

Optimization of Fat Replacers and Sweetener Levels to Formulate Reduced- Calorie Pistachio Butter: A Response Surface Methodology

Emadzadeh B.^{1,2}, Razavi S. M. A. ^{*2}, Hashemi M.³, Nassiri Mahallati M. ⁴, Farhoosh R. ²

¹Khorasan Research Institute for Food Science and Technology (KRIFST), Mashhad, Iran

²Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM), POBox: 91775-1163, Mashhad, Iran

³Department of Food Processing, Iranian Academic Center for Education Culture and Research (ACECR), Mashhad, Iran

⁴Department of Agronomy, Ferdowsi University of Mashhad (FUM), POBox: 91775-1163, Mashhad, Iran

Abstract: Consumers' awareness about the nutritional profile of their diets has made the industry to respond their needs seriously. In this study, response surface methodology was used to analyze the effect of three fat replacers and two sweeteners on sensory attributes and viscosity of low- calorie pistachio butter. Balangu seed extract (BSG) (0.01-0.04), Reihan seed gum (RSG) (0.01-0.023), xanthan (0.06-0.1), isomalt (0-1) and sucrose (0.25-1) were the levels investigated. A central composite design was used to develop models for the responses. The optimum levels of ingredients according to the target values were as follows: xanthan (0.1%), isomalt: pistachio paste ratio (0.81), sucrose: pistachio paste ratio (0.71) for formulas prepared using xanthan gum; Balangu seed extract (0.034%), isomalt: pistachio paste ratio (1) and sucrose: pistachio paste ratio (0.25) for products containing Balangu seed extract; and RSG (0.023%), isomalt: pistachio paste ratio (0.333) and sucrose: pistachio paste ratio (1.0) for formulas prepared by RSG.

Keywords: Pistachio butter; Reduced- calorie; Fat replacers; RSM; Optimization; sensory

INTRODUCTION

Pistachio is one of the most important exports of Iran. According to the statistics reported by FAO (2008), Iran is the original home of pistachio and the annual amount of pistachio production in Iran constitutes 62% of the total world production. Pistachio butter is a pasty formed nutritive product which is made from blending the pistachio paste with sucrose, emulsifier and taste improver [3].

By increasing the obesity in many parts of the world and as consumers become increasingly aware about the assistance of food in calorie control, the food industry has responded to consumer demand by offering an ever-increasing reduced- calorie versions of standard products. According to Codex claims, reduced- calorie foods should have reduction $\geq 25\%$ in comparison to the full fat food [16].

In spite of the positive contribution of fats to taste, texture and aroma of foods, the high calorie content

of fat has made some anxieties for consumers and nourishing scientists. In general, fat replacers are implied to all the bulking agents or ingredients that somehow replaces fat in a system. The ideal fat replacer(s) reduces fat and calorie content of the product, while remains all the characteristics of the primary full fat product [28]. The manufacturers and legislatives' requirements should also be taken into account [38]. As hydrocolloids can provide some important functions of fat by texturizing, water-structuring, mouth coating and opacity properties, they are generally expected as proper fat replacers [32]. Xanthan is a versatile hydrocolloid that as a result of its ordered molecular structure can be used in low- fat products. It can give relatively viscous solutions at low concentrations and also stabilize the product's dispersion at rest [38].

Lallemantia royleana (with vernacular name Balangu seed) is a mucilaginous endemic plant which grows in different Middle East countries

Corresponding Author: Razavi S. M. A., Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM), POBox: 91775-1163, Mashhad, Iran Email: s.razavi@um.ac.ir

especially different parts of Iran. According to its mucilaginous extract, it is conventionally consumed as a stimulant, diuretic and expectorant medicine and used in a range of Iranian traditional products [29, 33]. Soaking in water, seeds absorb water quickly and produce a sticky, turbid and tasteless liquid [33]. The optimum extraction conditions of Balangu seed extract (BSG) has previously studied by [26]. Recent rheological researches have approved that its mucilaginous extract can be used as a novel food hydrocolloid in food formulations [34].

Ocimum basilicum also known as Reihan is another endemic medical plant which is distributed in the tropical regions of Asia, Africa and Central and South America [36]. The outer pericarp of Reihan seeds swells as it is soaked in water. The optimum conditions of Reihan seed gum (RSG) extraction have been determined before [35]. Hosseini-Parvar [20] studied the rheological characteristics of RSG and show that the existence of yield stress, the high low shear viscosity and pseudoplastic behavior of this hydrocolloid has made it a good stabilizer in food formulations.

Another food ingredient that can be considered in formulation of low- calorie foods is sweetener. The ideal sweetener to be altered in low- calorie food system should be as sweet as sucrose, colorless, odor less, water soluble and stable in both acidic and basic conditions and over a wide range of temperatures [28]. Isomalt is a sweet, low-calorie, bulking agent with properties and characteristics similar to sucrose. It is a non-reducing sugar and stable against chemical and enzymatic hydrolysis. It is also a suitable sweetener for diabetics [25, 28]. In fact, considering a perfect sweetener is impossible and therefore, mixing of sweeteners is commonly used in food formulations. The combination of sweeteners improved the acceptability, functionality and economics of each sweetener individually [30].

The formulation of reduced- calorie food products and its aspects have been studied by many researchers; water continuous low- fat spreads [8], fat- free process- cheese spreads [41], low- fat spread using fish gelatin and pectin [7], low- fat cheeses [37], calorie- reduced yoghurt [22], fat-free stirred yoghurt [11], reduced- calorie chocolate

[39], reduced- calorie salep drink [43] and many others.

