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DEVELOPMENT OF SPREADABLE HALVA FORTIFIED WITH SOY FLOUR AND OPTIMIZATION OF FORMULATION USING MIXTURE DESIGN

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ABSTRACT

A novel spread based on sesame paste fortified with soy flour was developed. A mixture experimental design was used to investigate effect of soy flour and mono- and diglycerides addition on the emulsion stability (ES), color, textural properties and sensory attributes of the spreadable halva and to optimize the formulation. The ES of all samples increased as a function of the emulsifier amount. The increase of temperature led to emulsion instability and oil separation intensification. Addition of soy flour had no significant effect on hardness and adhesiveness of different halva samples ($P > 0.05$). There was no significant difference in color parameters (L^*, a^* and b^*) of most halva samples ($P > 0.05$). Halva samples received scores of 4–7 in all evaluated attributes, and no significant difference was detected among most halva samples in all sensory properties. The range of optimum combination was determined by superimposing the contour plots of the responses.

PRACTICAL APPLICATIONS

Convenience of food consumption is an important factor in product design and development. Using a spreadable food is more favored than the molded ones. Development of spreadable halva can solve difficulty with consumption of molded halva. In addition, spreads are an excellent carrier for nutraceutical components such as soy flour. Spreadable halva can be considered as a carrier of soy flour in order to develop a novel food.

INTRODUCTION

Sesame paste (known as Tehinah, Tahinah, Tehineh, Tahin, Tahini, Tahena, Tehina and Tahina in Turkey, and Ardeh in Iran) is produced from dehulled, roasted and ground sesame seeds (Abu-Jdayil 2004; Lokumcu Altay and Ak 2005). The nutritional value of sesame paste is remarkable because of high amount of lipids (54–65 weight [wt]%), proteins (23–27 wt%), carbohydrates (6.4–9 wt%), dietary fiber (9.3 wt%), niacin (4.5 mg/100 g), thiamin (11.8 mg/100 g), phosphorous (692–840 mg/100 g), magnesium (362 mg/100 g), iron (7.19–9 mg/100 g), calcium (61–100 mg/100 g), zinc (7.82 mg/100 g), copper (1.96 mg/100 g), manganese (1.46 mg/100 g) and selenium (0.05 mg/100 g) (Abu-Jdayil *et al.* 2002; Abu-Jdayil 2004; Eissa and Zohair 2006; Akbulut and Coklar 2008). Presence of natural antioxidants (sesamol, sesaminol and tocopherols) in sesame seeds confer a high stability to sesame paste against oxidation and extend its shelf life (Sumainah *et al.* 2000; Ciftci *et al.* 2008).

Halva (also known as Halawa, Halaweh, Halvah and Helva) is one of the oldest sweets and traditional desserts (Abu-Jdayil 2004; Kahraman *et al.* 2010). There are many types of halva; the most famous form consumed throughout the Middle East, Balkan and North Africa is the halva that is prepared from sesame paste (Sengun *et al.* 2005). This type of halva mainly consists of sesame paste (50 wt%), sucrose (25–35 wt%) and glucose syrup (12–25 wt%) (Abu-Jdayil 2004; Sengun *et al.* 2005; Kahraman *et al.* 2010). In the industrial method to produce halva from sesame paste, sugar solution is concentrated, partially converted to invert sugar by citric acid, mixed with glucose and bleached by saponaria extract to produce a clear syrup. Sesame paste is then blended with the syrup, kneaded, molded and packaged (Sengun *et al.* 2005; Eissa and Zohair 2006; Kahraman *et al.* 2010).

