predicted models and indicating that it is a reliable method for determining the optimum mixture. Promising result of this study also showed that basil seed gum as a novel source of hydrocolloid could act very capable and produce desirable properties in ice cream. In addition, optimum concentration of 0.15 %, by lowering the amount of additives and cost, is useful for ice cream manufacturer in economic point of view. Due to the good results obtained in functionality of optimum stabilizers formulation as well as BSG alone, further research is necessary to take advantage of these gums.

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