According to Evans [15] optimization gives the possibility to achieve the best case among the possible alternatives. Response surface methodology (RSM) is an empirical modeling approach to understand the quantitative relationship between input variables and output response. Because of its comprehensive and high efficiency, it is a useful tool to achieve the optimum conditions [14, 19, and 40]. Some good examples of appropriate application of this technique in food formulation are the optimization of formulations of peanut- soy beverage [12], traditional baked cassava cake [18], mango soy fortified yoghurt [23], chocolate peanut spread [9], protein- and vitamin- fortified peanut spreads [47], reduced calorie mixed fruits jam [1], extruded snack food [44], improved wheat bread dough [10], chocolate-flavored, and powdered chocolate milk [21].

In the present study, investigations were undertaken to formulate a novel low- calorie food product, and to employ a central composite design (3 factors and 3 levels) to study the effects of independent variables on the viscosity and sensory attributes. It was also attended to optimize the fat replacer (xanthan gum, Balangu seed extract and Basil seed gum) and sweeteners (isomalt and sucrose) levels by response surface methodology.

MATERIALS AND METHODS

Preparation of formulas

The O'hadi pistachio was obtained from a local market in Kashmar city, Khorasan province in Iran in September 2009. It was manually peeled and cleaned to remove all foreign matters. The nuts were cracked and the kernels separated from the shells by hand. The $\geq 25\%$ oil reduction was achieved by pressing the pistachio kernels in an oil extraction plant. Isomalt was procured from Sim-Sim industry, (Mashhad, Iran). Sucrose and vanilla were obtained from local markets. Potassium sorbate and lecithin were purchased from Merck (Germany) and Acrose (Belgium) companies, respectively. At the first step for all formulas, the proper amount of hydrocolloid, potassium sorbate and lecithin were dissolved in distilled water using

a stirrer and then added to the pre- blended pistachio paste, sweetener and vanilla. All ingredients were then mixed with the pre-defined amount of distilled water and the final product was homogenized using ultra turrax T25 at 9500 rpm for 10 min (IKA Labortechnik, Germany). The basic composition formula was suggested by the results of pre- experiments carried out in our laboratory.

Sensory evaluation

The formulas were prepared one day in advance and kept at 4°C in refrigerator. They were stored at room temperature 30 min before testing. All samples were coded with random numbers and served in random order to a seven member trained panel. Instructions were given in full to panelists beforehand and they evaluated the odor, oily appearance, spreadability, hardness, graininess, cohesiveness, mouth feel, taste and total acceptance attributes (Table 1). According to the fact that texture, appearance and flavor are the three major characteristics which are mainly judged by the consumers, the sensory evaluation test was structured [42]. Samples were evaluated using a scaling nine point hedonic method. Panelists cleanse their palates with water before rating each sample.

Viscosity measurement

After the preparation process, the samples were kept at 4°C for 24 hours. Measurements were carried out using a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) equipped with a heating circulator (Julabo, Model F12-MCand, Julabo Labortechnik, Germany) and C14 spindle. All the experiments were performed at 25°C±0.2. The shear rate of 47 s⁻¹ was chosen as the reference shear rate as its determined thickness can be well correlated with the perceived thickness in mouth [5].

Experimental design

After determining the experimental range of the formulation variables through preliminary experiments, a faced central composite design (CCD) with 6 replicates at the centre point was used to develop predictive models for viscosity and

sensory score attributes. As there may occur some systematic errors and therefore some unexplained variability in the observed responses, experiments were replicated in the center of design to make the estimation of pure error possible [31]. The three independent variables (gum concentration, isomalt: pistachio paste ratio, and sucrose: pistachio paste ratio) and experimental design in terms of coded and uncoded values are presented in Table 2. Data from CCD were analyzed by multiple regressions to fit the following quadratic polynomial model.

$$Y = \beta_0 + \sum_{i=1}^3 \beta_i X_i + \sum_{i=1}^3 \beta_{ii} X_i^2 + \sum_{\substack{i=1 \\ i < j}}^3 \sum_{j=1}^3 \beta_{ij} X_i X_j$$

Where, Y is the estimated response; β_0 , β_i , β_{ii} , β_{ij} are constant coefficients. X_i , X_j are the concentration percentages of xanthan, isomalt: pistachio paste ratio, and sucrose: pistachio paste ratio, respectively. The significance of the equation parameters for each independent variable was evaluated using *p*- value. The goodness of fit was determined by model analysis, lack of fit and coefficient of determination parameters.

The optimization and the graphic presentations of the response surface models were performed using Minitab statistical software (version 13.2, MINITAB™, USA). Numerical optimization was carried out to determine the exact optimum value of independent variables. The desired goal and appropriate weight was assigned to each variable and the optimal condition was obtained using the predicted equations determined by RSM. The response surfaces for the models were plotted as a function of two variables, while keeping other variable at the average value.