One of the most important properties of semi-solid foods is spreadability. Spreadability is a subjective term related to how easy a semi-solid food is uniformly distributed over a surface such as toast bread (Di Monaco *et al.* 2008). Spreadable foods must flow easily under stress, but they must not flow under their own weight (Di Monaco *et al.* 2008). Up to now, spreads from different oilseeds such as sunflower seeds, hazelnuts, almonds, soybeans and peanuts are produced (Lima and Guraya 2005; Di Monaco *et al.* 2008). However, no published literature was found on spreadable halva. Convenience of food consumption is an important factor to develop a new product. The molded halva consumption is difficult because its texture is firm, crumbly and breaks into small pieces when consumer cuts it with a knife before eating. Development of spreadable halva can solve this difficulty and provide more convenience to consumers. Many studies have been carried out on the physicochemical and rheological properties of sesame paste, but there have been few studies concerning halva in literatures. Damir (1984) incorporated sunflower seeds flour into both sesame paste and halva formulation, and investigated their physicochemical properties. Researchers fortified halva with flour of mushroom to overcome essential amino acid deficiency and to improve the emulsion stability (ES), safety and sensory properties of halva (Eissa and Zohair 2006).

Utilization of soybean products in the food industry has increased steadily over the past decades. Some health-giving effects of soybean include hypocholesterolemic, anti-atherogenic, anticarcinogenic, antiallergenic, reduction of body fat and preventing osteoporosis (Sugano 2005). Consumption of 25 g of soy protein a day may reduce the risk of heart disease and protects bone density (Lynne-Brown 2001). Using soy supplements such as soy pill and soy powder can be dangerous because they may contain higher levels of isoflavones than more traditional soy foods. Because isoflavones are weak estrogens, eating too much (more than 100 mg a day) could possibly enhance the risk of cancer. Because of this, it is preferred to incorporate soybean into various foods in the form of flour rather than other forms (Lynne-Brown 2001). Despite all the benefits of soybean, there are some deficiencies that limit extensive applications of it in foods. Beany flavor, flatus-producing ability, oxidative and flavor instability, deficiency of sulfur-containing essential amino acids, and presence of antinutritional factors are major problems with soybeans (Du Bois *et al.* 2008).

There have been many investigations on fortification of spreads and cereals with soy flour. Yeh *et al.* (2002) enriched peanut spread with 19% roasted soy flour and some beneficial nutrients, and evaluated consumers preferences. A successful study was carried out on substitution of peanut spread by soy flour up to 20% (Mazaheri-Tehrani *et al.* 2009). To improve undesirable attributes of soybean, fermentation was conducted on soybeans. Fermented and unfermented soy flours were used for supplementation of biscuit (Shrestha and Noomhorm 2002). A new product from peanut was developed by Sumainah *et al.* (2000) via addition of soy flour as a nutraceutical additive and sesame paste by virtue of high antioxidative capacity.

The objective of this research was to determine an optimum formulation for novel spreadable halva fortified with soy flour by Design Expert software and determination sensory, physicochemical and ES of it.

MATERIALS AND METHODS

Materials

Whole soybean flour containing 22.8% fat (dry basis), sesame paste, commercial lecithin (melting point of 37C), commercial emulsifier (a blend of mono- and diglycerides with melting point of 65C) and sugar powder were prepared from local factories (Mashhad, Iran).

Experimental Design

A mixture experiment is a special type of response surface methodology in which the independent variables are the components (ingredients) of a mixture, and the response variables are a function of the proportions of the individual components. The feasible space for a mixture experiment with 3 ingredients is a triangle called a simplex. The composition of each mixture varies depending on its position on the simplex region (Myers and Montgomery 1995). A user-defined mixture design including four points of vertices, four points for axial check blends and four centers of edges points with total candidate points of 12 was used to optimize spreadable halva formulation. Based on subject-matter knowledge and preliminary experiments, 20% of the total weight of halva (only sesame paste component) was replaced by emulsifier (mono- and diglycerides) and soy flour. In all halva formulations, sesame paste varied between 30–50%. Lower and upper limits on the proportions (%) of the mixture components (X_1 = soy flour, X_2 = sesame paste and X_3 = mono- and diglycerides) were chosen as: $0 \leq X_1 \leq 20$, $0 \leq X_2 \leq 20$ and $0 \leq X_3 \leq 1$. The compositions of the mixtures were re-scaled so that the proportion of each ingredient ranged from 0 to 1 (pseudo components) and were used in this form for the statistical computations. The experimental design and statistical analysis were performed using Design Expert software (version 8.0.5.2, Stat-Ease, Inc., Minneapolis, MN). Twelve combinations of

