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Optimization of low-calorie sweet cream formulation via response surface methodology

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Abstract

In this study, the effect of stevia (0-0.04 g/100g) as a sucrose replacer, milk protein concentrate (mpc) (0-4 g/100g), and modified waxy corn starch (0-3 g/100g) as fat replacers on the physico-chemical and sensory characteristics of 15% fat cream were analyzed using a central composite rotatable design. Response surface methodology was used for optimization of low calorie cream formulation. Results showed that an increase in sucrose substitution with stevia and mpc concentration was followed by an increase in cream acidity, while pH decreased. Increasing sucrose substitution with stevia in cream decreased firmness, apparent viscosity and consistency, whereas increasing concentration of milk protein concentrate and modified starch increased the cream firmness, apparent viscosity and consistency. However, according to multiple response optimization, the optimum levels of 0.034 g/100g stevia, 1.64 g/100g mpc and 2.30 g/100g modified starch predicted acidity 0.15% acid lactic, pH 6.5, firmness 1.4 N, apparent viscosity 28730.3 mPa.s and consistency 0.52 cm/30 s. The calorie value of formulated cream was 46.44% less than the control sample (cream with 30% fat and 12% sucrose), and no significant difference in total acceptance between them was found, while formulated cream had higher score for taste and creamy state.

Keywords: Low calorie cream, Stevia, Milk protein concentrate, Modified starch, Response surface methodology, Optimization

Introduction

Sweet Cream is a milk product comparatively rich in fat separated from milk which takes the form of an emulsion of fat-in-skimmed milk (FAO, 2000). Sweet cream due to the high level of sucrose and fat content produces high calories. The relationship between dietary fat and calorie and the development of cardiovascular disease, hypertension, diabetes and obesity has created the increased demand for consumption of low calorie products. Therefore, food manufacturers' response to consumer demands has led to rapid market growth for low calorie products (Thaiudom *et al.* 2011). However, in addition to nutrition, fat influences rheological properties, sensory characteristics (flavor, mouthfeel and texture) and stability of fat-based product such as emulsion (Drake *et al.* 1999). Sucrose is not consumed only for its sweetness. It also has many functional properties in foods that make it useful as a bulking agent, texture modifier, mouthfeel modifier and preservative (Salminen *et al.* 2002). By increasing total solids Sucrose increases firmness and also provides sweetness and calories of product. These properties are very hard to reachieve in low/without fat and sucrose formulations. Modification of these products by using appropriate fat and sucrose replacers is often viewed as an effective way to overcome such problems due to the reduction in fat and sucrose content (Drake *et al.* 1999; Worrasinchai *et al.* 2006) but those properties might be changed (Thaiudom *et al.* 2011).

Stevia is a natural sweetener that is used as sucrose substitute (Cardello *et al.* 1999). The leaves of *Stevia Rebaudiana Bertoni* accumulate diterpenoids with sweet taste which is known as Steviol glycosides (Brandle *et al.* 2007). The major sweet compounds are rebaudioside A and stevioside. Rebaudioside

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A is 200-300 times sweeter than sucrose on a weight basis (Lindley, 2012). Rebaudioside A (purity>97% by HPLC) is also known as rebiana. Rebiana provides zero calories and has a clean sweet taste with no significant undesirable taste characteristics (Prakash *et al*, 2008). Milk protein concentrates (MPC_s) are dairy protein powders with protein content in the range of 42-85%. They are manufactured by removing the lactose and minerals from skim milk using membrane technology. The retentate obtained from this process is further concentrated by evaporation, and spray dried. MPCs are used as protein-based fat substitutes for their nutritional and functional properties. Higher-protein MPCs provide protein enhancement and a clean dairy flavor without adding significant levels of lactose to food and cream formulations. MPCs are multifunctional ingredients and provide benefits such as emulsification (Banach, 2012; Patel *et al.* 2006). Sodium octenyl succinate starch (E1450) is made by substituting hydroxyl groups in the polysaccharide chains by anhydrous octenyl succinic under alkaline conditions (Tesch *et al.* 2002). This polysaccharide exhibits amphiphilic character which enhances its emulsifying property. E1450 is also used as thickening agent by forming network with other polymers in aqueous solution through hydrophobic interaction. This increases the viscosity of the system and can stabilize droplet particles (Ortega-Ojeda *et al.* 2005). Various researches have been carried out about the use of sucrose and fat replacers in dairy products. Bagheri *et al.* (2014) investigated the possibility of substituting sugar with stevioside in breakfast cream and reported that if the bitter taste of stevioside can be covered, it could be used as an appropriate sugar replacer.

Response surface methodology (RSM) is a collection of statistical and mathematical technique useful for developing, improving and optimizing the formulation (Myers *et al.* 2009).

The objective of this study was to investigate the effects of fat replacers (MPC, and modified starch (MS)) and sucrose substitute (stevia) at different levels on the physico-chemical and sensory properties of low calorie sweet cream and optimize its formulation ingredient using RSM to obtain low calorie sweet cream with acceptable textural and sensory properties.

Materials and Methods

Pasteurized and homogenized milk with 2% fat content and sterilized and homogenized cream with 30% fat content were purchased from Damdaran Company, Tehran. MPC (with 70% protein content) and MS (sodium octenyl succinate waxy corn starch (E1450)) were purchased as fat replacers from Westland Company, New Zealand, and Pars Khoosheh Pardaz Company, Shiraz, Iran, respectively. Rebaudioside A 97% was obtained from Techfa Industrial Services Co., Tehran, Iran, as sucrose replacer and sucrose was procured from a local market.