RESULTS AND DISCUSSIONS

Diagnostic checking of the fitted models

According to the conditions constructed using CCD, twenty experiments were carried out for each fat replacer (Table 2). Analytical data from central composite design of samples were fitted to multiple regressions to estimate response surfaces of dependent quality variables. Developed regression models and coefficients of determination for

xanthan gum (XG), BSG and RSG are reported in Tables 3, 4 and 5, respectively. The fitted quadratic models accounted for more than 70% variations of the oily appearance, hardness, cohesiveness, taste and viscosity experimental data. All main effects, linear and quadratic, and interaction effects were calculated for each model. The significance of coefficients was evaluated using P-value in Tables 3, 4 and 5 for xanthan gum, BSG and RSG, respectively. This statistic was used as a tool to check the significance of each coefficient and also an indication of the pattern of interactions between variables [40]. The gum concentration has a great quadratic effect on the odor of formulas prepared

using xanthan gum ($p \leq 0.05$), graininess and taste characteristics of formulas containing BSG ($p \leq 0.1$) and oily paste ratio on the rated cohesiveness score. Higher levels of BSG led to higher cohesiveness scores. It is probably due to the appearance of an additional hydrocolloid network and therefore, an increase in the ability of granules to stay together. Aydi [4] reported similar results for the meat sausages containing carrageenan hydrocolloid. Increasing the sucrose: pistachio paste ratio resulted in a slow increase followed by a decrease in cohesiveness.

Table 1. Terms used in the sensory evaluation of reduced- calorie pistachio butter

Sensory attributes	Definition
Odor	Odor of the product in comparison to the odor of the full- fat control sample
Oily appearance	amount of oiliness on surface
Spread ability	ease of spread of sample on bread
Hardness	force required to compress between tongue and palate
Graininess	amount of particles or granules perceived in the mouth
Cohesiveness	amount of sample that deforms rather than shears/cuts (ability to stay together)
Perception of fat	Amount of oil perceived in mouth after sample is expectorated
Taste	taste on the tongue in comparison to the taste of full- fat control sample
Total acceptance	Total acceptability of the product

Table 2. Faced central composite design for the independent variables (coded and uncoded levels)

Run	Independent variables											
	Coded levels			Uncoded levels for XG			Uncoded levels for BSG			Uncoded levels for RSG		
	Gum concentration (A)	Isomalt ratio (B)	Sucrose ratio (C)	Gum concentration	Isomalt ratio	Sucrose ratio	Gum concentration	Isomalt ratio	Sucrose ratio	Gum Concentration	Isomalt ratio	Sucrose ratio
1	1	1	3	0.06	0	1	0.01	0	1	0.01	0	1
2	1	1	1	0.06	0	0.25	0.01	0	0.25	0.01	0	0.25
3	1	2	2	0.06	0.5	0.63	0.01	0.5	0.63	0.01	0.5	0.63
4	1	3	1	0.06	1	0.25	0.01	1	0.25	0.01	1	0.25
5	1	3	3	0.06	1	1	0.01	1	1	0.01	1	1
6	2	1	2	0.08	0	0.63	0.025	0	0.63	0.017	0	0.63
7	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
8	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
9	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
10	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
11	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
12	2	2	2	0.08	0.5	0.63	0.025	0.5	0.63	0.017	0.5	0.63
13	2	2	3	0.08	0.5	1	0.025	0.5	1	0.017	0.5	1
14	2	2	1	0.08	0.5	0.25	0.025	0.5	0.25	0.017	0.5	0.25
15	2	3	2	0.08	1	0.63	0.025	1	0.63	0.017	1	0.63
16	3	1	1	0.1	0	0.25	0.04	0	0.25	0.023	0	0.25
17	3	1	3	0.1	0	1	0.04	0	1	0.023	0	1
18	3	2	2	0.1	0.5	0.63	0.04	0.5	0.63	0.023	0.5	0.63
19	3	3	1	0.1	1	0.25	0.04	1	0.25	0.023	1	0.25
20	3	3	3	0.1	1	1	0.04	1	1	0.023	1	1

Table 3. Estimated coefficients and coefficients of determination (R2) of the fitted quadratic equations for different responses for products prepared using xanthan gum

Coefficients	Estimated coefficients									
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Cons.	10.6**	6.50 ^a	3.9	3	5.72	2.469	4.97 ^a	-2.4	-2.4	10
A	-169.7*	-55.23	50.7	19.9	25.20	-1.345	-35.11	155.2 ^a	148.2	269
B	4.2**	4.08**	-2.2	-3.8*	0.43	-2.656**	-0.82	6.3**	2.1	-23**
C	0.5	3.73	2.8	-0.6	-2.21	4.491**	2.39	5.8*	5.8 ^a	-11
A ²	1227.3*	361.74	-312.5	-248.1	11.36	64.394	361.79	-761.4	-687.5	-1945
B ²	-2.4**	-0.62	1.9	1.2	-0.38	1.703**	0.58	-2.0*	-1.1	8
C ²	2.6*	-1.82	-0.9	-2.1	3.59	-4.089**	-1.10	-2.2	-1.2	9
AB	-6.2	40.21**	11.9	34.4*	-5.42	8.750	-11.04	-31.7**	-6.9	95
AC	-41.7**	8.06	-17.5	32.5 ^a	-32.22	6.667	-19.72	-20.6	-40.8 ^a	-83
BC	-1.0 ^a	-0.66	-1.8	0.0	0.22	-0.267	1.26*	-1.2 ^a	-0.8	7*
R ²	0.84	0.86	0.40	0.77	0.41	0.86	0.66	0.92	0.63	0.77
<i>P</i> -values										
Model	0.005	0.003	0.66	0.024	0.63	0.003	0.125	0.00	0.168	0.027
Lack of fit	0.100	0.007	0.431	0.566	0.002	0.208	0.029	0.010	0.341	0.437