TABLE 1. LEVEL AND PROPORTION OF SESAME PASTE, SOY FLOUR AND EMULSIFIER IN EACH RUN

	Pseudocomponent			Component proportion (%)		
Run	X1	X2	X3	Soy flour	Sesame paste	Emulsifier
1	0.74375	0.24375	0.0125	14.875	4.875	0.25
2	0.5	0.5	0	10	10	0
3	1	0	0	20	0	0
4	0.95	0	0.05	19	0	1
5	0.71875	0.24375	0.0375	14.375	4.875	0.75
6	0.475	0.475	0.05	9.5	9.5	1
7	0	1	0	0	20	0
8	0	0.975	0.025	0	19.5	0.5
9	0.24375	0.71875	0.0375	4.875	14.375	0.75
10	0	0.95	0.05	0	19	1
11	0.975	0	0.025	19.5	0	0.5
12	0.24375	0.74375	0.0125	4.875	14.875	0.25

three components obtained from the Design Expert were tested (Table 1). The predicted equation for each parameter was obtained. To obtain the optimum region, desired goals for each variables and response were chosen. All the independents variables were kept within range while the responses were minimized, maximized and/or set in range according to desired properties and applications.

Method of Halva Preparation

To prepare halva, we used a pilot plant ball mill apparatus. Water was introduced into the water jacket and heated to ensure a temperature of 55C. At first, sesame paste was poured into the ball mill. Sesame paste was circulated for 15 min inside ball mill, and then other components including sugar powder, soy flour, vanillin, mono- and diglycerides, sunflower vegetable oil (83% w/w oil amount of replaced sesame paste) and lecithin were gradually added. To increase oxidation stability of halva, butylated hydroxytoluene (200 ppm based on weight of added vegetable oil) was added. After 3 h, halva was deposited and stored at room temperature.

Chemical Measurement

Moisture content was measured by drying the samples at 105 ± 2C until a constant weight was achieved. The ash content was determined by igniting the sample at 550C until a constant weight was obtained. The oil content of halva mixtures was determined using Soxhlet apparatus with petroleum ether as the carrier. Protein was determined by Kjeldahl's method. In the protein determination, a nitrogen-to-protein conversion factor of 6.25 was used. Total carbohydrate content was determined by difference.

Color Measurement

Samples were placed into a black wooden box and were illuminated using 16 fluorescent tube lights (10 W, 6500 K; 40 cm in length). An eight megapixels digital camera (Canon EOS 1000D, Powershot, Taiwan) was located vertically at a distance of 20 cm from the sample. The images were captured using the camera mentioned earlier with no zoom and flash, a lens aperture of 4 and speed of 1/80 s. Images were preprocessed by Adobe Photoshop version 6.0 image-editing software (Adobe Systems, San Jose, CA). The color properties were analyzed using ImageJ software, version 1.44o (National Institutes of Health, Bethesda, MD). For this purpose, sample was segmented from the background using threshold combined with an edge detection approach based on the Laplacian-of-Gaussian filter. Finally, RGB color space was converted into $L^*a^*b^*$ space based on direct model (Leon *et al.* 2006). L^* is lightness component, which ranges from 0 to 100 and parameters a^* (green to red or redness) and b^* (blue to yellow or yellowness) are two chromatic components, which range from −120 to 120.

ES

ES of halva samples was measured according to Ciftci *et al.* (2008) method. Test tubes (1.5 cm diameter, 10 cm height) containing 11 ± 0.5 g of freshly prepared halva samples were stored at 20, 30 and 40 ± 2C for 54 days. The height of the formed free oil-phase resulting from the centrifugation of test tubes at 3420 × g for 5 min was measured using a Vernier caliper. Percent ES was determined using the following equation:

$$ES\% = \frac{H_t - H_o}{H_t} \times 100$$

where H_o is the height of oil phase and H_t is the total height of halva in the test tubes.