Experimental design

Response surface methodology (RSM) which involves design of experiments, selection of levels of variables in experimental runs, fitting mathematical models and, finally, selecting variables' levels by optimizing the response was employed in the study. A central composite rotatable design (CCRD) was used to design the experiments comprising three independent variables at five levels each (Myers *et al.* 2009). One sucrose replacer (stevia) and two fat replacers (MPC and MS) were selected as independent variables. Moreover, six dependent variables (responses)-namely acidity, pH, firmness, syneresis, apparent viscosity, and consistency- were determined by the model to evaluate the optimum levels of the independent variables. The complete design included 20 experiments with six replications of the center point. The independent variables, their levels, and experimental results from this study are presented in Table 1.

Table 1. Central composite rotatable design for the independent variables and responses of dependent variables

Run no.	Independent variables						Response variables					
	X_1		X_2		X_3		Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
	Coded	Actual	Coded	Actual	Coded	Actual						
1	-1	0.008	-1	0.81	-1	0.61	0.12	6.61	0.417	14.24	5100	5.6
2	1	0.032	-1	0.81	-1	0.61	0.13	6.57	0.451	11.5	4600	6.3
3	-1	0.008	1	3.19	-1	0.61	0.17	6.46	0.515	3.04	10600	5
4	1	0.032	1	3.19	-1	0.61	0.18	6.41	0.446	0	5600	5.3
5	-1	0.008	-1	0.81	1	2.39	0.12	6.62	1.908	0	34800	0.3
6	1	0.032	-1	0.81	1	2.39	0.13	6.55	1.315	0	26200	0.6
7	-1	0.008	1	3.19	1	2.39	0.17	6.42	1.947	0	37100	0
8	1	0.032	1	3.19	1	2.39	0.18	6.38	1.908	0	36300	0
9	-α	0	0	2	0	1.5	0.15	6.53	1.187	0.34	21700	0.8
10	+α	0.04	0	2	0	1.5	0.16	6.49	0.741	0	12200	2.3
11	0	0.02	-α	0	0	1.5	0.11	6.64	0.716	0.4	17900	3.1
12	0	0.02	+α	4	0	1.5	0.19	6.35	1.045	0	21600	1.8
13	0	0.02	0	2	-α	0	0.16	6.52	0.314	15.88	3100	8.3
14	0	0.02	0	2	+α	3	0.15	6.51	2.477	0	46000	0
15	0	0.02	0	2	0	1.5	0.15	6.54	0.868	0.2	18900	2.4
16	0	0.02	0	2	0	1.5	0.15	6.55	0.878	0.1	16600	1.8
17	0	0.02	0	2	0	1.5	0.15	6.51	0.829	0.2	17900	2
18	0	0.02	0	2	0	1.5	0.15	6.50	0.849	0.1	20000	2.4
19	0	0.02	0	2	0	1.5	0.15	6.48	1.104	0	23200	2.1
20	0	0.02	0	2	0	1.5	0.16	6.44	1.01	0	23200	2.4

X_1 (concentration of Stevia, g/100g), X_2 (concentration of MPC, g/100g), X_3 (concentration of MS, g/100g)
Y_1 (Acidity, % acid lactic), Y_2 (pH), Y_3 (Firmness, N), Y_4 (Syneresis, %), Y_5 (Apparent viscosity, mPa.s), Y_6 (Consistency, cm/30 s)

Cream preparation

Control cream was prepared by addition of sucrose (12 g/100g) to UHT cream with 30% fat. Experimental creams were prepared based on the 15% fat in the formulated cream. The amount of stevia, MPC and MS were followed at certain level suggested by RSM (Table 1). As per the experimental design (Table 1), stevia and sugar powder composition were added to cream and mixed using mixer (Black & Decker.250w, England) for 20 s. MPC and MS were added to milk respectively and mixed well at room temperature. Milk mix and cream were mixed for 30 s and then the mix temperature reached 90ºC using a hot water bath in 20 min and was kept at this temperature for 20 s. Then, formulated cream was cooled in an ice bath to 60ºC and immediately stored at 6ºC until the day of analysis.

Analytical methods

Acidity

Titratable acidity was measured using the method of AOAC (1990), by titration of samples with 0.1 N NaOH solution containing 1% phenolphthalein as an indicator. Titratable acidity was calculated as a lactic acid percentage (%) as Eq. (1):

$$Acidity(\%) = \frac{0.1N\ NaoH(ml) \times 0.009}{sample(g)} \times 100 \quad (1)$$

pH

The pH was determined by using a digital pH meter (model Jenway, 3505, VK) at 20ºC. Buffer solutions of pH 7 and 4 were used to standardize the pH meter (Gonzalez-Martinez *et al*. 2002).

Firmness

The firmness of cream samples was determined at 7ºC by texture analyzer (STM-5, Santam, Iran). The firmness is defined as the force (N) necessary to puncture the cylindrical probe (diameter 22 mm) into the depth of 10 mm of the cream sample at a constant speed of 1 mm/s (Kovacova *et al.* 2010).

Syneresis

The cream samples were kept at room temperature of 25ºC in order to reach uniform temperature in the samples, and then 10 g of each cream sample was centrifuged in a centrifuge Z200A HERMLE (4000 rpm, at 20ºC for 15 min). After centrifugation, the mass of the separated water was determined. The percentage of syneresis was calculated as follows in Eq. (2) (Gonzalez-Martinez *et al.* 2002):

$$Syneresis(\%) = \frac{Separated\ water(g)}{Cream(g)} \times 100 \qquad (2)$$

Apparent viscosity

Viscosity of the cream samples was measured using a digital rotational viscometer (Myr, model V2-R, VISCOTEC Co., Spain) at 7ºC with spindle TR11. All measurements were recorded after 5 s at 20 rpm (shear rate $=5\ s^{-1}$) and reported as the apparent viscosity (Emam-Djome *et al.* 2008).

Bostwick consistency

Consistency was determined by measuring the distance (cm) over which the sample flowed in a Bostwick consistometer at 6ºC for 30 s. Consistency was related to distance inversely (Gonzalez-Martinez *et al.* 2002).