Y1: Odor; Y2: Oily appearance; Y3: Spread ability; Y4: Hardness; Y5: Graininess; Y6: Cohesiveness; Y7: Perception of fat; Y8: taste; Y9: total acceptance; Y10: viscosity

* P≤0.05 **P≤0.01 ^aP≤0.1

Table 4. Estimated coefficients and coefficients of determination (R²) of the fitted quadratic equations for different responses of products prepared using BSG

Coefficients	Estimated coefficients									
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Cons.	5 ^{**}	5.05 ^{**}	5.68 ^{**}	5 ^{**}	6.80 ^{**}	2.97 [*]	3.61	2	4.3 ^{**}	11.3 ^{**}
A	182 [*]	-14.67	-58.62	14	-74.92	-19.99	-12.49	221 [*]	67.5	-83.3
B	3	2.69 ^a	1.74	-2	1.47	-0.16	-0.59	4 [*]	-0.4	-2.1
C	-8 [*]	0.97	1.39	-4 ^a	2.47	3.28	1.44	-1	2.7	-9.2
A2	-2364	383.84	720.54	-1556	1838.38 ^a	942.76	316.50	-3017 ^a	-579.1	-336
B2	0	-1.65	-1.22	1	-1.68 ^a	0.85	-0.28	1	1.4	3.3
C2	6 [*]	0.38	-0.03	2	-2.04	-2.76	0.03	3	-1.4	5.8
AB	-86 ^{**}	-8.89	6.11	38 ^a	-25	-6.11	51.67	-69 [*]	-10.6	-42.7
AC	-1	-2.96	43.70 ^a	60 [*]	-11.11	22.96	-91.11	-12	-23	137.2 ^a
BC	-1	0.04	-2.16 [*]	-1	0.64	-1.27	0.02	-4 ^{**}	-1.4	-4.2 ^a
R ²	0.75	0.74	0.80	0.68	0.64	0.59	0.38	0.78	0.43	0.76
<i>P</i> -values										
Model	0.036	0.041	0.015	0.100	0.153	0.233	0.715	0.022	0.604	0.032
Lack of fit	0.770	0.101	0.053	0.255	0.454	0.142	0.109	0.545	0.777	0.032

Y1: Odor; Y2: Oily appearance; Y3: Spread ability; Y4: Hardness; Y5: Graininess; Y6: Cohesiveness; Y7: Perception of fat; Y8: taste; Y9: total acceptance; Y10: viscosity

* P≤0.05 **P≤0.01 ^aP≤0.1

Table 5. Estimated coefficients and coefficients of determination (R^2) of the fitted quadratic equations for different responses of products prepared using RSG

Coefficients	Estimated coefficients									
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Cons.	6.03**	6.9**	2	4**	8.6**	4.96*	5.3*	4.3*	3.9*	6.0
A	-80.57	-354.3 ^a	417	127	-190.7	-56.31	-208.0	-451.1 ^a	-288.0	943 ^a
B	-1.14	2.1 ^a	-1	-1	-1.3	-1.60	4.0	2.0	1.4	-9*
C	-0.66	3.8 ^a	3	-4*	-1	-4.12	0.8	10.0**	8.6**	-21**
A ²	4966.83	9144.7 ^a	-9001	-7280 ^a	3424.8	2599.96	1201.4	14290.8 ^a	10328.1	-24938 ^a
B ²	1.01	-0.7	0	0	0.2	-0.46	-2.4	0	-0.4	3
C ²	1.49	-1.9	-2	2 ^a	0	2.38	-1.4	-6.7**	-5.4**	14**
AB	-9062	29.5	46	39	78.2*	96.15 ^a	-74.4	-5.1	59.0	195 ^a
AC	-64.10	35.9	-103	146**	66.7	35.90	160.7 ^a	82.1	30.8	-17
BC	-0.50	-1.4*	-1	0	-0.4	0.33	-0.8	-2.3*	-2.6**	5*
R ²	56.7	85.2	68.9	77.3	53.8	72.1	78.6	83.3	86.1	84.1
<i>P</i> -values										
Model	0.283	0.004	0.089	0.025	0.345	0.058	0.019	0.007	0.003	0.005
Lack of fit	0.317	0.644	0.032	0.260	0.750	0.192	0.398	0.008	0.210	0.387

Y1: Odor; Y2: Oily appearance; Y3: Spread ability; Y4: Hardness; Y5: Graininess; Y6: Cohesiveness; Y7: Perception of fat; Y8: taste; Y9: total acceptance; Y10: viscosity