Texture Measurement

Textural properties of halva samples were determined using a QTS texture analyzer (CNS Farnell, Essex, UK) equipped

TABLE 2. CHEMICAL COMPOSITION OF HALVA MIXTURES*

Formulation	Moisture content (w.b%)	Ash (%)	Crude oil (%)	Total carbohydrate (%)	Protein (%)
1	1.12 ± 0.12	1.50 ± 0.29	34.36 ± 1.61	49.60 ± 0.06	13.40 ± 0.23
2	0.83 ± 0.14	1.71 ± 0.38	31.71 ± 1.51	52.10 ± 0.68	13.63 ± 0.44
3	1.25 ± 0.00	2.16 ± 0.98	31.16 ± 0.48	50.19 ± 1.77	15.21 ± 1.28
4	1.04 ± 0.07	1.58 ± 0.13	32.28 ± 2.11	51.44 ± 2.36	13.65 ± 0.11
5	1.00 ± 0.25	1.39 ± 0.15	33.27 ± 3.77	50.93 ± 2.88	13.40 ± 0.73
6	0.66 ± 0.19	1.46 ± 0.17	32.03 ± 1.01	51.89 ± 0.06	13.94 ± 0.77
7	0.91 ± 0.07	1.36 ± 0.15	34.77 ± 1.05	49.25 ± 3.01	13.69 ± 2.10
8	0.87 ± 0.12	1.41 ± 0.01	33.25 ± 1.68	51.93 ± 2.30	12.52 ± 0.61
9	0.95 ± 0.07	1.56 ± 0.107	34.49 ± 0.98	49.97 ± 1.26	13.01 ± 0.38
10	1.08 ± 0.14	1.80 ± 0.06	35.99 ± 1.64	49.07 ± 1.59	12.04 ± 0.02
11	0.79 ± 0.19	2.13 ± 0.75	33.73 ± 1.62	48.77 ± 0.53	14.57 ± 1.01
12	0.75 ± 0.12	2.15 ± 0.15	35.67 ± 1.86	47.67 ± 1.68	13.75 ± 0.33

* Data are mean of two replications ± standard deviation.

with a 25 kg load cell. Samples (250 ± 0.5 g) were filled into cups (65 mm diameter, 60 mm depth), and compression test was carried out using a 45° angle acrylic cone probe (30 mm diameter, 35 mm length). The maximum force (N) required for the cone to penetrate a distance of 10 mm into the halva at a crosshead speed of 30 mm/min and trigger value of 0.04 N were determined as hardness. Adhesiveness was defined as the work necessary to pull the probe away from samples.

Sensory Evaluation

The taste panel was performed by 10 panelists (consisted of 4 female and 6 male, aged between 22 and 39 years) familiar with sensory evaluation of food materials, selected from students and staffs of Ferdowsi University of Mashhad. Sensory panel was carried out at room temperature under normal lighting conditions. The characteristics of interest for the taste panel were color intensity, color acceptance, aroma, flavor, hardness, adhesiveness, spreadability and overall acceptability. Hardness was judged by each panel member by placing a sample in the mouth, between the molar teeth and biting down evenly, estimating the maximum force required to deform the halva. Adhesiveness was gauged by the panel by pressing each sample to the palate with the tongue. The force required to subsequently move the sample with the tongue was evaluated. Spreadability was determined by spreading sample on the toasted bread and evaluating the force required to spread. A 9-point hedonic scale sensory test was used (9 = like extremely/high intensity, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely/low intensity) (Lawless and Heymann 2010). Panelists were asked to rinse their mouths with water between samples. The average values of the sensory scores were used in the analysis.

Statistical Analysis

Data were analyzed by one-way analysis of variance using MSTAT-C software, version 1.42 (Michigan State University, East Lansing, MI). The differences of means were detected by the least significant difference at a probability level of $P < 0.05$. Three independent replicates were conducted for texture analysis and two for ES, chemical and color measurements. Pearson's correlations between measurements were made using Minitab for Windows, version 13.0 (Minitab Inc., State College, PA).

RESULTS AND DISCUSSION

Chemical Composition

Results of chemical analysis of halva mixtures are given in Table 2. Moisture content, ash, crude oil, total carbohydrate and protein ranged from 0.66 to 1.25%, 1.36 to 2.16%, 31.16 to 35.99%, 47.67 to 52.10%, and 12.04 to 15.21%, respectively. These values are similar to results of halva fortified with mushroom (Eissa and Zohair 2006) and Tahin halva (Kotzekidou 1998). The use of vegetable oil caused chemical composition of halva mixtures was constrained in a narrow range. Energy content of all samples was approximately the same, but the samples rich in soy flour possess high nutraceutical value.