Calorie values

Moisture, ash, fat, and protein contents were determined according to AOAC (1990) official methods. Carbohydrates were determined by subtracting the sum of moisture, protein, fat, and ash percentages from 100%. Calorie values of control and optimum samples were calculated as follows in Eq. (3) (Worrasinchai *et al.* 2006):

$$Calorie\ Values = (4 \times protein) + (9 \times fat) + (4 \times carbohydrate) \qquad (3)$$

Sensory evaluation

A semi trained consumer panel, consisted of ten students (8 female and 2 male), of Food Science and Technology Department of Sari Agricultural Sciences and Natural Resources University, rated the sensory quality of control and optimum samples on the following attributes: appearance (color, separation of whey, foaming), odour, flavour, mouthfeel, consistency, spreadability, creamy texture and overall acceptance. The samples from each test were placed in glass containers and presented to each panelist at once. The samples were coded without a name, with a form that was pre-designed for this test, along with a meal presented to the panelists. A 5-point hedonic scale (1-1.99=dislike, 2-2.99=neither like nor dislike, 2-3.99=like moderately, 4-4.99=like very much and 5=like extremely) was used to evaluate the samples (Barzegari, 2012).

Statistical analysis

The obtained experimental data were fitted to a backward quadratic polynomial equation, and the 1% and 5% levels of significance were selected as the significance threshold. The CCRD test results were analyzed using Design-Expert software (version 7.0.0) to define a regression model and produce analysis of variance (ANOVA) tables and surface profile plots for all six responses. The results of sensory evaluation were analyzed in a randomized complete block design using SPSS 16.0 software to determine the difference between panelists, so that panelists were considered as blocks and samples (control and optimum) as treatments, but due to not significant difference between blocks, difference between treatments was analyzed in a complete randomized design.

Optimization

Numerical optimization technique of the Design-Expert (7.0.0) software was used for simultaneous optimization of the multiple responses. The desired goal for each independent factor and response was chosen. All the independent factors were kept within the range of the experimental study (Table 1). The responses, acidity and pH were kept within the range of standards of Iran, firmness was kept within the range of control cream and apparent viscosity and consistency were maximized.

Results and Discussion

Response models

The experimental results of the optimization study are given in Table 1. Also, the results obtained from the ANOVA are shown in Table 2. *P*-values of <0.01 indicate that all predicted response surface models were statistically significant at 99% confidence interval. Meanwhile, it was observed that the lack-of-fit test (Table 2) for all the models except syneresis were insignificant, implying that the models were accurate enough to predict the responses, while syneresis model due to the significant lack of fit was not appropriate. The variability explained by all the models was more than 80 percent ($R^2 > 0.80$). Ergo, all the models exept syneresis exhibited statistical adequacy and were hence used to study the effect of independent variables on the various responses. The results of calculating the coefficients of regression to predict the regression model obtained by using the Design-Expert statistic software are shown in Table 2. The coefficients of the terms along with their *p*-values show which terms contributed significantly to the responses ($p<0.01$ and $p<0.05$).

Table 2 Regression coefficients (*β*) and ANOVA for the response surface models in terms of coded units

particulars	Acidity	pH	Firmness	Syneresis	Apparent viscosity	Consistency
Intercept	0.15	6.50	0.93	0.33	19846.89	2.28
X_1	0.00416^{**}	-0.020^{*}	-0.10^{**}	-	-2260.92^{**}	0.28^{**}
X_2	0.024^{**}	-0.086^{**}	0.094^{*}	-1.71^{**}	1839.56^{*}	-0.34^{**}
X_3	-	-	0.65^{**}	-4.06^{**}	13227.71^{**}	-2.58^{**}
X_1^2	-	-	-	-	-1136.20	-0.21
X_2^2	-	-	-	-	-	-
X_3^2	-	-	0.17^{**}	2.88^{**}	1550.80^{*}	0.71^{**}
X_1X_2	-	-	-	-	-	-
X_1X_3	-	-	-0.075	-	-	-
X_2X_3	-	-	-	2.84^{**}	-	-
Model F-value	320.64^{**}	82.67^{**}	94.39^{**}	43.07^{**}	94.98^{**}	206.97^{**}
Lack of fit	0.7165^{NS}	0.9977^{NS}	0.4250^{NS}	$<0.0001^{**}$	0.7882^{NS}	0.2730^{NS}
R^2	0.9742	0.9068	0.9712	0.9199	0.9714	0.9867
C.V. %	2.39	0.39	11.24	70.40	11.54	11.86
Adequate precision	58.672	29.456	33.987	22.063	34.957	52.504

** Highly Significant ($p < 0.01$)

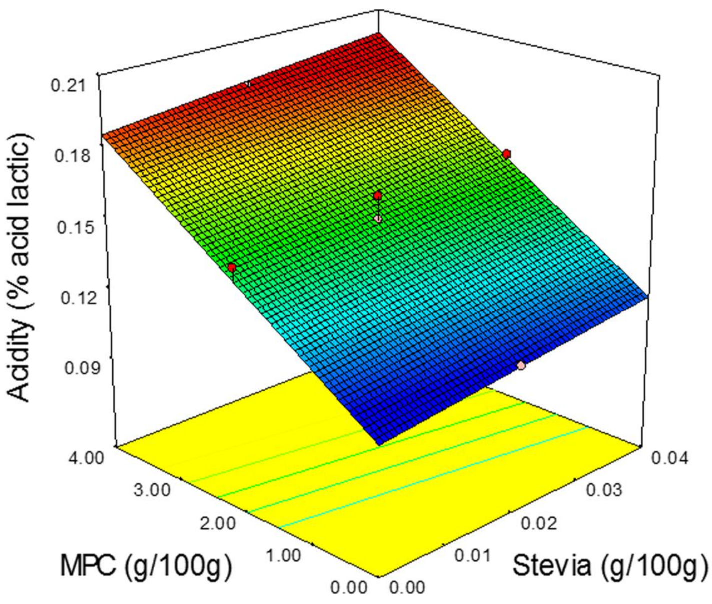
* Significant ($p < 0.05$)