* $P \leq 0.05$ ** $P \leq 0.01$ ^a $P \leq 0.1$

Table 6. Analysis of variance for the quadratic model of different attribute

Responses	Sources of variation	Xanthan gum			BSG			RSG		
		DF	MS	F	DF	MS	F	DF	MS	F
Odor	Regression	9	0.369	2.01	9	0.984	3.36	9	0.309	1.45
	Residual	10	0.184		10	0.293		10	0.212	
	Total	19			19			19		
Oily appearance	Regression	9	1.099	9.22	9	0.567	3.22	9	0.710	6.42
	Residual	10	0.119		10	0.176		10	0.111	
	Total	19			19			19		
Spread ability	Regression	9	0.370	0.97	9	0.664	4.42	9	0.560	2.46
	Residual	10	0.380		10	0.150		10	0.228	
	Total	19			19			19		
Hardness	Regression	9	0.556	4.84	9	0.397	2.35	9	0.268	3.78
	Residual	10	0.115		10	0.169		10	0.071	
	Total	19			19			19		
Graininess	Regression	9	0.130	0.47	9	0.225	1.97	9	0.108	1.29
	Residual	10	0.279		10	0.114		10	0.084	
	Total	19			19			19		
Cohesiveness	Regression	9	0.305	2.58	9	0.517	1.61	9	0.677	2.87
	Residual	10	0.118		10	0.320		10	0.236	
	Total	19			19			19		
Mouth feel	Regression	9	0.183	2.80	9	0.711	0.68	9	1.236	4.08
	Residual	10	0.065		10	1.049		10	0.303	
	Total	19			19			19		
Taste	Regression	9	0.840	2.01	9	1.053	3.92	9	1.292	5.52
	Residual	10	0.418		10	0.268		10	0.234	
	Total	19			19			19		
Total acceptance	Regression	9	0.303	0.95	9	0.220	0.83	9	1.160	6.90
	Residual	10	0.320		10	0.265		10	0.168	
	Total	19			19			19		
Viscosity	Regression	9	12.902	2.77	9	4.362	3.51	9	5.423	5.89
	Residual	10	4.663		10	1.244		10	0.921	
	Total	19			19			19		

The response surface in Figure 2 shows the combined effects of isomalt: pistachio paste ratio and xanthan concentration on the rated hardness score. The hardness score increased rapidly with the increase in both variables. The effect of isomalt: pistachio paste ratio was markedly shown for higher concentrations of xanthan gum. A reversed effect is observed at the lowest concentration of fat replacer. It seems that higher concentrations of xanthan increase the hydrocolloid network and subsequently the water holding capacity of network and rated hardness score. The maximum hardness score was attained at the maximum limit of two variables which was an indication of the competition between sweetener and fat replacer in water adsorption. Similar result was also obtained for the interaction between other sweetener and xanthan gum (not shown).

Figure 3 shows the response surface of sucrose: pistachio paste ratio and xanthan concentration, indicating that the spreadability of product decreased by increasing the sweetener and fat replacer levels. It was expected according to the results obtained for hardness characteristic.

The correlative effect of xanthan concentration and sucrose: pistachio paste ratio on total acceptance score indicates that the total acceptance score is rapidly increased by increasing the gum concentration (not shown). It was found that the panelists have preferred more textured spread. The precise effect of sweetener level on total acceptance was observed at lower levels of xanthan concentration. According to the fact that higher levels of sucrose can lead to higher taste acceptance, it can be concluded that the observed effect has been resulted from the fat replacer concentration. Earlier Bayarri [6] reported that higher concentrations of hydrocolloid produce a decrease in sweetness intensity, regardless of the type and concentration of sweetener. Other researchers have also shown that the increase in solution viscosity reduces the rated taste sensation at sensory evaluation tests [27, 46].

Conditions of optimum responses of Balangu seed gum (BSG)

The interaction effects of sucrose and isomalt: pistachio paste ratios on taste of formula produced

appearance, hardness, taste and viscosity of products containing RSG ($P \leq 0.1$). For formula prepared using xanthan gum, isomalt and sucrose individually have a positive significant effect on taste characteristic ($P \leq 0.05$) and a negative ($P \leq 0.01$) and non-significant effect on viscosity, respectively. However, the interaction of two sweeteners shows a negative significant effect on taste and a significant positive effect on viscosity characteristics. Similar effect of interaction is observed for the taste of formulas containing BSG and RSG (although the effect of isomalt on rated taste score was not significant). Isomalt shows a significant negative linear effect on the viscosity of formulas containing xanthan gum ($P \leq 0.01$). There was a significant effect of RSG ($P \leq 0.1$) and negative effects of isomalt ($P \leq 0.05$) and sucrose ($P \leq 0.01$) on the low-fat products. P-values of models and lack of fit are presented in Tables 3, 4 and 5 for xanthan, BSG and RSG, respectively. The analysis of variance was performed to assess how well the model represents the experimental data (Table 6). Results show that in most cases the quadratic regression was adequate for prediction within the range of experiments.

Analysis of response surface

Conditions of optimum responses of xanthan gum

The relationship between dependent and independent variables can be illustrated using three dimensional response surface graphs. Figure 1 shows the interaction effect of isomalt and sucrose: pistachio paste ratios on the rated total acceptance score. By increasing both variables, total acceptance showed an increase. Further increase in the amount of isomalt led to a rapid decrease in total acceptance score, whereas higher levels of sucrose did not make significant changes in total acceptance.

Similar effect was observed for the rated scores of taste (not shown). Drewnowski [13] reported that changing the sweetener level will have an adverse effect on overall acceptability. Theunissen & Kroeze [45] suggested the sweetness as a sensation with hedonic meaning. They also mentioned that this hedonic sensation increases with sweetener concentration until an optimum value is reached.

level of sweetness is achieved at lower levels, when one of the sweeteners is at its highest level. Similar result was obtained for products prepared using RSG (not shown).