ES

One of the most common problems encountered by spreads is oil separation, which may lead to decrease in consumer acceptability and acceleration of oil oxidation. Incorporation of emulsifier induces a decrease in the oil separation and provides a firm, but spreadable texture. Commercial lecithin was used for stabilizing molded halva emulsion. It seems that more structural continuity of spreadable halva in

TABLE 3. EMULSION STABILITY OF HALVA MIXTURES AT TEMPERATURES OF 20, 30 AND 40C*

Formulation	20C	30C	40C
1	94.82 ± 0.05^{bcd}	92.64 ± 0.10^{b}	88.50 ± 0.10^{ef}
2	93.07 ± 0.30^{g}	90.36 ± 0.71^{de}	89.18 ± 0.35^{de}
3	93.43 ± 0.40^{fg}	91.53 ± 0.66^{c}	90.93 ± 0.30^{a}
4	95.28 ± 0.61^{abc}	92.82 ± 0.45^{ab}	89.96 ± 0.65^{bc}
5	95.93 ± 0.10^{a}	93.64 ± 0.10^{a}	87.89 ± 0.25^{fg}
6	94.14 ± 0.81^{def}	91.07 ± 0.50^{cd}	89.82 ± 0.05^{bcd}
7	93.43 ± 0.20^{fg}	89.75 ± 0.25^{e}	87.50 ± 0.10^{g}
8	93.93 ± 0.30^{ef}	90.86 ± 0.20^{cd}	89.64 ± 0.10^{cd}
9	95.43 ± 0.35^{ab}	91.50 ± 0.10^{c}	90.43 ± 0.20^{ab}
10	95.64 ± 0.30^{a}	92.86 ± 0.00^{ab}	89.57 ± 0.61^{cd}
11	94.57 ± 0.00^{cde}	91.07 ± 0.50^{cd}	90.21 ± 0.10^{bc}
12	92.82 ± 0.05^{g}	90.78 ± 0.71^{cd}	85.64 ± 0.30^{h}

* Data are mean of two replications ± standard deviation. Different letters within the columns indicate significant difference ($P < 0.05$).

comparison with molded ones leads to more emulsion instability. For this reason, we used a blend of mono- and diglycerides to provide more ES of spreadable halva. Results of ES measurements at temperatures of 20, 30 and 40C after 54 days storage are presented in Table 3. Amount of mono- and diglycerides significantly ($P < 0.05$) influenced ES of halva mixtures at 20 and 30C. As the amount of the emulsifier was increased, ES increased. The ES can be explained by the power of the emulsifier to increase the viscosity of the oil phase by causing the solidification of halva oil (liquid at ambient temperature) because the emulsifier present a high melting point (65C). Effectiveness of the emulsifier was diminished at 40C, probably because of decreased viscosity of halva mixtures. ES of all halva samples was decreased significantly ($P < 0.05$) by raising temperature from 20 to 30C (Fig. 1). Except samples 2, 3, 6 and 11, ES of others at 30C was significantly ($P < 0.05$) higher than that of samples stored at 40C. Ciftci *et al.* (2008) stated that increase in temperature and particle size of sesame paste led to colloidal instability, and the temperature was more effective than particle size. Addition of sunflower seeds flour to halva decreased ES. Using glycerol monostearate resulted in increased stability of the emulsion system of modified halva (Damir 1984). McSweeney *et al.* (2008) observed that monoglycerides decreased heat stability of the model infant formula emulsion and induced fat aggregation.