^{NS} Non- Significant ($p > 0.05$)

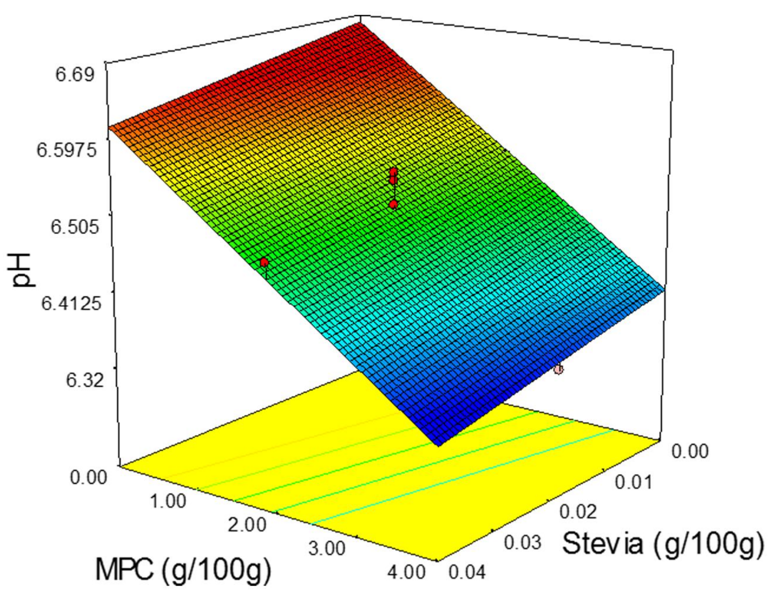
X_1 (concentration of Stevia, g/100g), X_2 (concentration of MPC, g/100g), X_3 (concentration of MS, g/100g)

Acidity

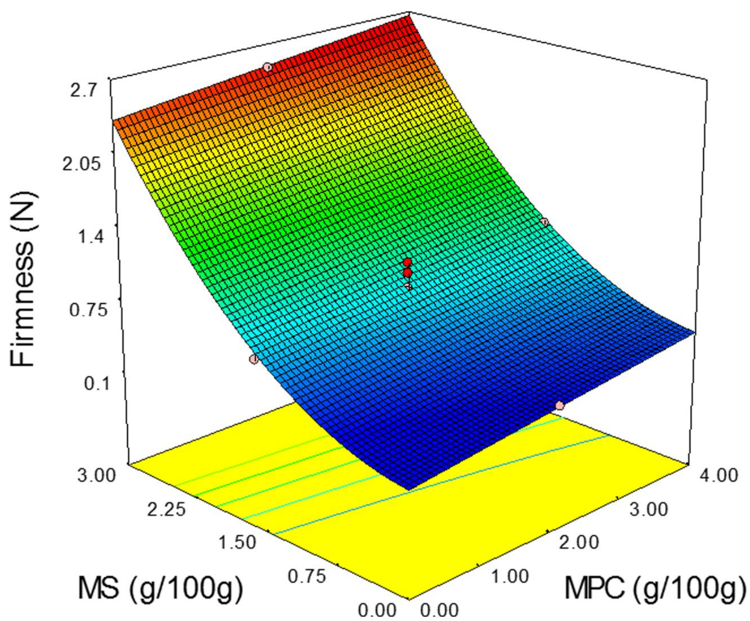
ANOVA of the independent variables impact on cream acidity (Table 2) indicated that the effects of stevia (X_1) and MPC (X_2) were significant ($p<0.01$) and the general regression model could be described as a linear equation. The effect of MPC was more pronounced (β =0.024) and pursued. Positive coefficients of X_1 and X_2 indicated linear effect to increase acidity. No significant effect was observed for MS (X_3) on acidity. The three-dimensional Fig. 1(a) shows two independent variables of the predictive model for acidity.


Acidity (% acid lactic)
0.21
0.18
0.15
0.12
0.09
4.00
3.00
2.00
1.00
0.00
MPC (g/100g)
0.00
0.01
0.02
0.03
0.04
Stevia (g/100g)

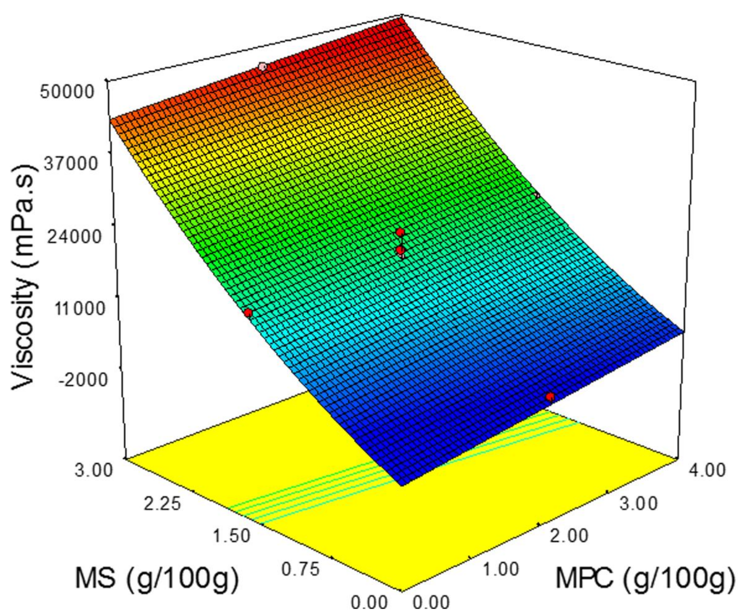
(a)


pH
6.69
6.5975
6.505
6.4125
6.32
0.00
1.00
2.00
3.00
4.00
MPC (g/100g)
0.00
0.01
0.02
0.03
0.04
Stevia (g/100g)