The response surface in Figure 5 shows the correlative effect of BSG and sucrose: pistachio

Conditions of optimum responses of Basil seed gum (RSG)

The response surface for the perception of fat and viscosity with varying BSG concentration and isomalt: pistachio paste

by BSG showed an antagonistic behavior. The highest taste scores were obtained at points where one sweetener was at its highest and the other one at its lowest level (Figure 4). Meanwhile, these sweeteners made a synergistic effect on taste of formulas prepared by xanthan gum. It is additionally obvious that when one of the sweeteners is at its lowest level, the other sweetener shows an adverse increasing effect on rated taste score but when the second sweetener is at its highest level the taste score primarily increases and then shows decrease. It seems that the optimum

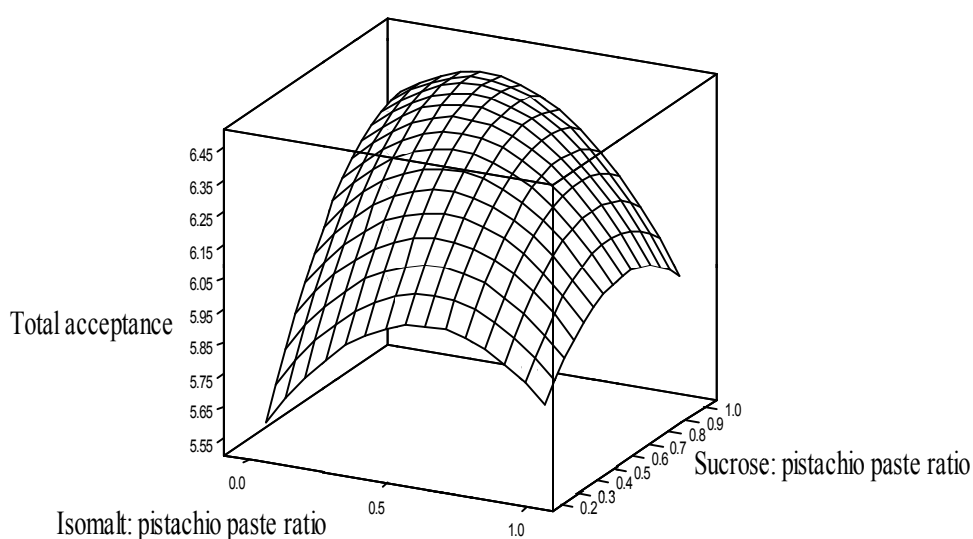


Fig. 1. Response surface for the effect of isomalt: pistachio paste ratio and sucrose: pistachio paste ratio on total acceptance of formulas prepared by xanthan gum.

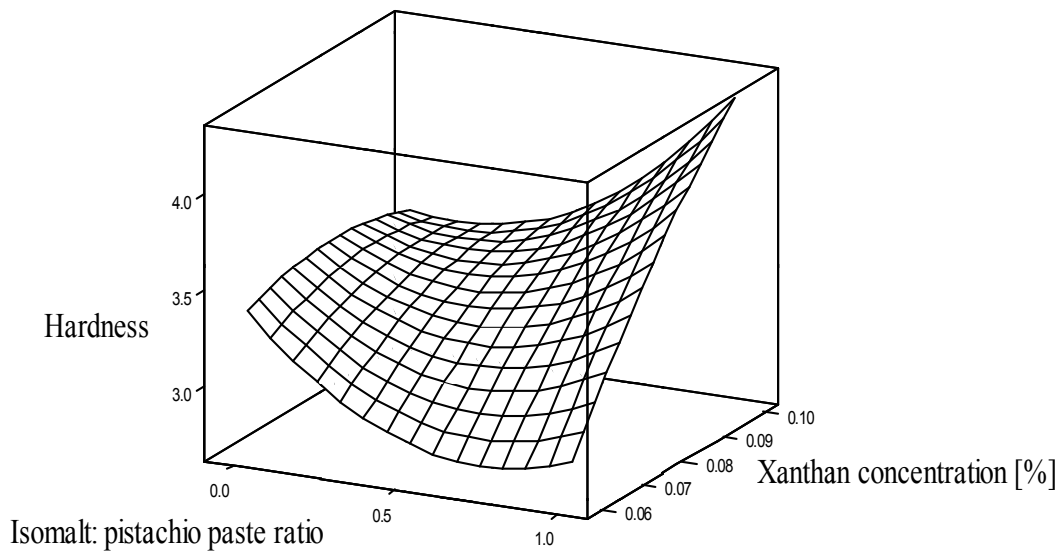


Fig. 2. Response surface for the effect of isomalt: pistachio paste ratio and xanthan concentration on hardness of formulas prepared by xanthan gum.

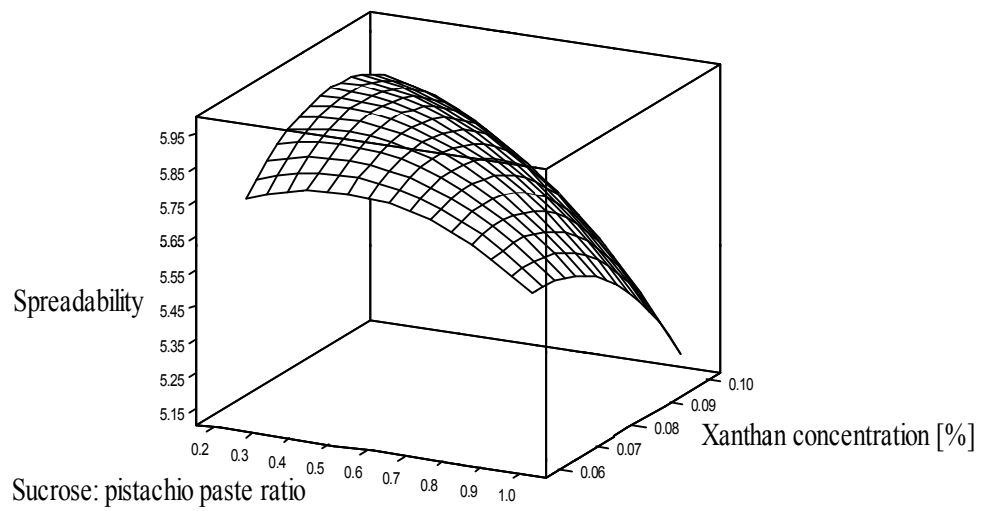


Fig. 3. Response surface for the effect of sucrose: pistachio paste ratio and xanthan concentration on spread ability of formulas prepared by xanthan gum.