Texture

It is sometimes preferable to use instrumental methods to assess texture rather than sensory evaluations because sensory evaluations involve substantial time and money expenditures, and often exhibit poor reproducibility (Szczesniak 1987). Results of texture measurements are presented in Table 4. No significant difference ($P > 0.05$) was observed among hardness value of the most samples. Hardness of samples 5 and 2 were the highest and lowest, respectively, whereas difference between soy flour amounts of these samples was 4%. These results were expected because we added vegetable oil to halva formulations in order to decrease hardening effect of soy flour and to increase spreadability. The amount of added oil was directly proportional to the amount of soy flour. Dubost *et al.* (2003) reported that hardness and adhesiveness of peanut spreads prepared with 9, 16 and 23% soy protein isolate were significantly lower than those of commercial peanut and soy nut spreads. They also observed that as soy protein isolate was increased, hardness and adhesiveness increased. In

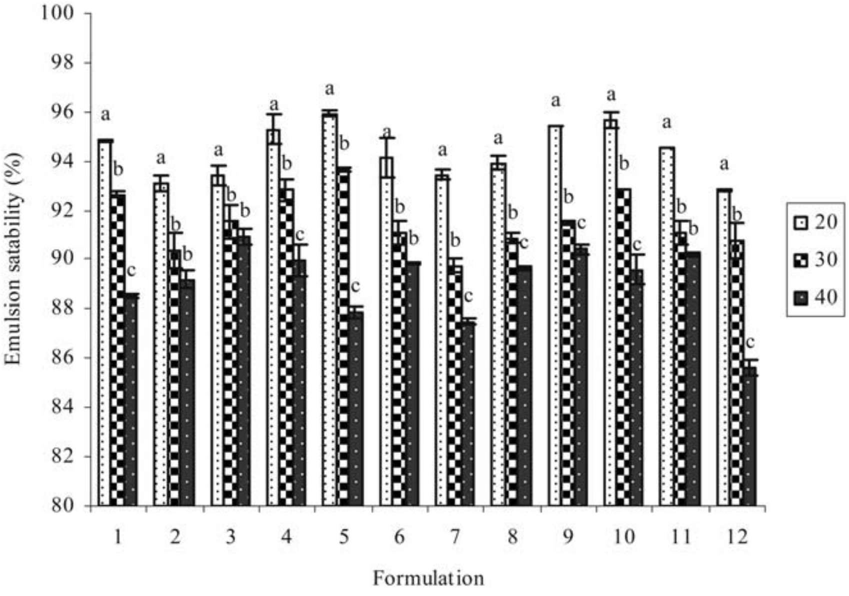

FIG. 1. EFFECT OF TEMPERATURE ON THE EMULSION STABILITY OF HALVA MIXTURES (12 FORMULATIONS)

Different letters represent significant differences ($P < 0.05$) according to the least significant difference test.

TABLE 4. TEXTURAL AND COLOR PARAMETERS OF HALVA MIXTURES*

Formulation	Hardness (N)	Adhesiveness (N.s)	L^*	a^*	b^*
1	0.136 ± 0.011^{bc}	2.543 ± 0.116^{bcd}	50.5 ± 1.2^{abc}	-4.2 ± 0.3^{b}	21.8 ± 0.2^{bcd}
2	0.103 ± 0.011^{d}	1.683 ± 0.306^{e}	51.1 ± 1.5^{a}	-6.6 ± 0.0^{cd}	22.1 ± 0.8^{abcd}
3	0.130 ± 0.010^{c}	2.343 ± 0.198^{cd}	50.7 ± 0.0^{abc}	-7.9 ± 0.1^{d}	22.8 ± 0.2^{ab}
4	0.156 ± 0.020^{ab}	3.233 ± 0.284^{a}	48.7 ± 0.4^{abcd}	-4.6 ± 0.3^{bc}	23.5 ± 0.1^{a}
5	0.166 ± 0.032^{a}	2.91 ± 0.495^{ab}	43.4 ± 0.1^{e}	-4.4 ± 0.0^{b}	21.2 ± 0.3^{cd}
6	0.143 ± 0.005^{abc}	2.656 ± 0.375^{bcd}	49.8 ± 0.4^{abc}	-5.6 ± 1.9^{bc}	21.9 ± 1.9^{bcd}
7	0.123 ± 0.021^{cd}	2.130 ± 0.340^{de}	48.3 ± 0.4^{bcd}	-2.1 ± 1.8^{a}	20.6 ± 0.6^{de}
8	0.133 ± 0.015^{bc}	2.296 ± 0.238^{cd}	50.9 ± 0.0^{ab}	-3.6 ± 0.2^{ab}	21.1 ± 0.1^{d}
9	0.126 ± 0.015^{cd}	2.343 ± 0.359^{cd}	48.6 ± 0.7^{abcd}	-3.6 ± 0.1^{ab}	20.6 ± 0.3^{de}
10	0.146 ± 0.005^{abc}	2.793 ± 0.491^{abc}	46.3 ± 0.4^{d}	-3.6 ± 1.0^{ab}	19.5 ± 0.4^{e}
11	0.143 ± 0.015^{abc}	2.720 ± 0.413^{abc}	48.1 ± 3.1^{cd}	-5.5 ± 1.3^{bc}	22.6 ± 0.3^{abc}
12	0.130 ± 0.010^{c}	2.623 ± 0.124^{bcd}	48.7 ± 0.5^{abcd}	-3.9 ± 0.9^{ab}	22.0 ± 0.4^{bcd}