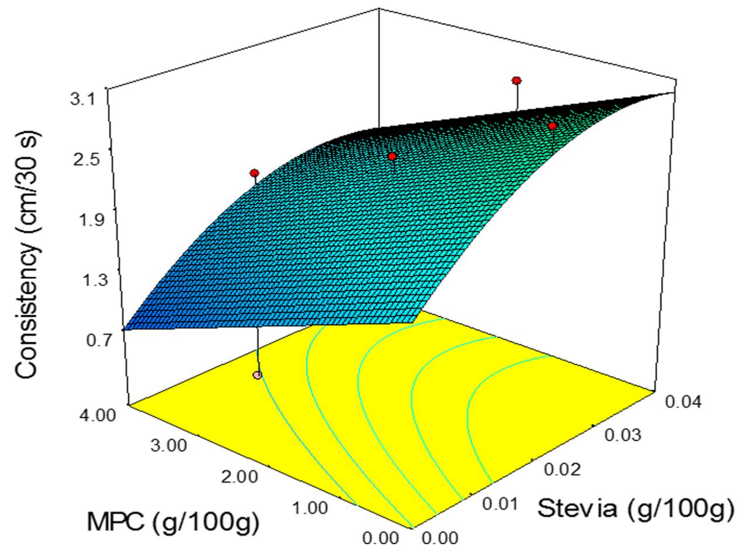
(b)


Firmness (N)
2.7
2.05
1.4
0.75
0.1
MS (g/100g)
3.00
2.25
1.50
0.75
0.00
MPC (g/100g)
0.00
1.00
2.00
3.00
4.00

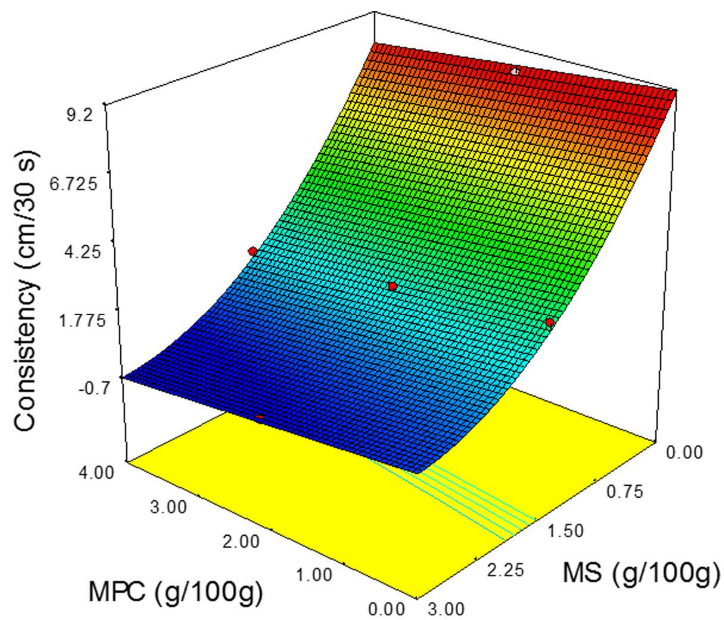
(c)


Viscosity (mPa.s)
50000
37000
24000
11000
-2000
MS (g/100g)
3.00
2.25
1.50
0.75
0.00
MPC (g/100g)
0.00
1.00
2.00
3.00
4.00

(d)



(e)



(f)

Fig. 1 Response surface plots showing the effects of stevia and MPC on acidity (a), stevia and MPC on pH (b), MPC and MS on firmness (c), MPC and MS on apparent viscosity (d), stevia and MPC on consistency (e), and MPC and MS on consistency (f) of creams

These provide geometrical representation of the behavior of acidity within the experimental design. In this study, acidity was in the range of 0.11 to 0.19% acid lactic for formulated creams. Based on the results, with increasing sucrose substitution with stevia at different MPC concentrations, acidity increased (Fig. 1(a)). It seems that the presence of amino acids and fatty acids in the extract of the leaves of Stevia plant is effective. Tadhani *et al.* (2006) identified six fatty acids in the leaf extract of Stevia that contains palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid and linolenic acid. Furthermore, increasing MPC concentration increased acidity so that the maximum acidity was observed in the sample with the maximum concentration of MPC, thus this can be attributed to higher acidity of MPC to cream. Increase in acidity with an increase of stevia substitution and MPC concentration has been reported by Bagheri *et al.* (2014).

pH

It is evident from ANOVA (Table 2) that pH was dependent on stevia (X_1) and MPC (X_2). However, no significant effect was observed for MS (X_3) or any quadratic and interaction terms on pH. In this study, pH was in the range of 6.35 to 6.64 for formulated creams. The pH was affected more significantly ($p<0.01$) by MPC than by stevia ($p<0.05$). Negative coefficients of stevia and MPC indicated linear effect to decrease pH. As seen in Fig. 1(b) pH linearly decreased as sucrose substitution with stevia increased due to increase of acidity. Moreover, decrease in pH was followed by an increase in MPC. So that the minimum pH was observed in the sample with the maximum concentration of MPC. It seems that the MPC has affected water absorption and mobility of hydrogen ions and thus has reduced the cream pH. Decrease in pH with an increase of MPC concentration has been reported by Patel *et al.* (2006).

Firmness

The firmness of cream texture is defined as its resistance to deformation by external forces and processes such as homogenization of cream fat and protein contents can affect the texture of the final product. The force necessary for the probe to penetrate into the cream samples, which is indicative of texture firmness, was in the range of 0.314 to 2.477 Newton for formulated creams in this research. Review of Table 2 shows significant effect of all the independent variables on firmness. The effect of stevia (X_1), MS (X_3) and its quadratic term (X_3^2) upon firmness was significant at $p<0.01$, whereas firmness was significantly affected at $p<0.05$ by MPC (X_2). The MS had the largest coefficient (β= 0.65) (Table 2) and maximum effect. No significant effect was observed for any interaction terms on firmness. The interaction effect of stevia and MS (X_1X_3) on firmness was not significant, however, it was not removed from the model due to its impact on the regression coefficients. As seen in Table 2 firmness linearly decreased as sucrose substitution with stevia increased due to reduction of total solid. According to Fig. 1(c) there was an increase in the firmness as the MPC and MS concentration were increased. The firmness of cream is highly dependent on total solids content, on the protein content of the product and also on the type of protein (Oliveira *et al.* 2001). Thus, in the present study, firmness increased with increase of MPC concentration along with increase of total solids and casein content. Moreover, increase in firmness was followed by an increase in MS concentration. So that the sample with the maximum concentration of MS had the maximum firmness. MS may cause increased firmness due to water absorption ability and strong network formation (Woo *et al.* 2002).