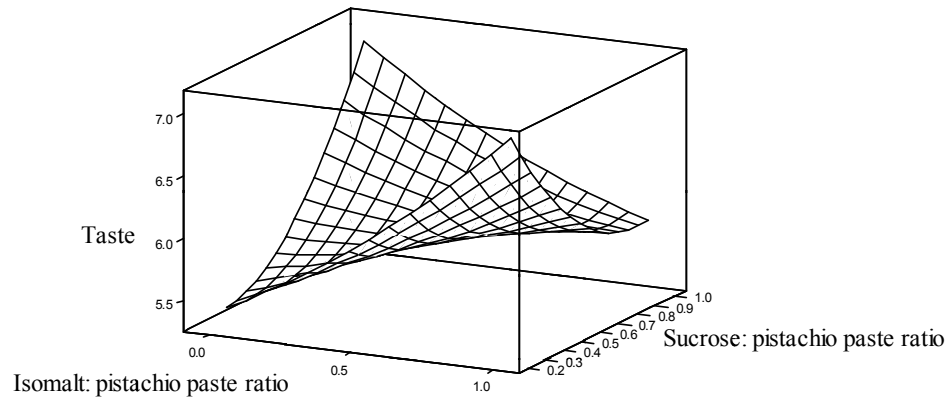


Fig. 4. Response surface for the effect of sucrose: pistachio paste ratio and isomalt: pistachio paste ratio on taste of formulas prepared by BSG.

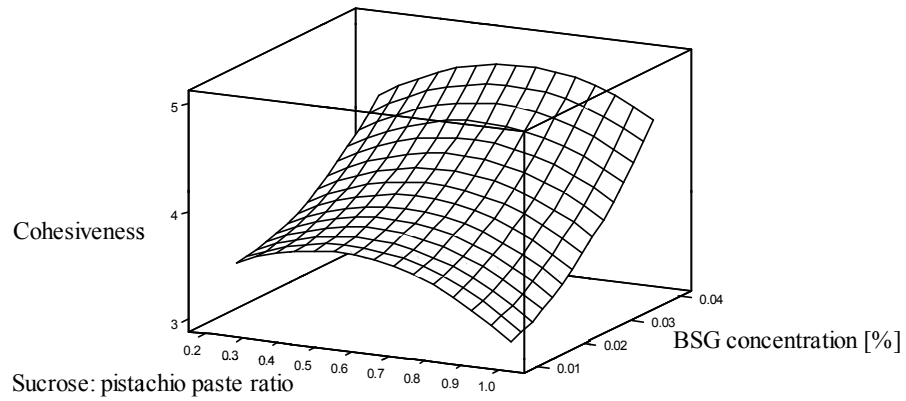


Fig. 5. Response surface for the effect of sucrose: pistachio paste ratio and BSG concentration on cohesiveness of formulas prepared by BSG.

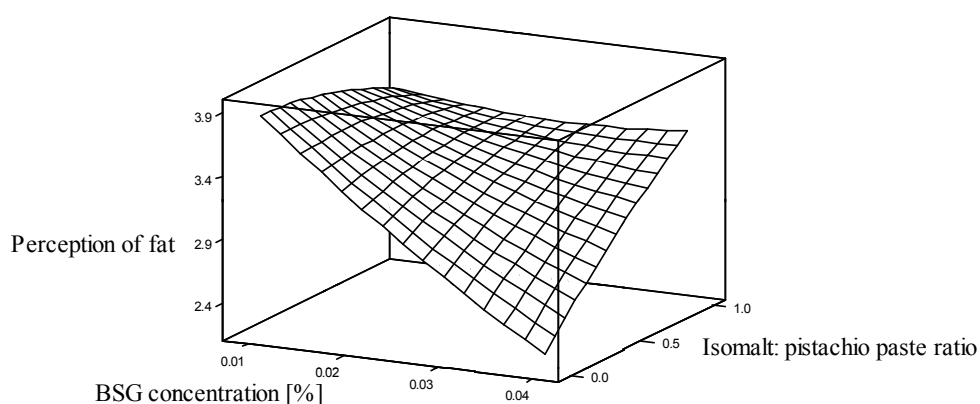


Fig. 6. Response surface for the effect of isomalt: pistachio paste ratio and BSG concentration on perception of fat in formulas prepared by BSG.