* Data are mean of three replications ± standard deviation. Different letters within the columns indicate significant difference ($P < 0.05$).

another study hardening effect of soy flour on peanut spreads was found (Sumainah *et al.* 2000). They discussed that hardness increase pertained to effect of soy proteins on dimensional structure stability of spread. Similar to soy flour, hardness value of halva mixtures was not affected by the emulsifier amount. Some studies on the peanut butter (Aryana *et al.* 2000; Yeh *et al.* 2003) and pumpkin seed oil press-cake spread (Radoacj *et al.* 2011) indicated that hardness increased as a function of stabilizer content. The force necessary to pull the probe away from the halva samples was the lowest for sample 2. Similar to hardness, variations of adhesiveness were not governed by soy flour and emulsifier amounts. Yeh *et al.* (2002) stated that because of hydrophobic binding effect of soy proteins, peanut spread containing soy was stickier than the ones with milk powder.

Color

Color is a phenomenon that involves both physical and psychological components. Spreads are a type of emulsion and their color depends on interactions between emulsion droplets and electromagnetic radiation in the visible region (McClements 1999). The L^*, a^* and b^* values of most halva samples had no significant difference ($P > 0.05$) (Table 4). Lightness (L^*) of the halva samples varied from 43.4 to 51 without specific trend. The L^* value of sample 5 was significantly lower than that of others. Redness (a^*) of the samples poor in soy flour was higher than that of others. The a^* value of sample 3, which had the highest amount of soy flour, was lowest. Most of halva samples rich in soy flour had greater yellowness (b^*) and the samples without soy flour had lowest b^* value. Color of soy flour was a creamy pale yellow color, while sesame paste had a light brown color. Thus, addition of soy flour caused appreciable reduction in color intensity of halva samples.

Sensory Evaluation

The mean scores of the panel evaluation of halva characteristic are presented in Table 5. There was no significant difference ($P > 0.05$) in all sensory properties among most