Syneresis

The experimental results showed that syneresis decreased with increase of MPC concentration despite increased acidity (Table 1), which is due to the high water absorption of MPC. Also, according to Table 1 syneresis decreased with increase of MS concentration in the constant concentration of Stevia and MPC, so that in the maximum concentration of MS no syneresis was observed but the maximum syneresis (15.88%) was observed in the sample without MS. On the other hand, according to the ANOVA (Table 2), the model of syneresis was statistically significant ($p<0.01$) but the lack-of-fit test was significant ($p<0.01$). The significant lack of fit for a model does not endorse the accuracy of the model to fit the data and indicates that the points are not well-located around the model. Therefore, the model cannot be used to predict the values of function variables. Emam-Djome *et al.* (2008) also concluded that with increase of whey protein concentrate, syneresis of cream decreased.

Apparent viscosity

Apparent viscosity of formulated creams varied from 3100 to 46000 mPa.s. According to the ANOVA (Table 2), stevia (X_1), MPC (X_2) and MS (X3) significantly (p<0.01 and p<0.05) influenced the viscosity. As seen in Table 2, by increasing sucrose substitution with stevia, viscosity decreased due to reduction of total solid followed by decrease of sucrose concentration. Disaccharides such as sucrose produce high osmolality solutions due to their solubility and hydrophilic characteristic and have the capacity to make hydrogen bonds with water molecules by a hydroxyl group, which in turn augments viscosity of the creams (Alizadeh *et al.* 2014). Guggisberg *et al.* (2011) also reported that the apparent viscosity of low-fat set yoghurt decreased as the substitution of sucrose with stevia increased. Figure 1(d) shows the 3D response surface plot at varying MPC and MS concentrations. From Fig. 1(d) it can be concluded that the viscosity of formulas increases with increase in both variables. It is obvious that the increase made by MS addition was more evere. So that the maximum viscosity was observed in the sample with the high content of MS. It is also evident from the results shown in Table 2 that apparent viscosity was severely dependent on MS. By increase in protein level of creams followed by increase of MPC concentration, increased water absorption ability and viscosity improved (Aminigo *et al.* 2009). The increase of MS concentration enhances total solids and firmness of creams and increases creams viscosity followed by reduction of molecules mobility and increase of emulsion stability.

Bostwick consistency

In Bostwick consistometer, less traveled distance by sample over time (30 s) is indicative of its higher consistency. The consistency of formulated creams varied from 0 to 8.3 cm/30 s. Analysis of variance of the independent variables (Table 2) showed that the effect of all the independent variables upon consistency was significant at p<0.01. The MS had the largest coefficient (β= -2.58) and maximum effect on cream consistency (Table 2). Positive coefficient of stevia (X_1) indicated linear effect to increase traveled distance by sample and decreased consistency. It can be concluded from the Fig. 1(e) that with increasing the level of sucrose substitution with stevia at different MPC concentrations, traveled distance by sample increased; thus, cream consistency decreased due to reduction of total solids as a result of decrease of sucrose concentration. However, the regression coefficient of cream consistency (Table 2) showed that with increase of MPC and MS concentration traveled distance by sample decreased and consistency increased. It can be inferred from Fig. 1(f) that the traveled distance by sample would be minimized as the MPC and MS reached their maximum values. Protein matrix of MPC is formed from the casein micelles; and casein is the key factor to obtain a firm consistency. By increase in MS concentration, traveled distance by formulated creams decreased; thus, cream consistency increased due to increase of viscosity and firmness, and also reduce of molecules mobility.

Numerical optimization of formulations

Design Expert statistics software (version 7.0.0) was used for simultaneous numerical optimization of the processing variables. The optimum values of the independent variables were achieved after assigning certain constraints upon the processing conditions and the responses (Table 3). The value of importance was as per the default setting of the software (importance= 3) for all the variables. The optimum values of the independent variables and their corresponding responses are reported in Table 3. The best conditions for meeting the maximum desirability (0.978) were obtained at 0.034 g/100g stevia (equivalent to 10.2 g/100g of sucrose), 1.64 g/100g MPC, and 2.30 g/100g MS. The corresponding predictions for the dependent variables under these conditions were 0.15% acid lactic for acidity, pH 6.5, firmness 1.4 N, apparent viscosity 28730.3 mPa.s and consistency 0.52 cm/30 s. The experiments were also conducted under the predicted optimum conditions to verify the efficacy of the models. Review of Table 3 shows that the predicted values had non-significant difference from experimental values.