Ratio is shown in Figures 6 and 7, respectively. As it was expected, increasing the BSG concentration had a decreasing effect on the perception of fat, although the viscosity decrease was not adverse (Figure 6). Mela [24] reported that increasing the viscosity resulted in more perception of fat by sensory panel. The results of Akhtar [2] also showed that the perception of creaminess increases with increase in the viscosity of the continuous phase in a dairy fat-in-water emulsion. While higher concentration of hydrocolloid may adversely decrease the oral perception of fat, the oily appearance only shows small changes (not shown). Figure 6 also indicates that the changes in the viscosity produced by sweetener can not affect the fat perception of the emulsion. It is emphasized that besides the rheological matter, the sensory characteristics of a novel low- fat product should be taken in consideration [2]. Similar results were obtained for RSG (not shown). Since the sweetener level is proportional to pistachio paste, increasing the isomalt ratio means the reduction in the pistachio paste proportion. Pistachio is a source of fiber and cellulose and these components can absorb water easily. Then it seems that decreasing of the viscosity as a function of sweetener level is

mainly according to the decreasing level of pistachio paste.

Figure 8 shows the 3D response surface plot at varying RSG concentration and sucrose: pistachio paste ratio. From Figure 8 it can be seen that the rated total acceptance score increases with increase in RSG concentration. Again it is probably due to the structured form of the product. The rated score is found to increase rapidly with the increase of isomalt: pistachio paste ratio; but at ratios higher than 0.8 the rated score shows a decrease. Similar result was obtained for formulas prepared using BSG (not shown).

Optimization

The 3-D response surface and the contour plots derived from the mathematical models and a numerical optimization was applied to determine the optimal conditions. Optimal conditions were generated by setting the sensory characteristics and viscosity as similar as or better than the full fat standard pistachio butter. The responses were then analyzed by conferring them the appropriate weight. The optimum set of variables was determined using the response optimizer. The optimal formulations of the reduced- calorie pistachio butter prepared by a commercial and two

Iranian endemic fat replacers are presented in Table 7.

Table 7. Predicted levels of ingredients yielding maximum sensory scores and viscosity

Ingredient	Levels for optimum response		
	Xanthan	BSG	RSG
Fat replacer concentration (%)	0.1	0.034	0.023
Isomalt: pistachio paste ratio	0.81	1.0	0.333
Sucrose: pistachio paste ratio	0.71	0.25	1.0

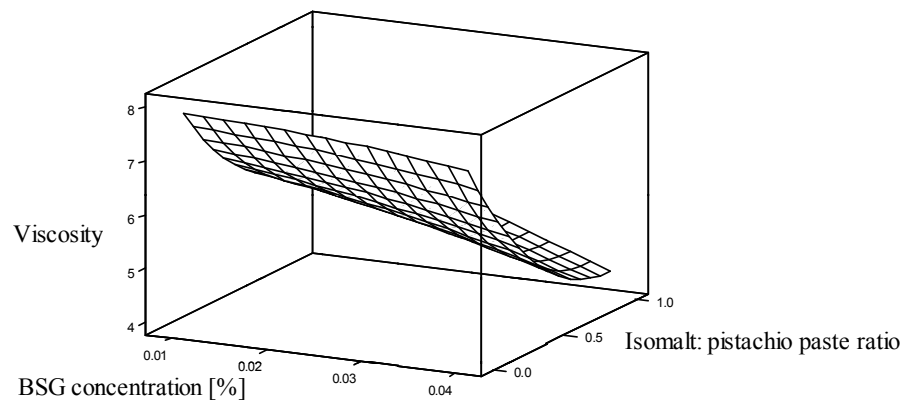


Fig. 7. Response surface for the effect of isomalt: pistachio paste ratio and BSG concentration on viscosity of formulas prepared by BSG.

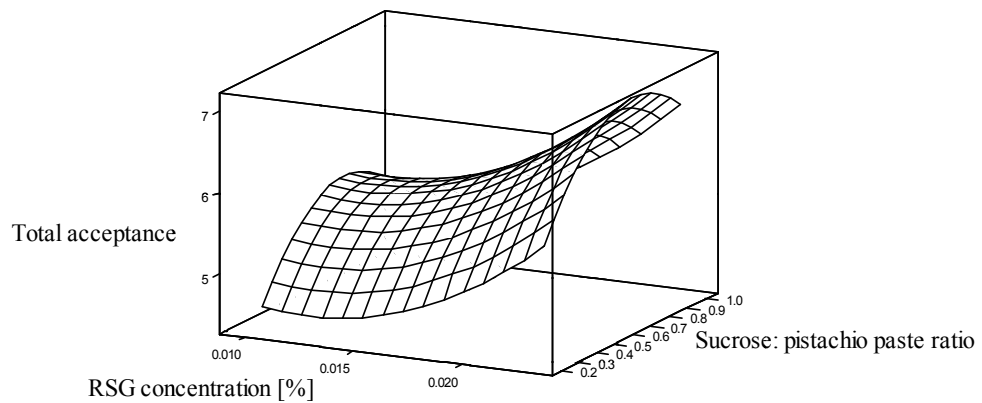


Fig. 8. Response surface for the effect of sucrose: pistachio paste ratio and RSG concentration on total acceptance of formulas prepared by RSG.

CONCLUSIONS

The response surface methodology was found suitable for optimizing the fat replacers and sweeteners in low-calorie pistachio butter formulation. The amount of fat replacer needed to achieve the optimum formula is the least for Basil seed gum. For obtaining the sweetness sensation goal, the order of isomalt level was in formulas prepared using Balangu seed extract, xanthan and Basil seed gum, respectively. The results also demonstrated the capability of BSG and RSG as appropriate fat replacers and isomalt as healthy alternative for sucrose in the formulation of low-calorie pistachio butter.

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