Table 3. Goals set for constraints to optimize the formulation of low calorie sweet cream and verification of the response models by comparing the experimental values with the predicted values

Independent variable	Goal	Lower limit	Upper limit	Optimum value [a]		
Stevia (g/100g)	in range	0	0.04	0.034		
MPC (g/100g)	in range	0	4	1.64		
MS (g/100g)	in range	0	3	2.30		
Responses				Predicted value	Actual value [b] ± SD	p-value
Acidity (% acid lactic)	in range	0.09	0.15	0.15	0.155±0.007	0.500
pH	in range	6.5	6.8	6.5	6.56±0.01	0.105
Firmness (N)	in range	1	1.4	1.4	0.95±0.07	0.070
Apparent viscosity (mPa.s)	maximize	3100	46000	28730.3	26550±353.55	0.073
Bostwick distance (cm/30 s)	minimize	0	8.3	0.52	0.15±0.07	0.086

[a] the desirability for this result was 0.978
[b] means from triplicate experiments

Calorie values

The proximate analysis and calorie values of the optimized and control cream are listed in Table 4. The moisture content of optimized cream decreased with increasing level of sucrose substitution with stevia and decreasing fat content due to reduction of total solids. The calorie value of optimized cream was 46.44% less than the control sample. This calorie reduction was due more to reduction of fat content. Although by addition of MPC as a fat replacer protein content of optimized cream increased and also carbohydrate content decreased due to reduction of sucrose amount in cream formulation. Besides, the energy amount produced by carbohydrate and protein is less than the one produced by fat.

Table 4. Chemical compositions (g/100g) and calorie values of cream samples

Sample	Moisture	Fat	Protein	Ash	Carbohydrate	Calorie values (Kcal/100g)
Control	52	30	2.02	0.70	15.28	338
Optimized	72.7	15	3.36	0.795	8.14	181.02

Sensory evaluations

As seen in Fig. 2, no significant difference between the optimum and control creams in appearance, odour, mouthfeel, consistency, spreadability and overall acceptance was found and both of them earned high scores, while in terms of flavour and creamy texture there was a significant difference (p<0.01) between them. The flavour score of formulated cream was significantly higher than control. This can be attributed to more favorable sweetness and flavour as a result of sucrose substitution with rebaudioside A and adding MPC as a fat replacer. MS had no effect on flavour. Also, in terms of creamy texture the formulated cream earned a higher score than the control which shows that simultaneous use of MS and MPC can cover qualitative defects caused by reduction of fat in low fat cream.

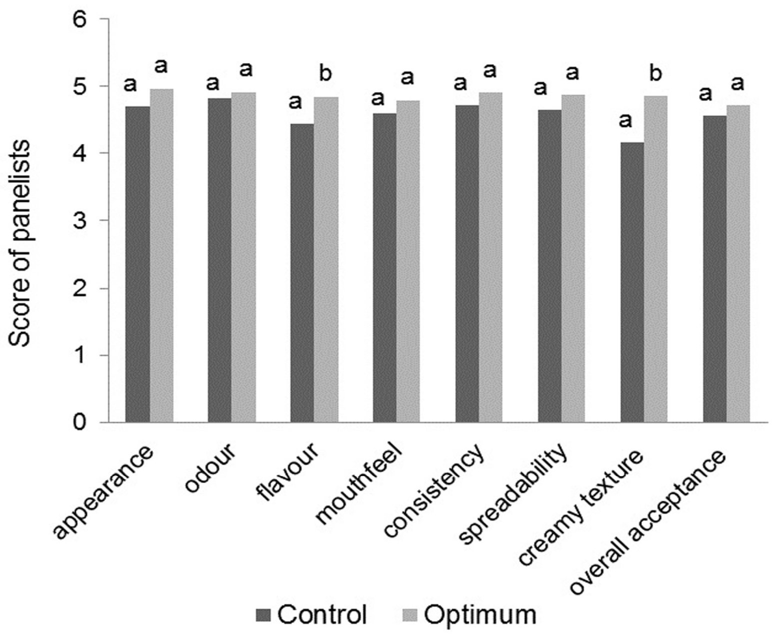


Fig. 2. The results of sensory evaluation based on obtained scores

Conclusion

Response surface methodology was effective in optimizing formulation for the manufacture of low calorie sweet cream form different blends of stevia, MPC and MS. The regression analysis yielded models that were used for obtaining optimum formulation for desired responses within the range of conditions applied in this study. The formulation with 0.034 g/100g of stevia, 1.64 g/100g of MPC and 2.30 g/100g of MS was found optimum for low calorie sweet cream preparation. Price per kilogram of optimized and control creams was estimated 38500 and 40000 Rials respectively, that shows new formulation is more affordable for the consumer economically.

References

Alizadeh, M., Azizi-Lalabadi, M. & Kheirouri, S., 2014, Impact of Using Stevia on Physicochemical, Sensory, Rheology and Glycemic Index of Soft Ice Cream. *Food and Nutrition Sciences*, 5, 390–396.

Aminigo, E.R., Metzger, L. & Lehtola. P.S., 2009, Biochemical composition and storage stability of a yogurt-like product from African yam bean (*Sphenostylis stenocarpa*). *International Journal of Food Science and Technology*, 44, 560–566.

AOAC, 1990, Official Methods of Analysis.

Bagheri, F., Radi, M. & Amiri, S., 2014, Use of Sweetener Stevioside for Produce Dietary Breakfast Cream. *Agriculture Science Developments*, 3(9), 284–291.

Banach, J.C., 2012, Modification of milk protein concentrate and applicability in high-protein nutrition bars. MS Thesis, Iowa State University, Ames, Iowa.

Barzegari, M., 2012, The effect of xanthan and carboxy methyl cellulose substitution with Persian gum on the quality of mayonnaise. MS Thesis, Sari Agricultural Sciences and Natural Resources University.

Brandle, J.E., & Telmer, P.G., 2007, Steviol glycoside biosynthesis. *Phytochemistry*, 68, 1855–

1863.

Cardello, H.M.A.B., Dasilva, M.A.P.A., & Damasio, M.H., 1999, Measurement of the relative sweetness of stevia extract, aspartame and cyclamate/saccharin blend as compared to sucrose at different concentrations. *Plant Foods for Human Nutrition*, 54, 119–130.

Drake, M.A., Truong, V.D., Daubert, C.R., 1999, Rheological and sensory properties of reduced-fat processed cheeses containing lecithin. *Journal of Food Science*, 64, 744–747.

Emam-Djome, Z., Mousavi, M.E., Ghorbani, A.V., and Madadlou, A., 2008, Effect of whey protein concentrate addition on the physical properties of homogenized sweetened dairy creams. *International Journal of Dairy Technology*, 61(2), 183–191.

FAO, 2000, Food and Agriculture Organization of the United Nations. Codex standard for cream for direct consumption, 2nd edn. In Codex Alimentarius: *Milk and milk products*, pp. 39–41.

Gonzalez-Martinez, C., Becerra, M., Chafer, M., Alborz, A., Carot, J.M., & Chiralt, A., 2002, Influence of substituting milk powder for whey powder on yoghurt quality. *Food Science and Technology*, 13, 334–340.

Guggisberg, D., Piccinali, P., & Schreier, K., 2011, Effects of sugar substitution with Stevia, Actilight and Stevia combinations or Palatinose on rheological and sensory characteristics of low-fat and whole milk set yoghurt. *International Dairy Journal*, 21, 636–644.

Kovacova, R., Stetina, J., & Curda, L., 2010, Influence of processing and κ-carrageenan on properties of whipping cream. *Journal of Food Engineering*, 99, 471–478.

Lindley, M.G., 2012, Natural High-Potency Sweeteners. In: O'Donnell, K., & Kearsley, M.W., eds. Sweeteners and Sugar Alternatives in Food Technology. John Wiley & Sons. New Delhi, pp: 185–207.

Myers, R.H., Montgomery, D.C., & Anderson-Cook, C.M., 2009, Response Surface Methodology: process and product optimization using designed experiments. Wiley and Sons. New Jersey.

Oliveira, M.N., Sodini, I., Remeuf, F., & Corrieu, G., 2001, Effect of milk supplementation andculture composition on acidification, textural properties and microbiological stability of fermentedmilks containing probiotic bacteria. *International Dairy Journal*, 11, 935–942.

Ortega-Ojeda, F.E., Larsson, H., & Eliasson, A.C., 2005, Gel formation in mixtures of hydrophobically modified potato and high amylopectin potato starch. *Carbohydrate Polymers*, 59, 313–327.

Patel, M.R., Baer, R.J., & Acharya, M.R., 2006, Increasing the Protein Content of Ice Cream. *Journal of Dairy Science*, 89, 1400–1406.

Prakash, I., DuBois, G.E., Clos, J.F., Wilkens, K.L., & Fosdick, L.E., 2008, Development of rebiana, a natural, non-caloric sweetener. *Food and Chemical Toxicology*, 75–82.

Salminen, S., & Hallikainen, N., 2002, Sweeteners. In: Branen, A.L., Davidson, P.M., Salminen, S. & Thorngate, III J.H., eds. Food Additives. Marcel Dekker. New York, pp: 447–475.

Tadhani, M., and Subhash, R., 2006, Preliminary studies on Stevia rebaudiana leaves: proximal composition, mineral analysis and phytochemical screening. *Journal of medical sciences*, 6(3), 321–326.

Tesch, S., Gerhards, Ch., & Schubert, H., 2002, Stabilization of emulsions by OSA starches. *Journal of Food Engineering*, 54, 167–174.

Thaiudom, S., & Khantarat, K., 2011, Stability and rheological properties of fat-reduced mayonnaises by using sodium octenyl succinate starch as fat replacer. *Procedia Food Science*, 1, 315–321.

Woo, K.S., & Seib, P.A., 2002, Cross-Linked Resistant Starch: *Preparation and Properties. Cereal Chemistry*, 79(6), 819–825.

Worrasinchai, S., Suphantharika, M., Pinjai, S., & Jamnong, P., 2006, ß-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. *Food Hydrocolloids*, 20, 68–78.

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بهینه‌سازی فرمولاسیون خامه شیرین کم‌کالری با استفاده از روش سطح پاسخ

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چکیده

در این تحقیق، تأثیر استویا (0/04-0 درصد وزنی) به‌عنوان جایگزین ساکارز، کنسانتره پروتئینی شیر (4-0 درصد وزنی) و نشاسته اصلاح‌شده ذرت مومی (3-0 درصد وزنی) به‌عنوان جایگزین‌های چربی بر روی خصوصیات فیزیکوشیمیایی و حسی خامه 15 درصد چربی با استفاده از طرح مرکب مرکزی چرخش‌پذیر بررسی شد. برای بهینه‌سازی فرمولاسیون خامه کم‌کالری از روش سطح پاسخ استفاده شد. نتایج نشان داد که افزایش جایگزینی ساکارز با استویا و غلظت کنسانتره پروتئینی شیر موجب افزایش اسیدیته خامه شد، در حالی‌که pH کاهش یافت. با افزایش جایگزینی ساکارز با استویا در خامه، سفتی بافت، ویسکوزیته ظاهری و قوام کاهش یافت، در حالی‌که افزایش غلظت کنسانتره پروتئینی شیر و نشاسته اصلاح‌شده منجر به افزایش فاکتورهای ذکر شده گردید. بر اساس بهینه‌سازی چند پاسخ، سطوح بهینه برای استویا 0/034 درصد، کنسانتره پروتئینی شیر 1/64 درصد و نشاسته اصلاح‌شده 2/30 درصد تعیین و مقادیر اسیدیته 0/15درصد بر مبنای اسیدلاکتیک، pH 6/5، سفتی بافت N 1/4، ویسکوزیته ظاهری 28730/3 mPa.s و قوام 0/52 cm/30se پیش‌بینی شدند. ارزش کالری خامه فرموله شده 44/46 درصد کمتر از نمونه شاهد (حاوی 30 درصد چربی و 12 درصد ساکاروز) بود. خامه فرموله شده از نظر پذیرش کلی اختلاف معنی داری با شاهد نداشته و در عین حال امتیاز بالاتری از نظر مزه و حالت خامه ای داشت.

واژه‌های کلیدی: خامه کم‌کالری، استویا، کنسانتره پروتئینی شیر، نشاسته اصلاح‌شده، روش سطح پاسخ، بهینه‌سازی

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