TABLE 5. SENSORY EVALUATION OF HALVA MIXTURES*

Formulation	Color intensity	Color acceptance	Aroma	Flavor	Hardness	Adhesiveness	Spreadability	Overall acceptability
1	4.5 ± 1.9^{de}	6.7 ± 1.7^{ab}	5.3 ± 2.4^{ab}	5.6 ± 2.5^{abc}	4.2 ± 1.2^{bc}	4.8 ± 1.8^{d}	5.5 ± 2.4^{abc}	6.1 ± 1.1^{abc}
2	2.8 ± 0.9^{f}	7.3 ± 1.7^{ab}	5.2 ± 1.5^{ab}	6.4 ± 1.1^{ab}	3.8 ± 1.7^{c}	5.4 ± 1.9^{bcd}	4.9 ± 2.1^{c}	6.1 ± 1.6^{abc}
3	4.4 ± 1.8^{def}	6.6 ± 1.6^{abc}	4.7 ± 1.9^{b}	6.2 ± 2.5^{abc}	5.5 ± 2.1^{ab}	6.1 ± 1.9^{abcd}	5 ± 1.8^{bc}	5.5 ± 1.6^{bc}
4	6.0 ± 1.9^{bcd}	4.2 ± 1.8^{ef}	4.1 ± 2.1^{b}	4.6 ± 1.8^{c}	7.0 ± 1.5^{a}	6.4 ± 1.3^{abcd}	5.6 ± 2.4^{abc}	5.1 ± 2.3^{c}
5	8.3 ± 1.3^{a}	3.3 ± 2.6^{f}	5.3 ± 2.7^{ab}	5.2 ± 1.9^{abc}	6.1 ± 2.1^{a}	6.8 ± 1.1^{ab}	6.3 ± 1.2^{abc}	5.5 ± 2.5^{bc}
6	3.4 ± 2.3^{ef}	7.8 ± 1.4^{a}	6.7 ± 2.4^{a}	6.7 ± 2.1^{a}	5.4 ± 2.7^{abc}	5.1 ± 2.6^{cd}	6.5 ± 2.3^{abc}	7.0 ± 1.7^{ab}
7	5.8 ± 2.2^{bcd}	6.4 ± 1.5^{abc}	5.9 ± 2.5^{ab}	6.5 ± 1.8^{ab}	3.8 ± 1.8^{c}	4.8 ± 2.0^{d}	6.5 ± 2.4^{abc}	6.9 ± 1.2^{ab}
8	6.2 ± 2.4^{bc}	6.7 ± 1.8^{ab}	5.6 ± 1.9^{ab}	6.2 ± 2.0^{abc}	4.1 ± 1.8^{bc}	5.5 ± 1.5^{bcd}	7 ± 1.0^{a}	7.6 ± 1.2^{a}
9	5.2 ± 1.7^{cd}	6.5 ± 1.3^{abc}	4.6 ± 2.1^{b}	6.5 ± 1.3^{ab}	6.0 ± 1.7^{a}	6.0 ± 2.4^{abcd}	6.6 ± 1.2^{ab}	6.3 ± 2.1^{abc}
10	7.3 ± 1.5^{ab}	5.0 ± 2.5^{cde}	5.6 ± 2.3^{ab}	4.8 ± 1.9^{bc}	5.9 ± 2.1^{a}	6.6 ± 2.5^{abc}	6.7 ± 0.9^{a}	6.0 ± 2.2^{abc}
11	6.3 ± 1.7^{bc}	4.7 ± 1.9^{def}	4.7 ± 2.0^{b}	5.5 ± 2.6^{abc}	6.9 ± 1.6^{a}	7.6 ± 1.0^{a}	5.9 ± 1.4^{abc}	5.5 ± 2.2^{bc}
12	5.3 ± 2.0^{cd}	6.1 ± 1.9^{bcd}	5.4 ± 1.8^{ab}	6.7 ± 1.4^{a}	6.3 ± 1.9^{a}	7.3 ± 1.9^{a}	6.7 ± 2.0^{a}	5.4 ± 1.7^{bc}

* Different letters within the columns indicate significant difference ($P < 0.05$).

halva samples. Sample 6 received the highest score from panelists for color acceptance. Average of color acceptance scores for samples rich in soy flour was lower in comparison to the samples poor in soy flour. The mean scores of aroma ranged from 4 (dislike slightly) to 6 (like slightly). Sample 6 tended to receive the highest aroma scores compared to the other samples. Flavor scores of most samples had no significant difference ($P > 0.05$). Similar to aroma, sample 6 received higher overall product liking scores. Hardness and adhesiveness are negative attributes and samples with the highest intensity of these parameters were given the highest score. Halva samples 2 and 7 were judged as the samples with the hardest texture, and sample 4 received the lowest panelist's score (the softest sample). Panelists judged that sample 11 was more adhesive than others. This was probably related to high amount of soy flour. Adhesiveness of samples without soy flour (7 and 8) received lower score in comparison with most samples. Similar to other sensory characteristics, spreadability of most samples had no significant difference ($P > 0.05$). Sample 8 had the highest spreadability; this was reflected by the panelists' liking scores. Mean score of overall acceptability of most samples were not significantly different ($P > 0.05$). Samples 8 and 4 received the highest and lowest score for overall acceptability, respectively.

Correlation between Measurements

Investigators try to find correlations between instrumental and sensory measurements in order to assess quality control tools, prevision of consumer response, modification of instrumental assay methods and fabrication of a texture analyzer to duplicate sensory perceptions (Szczesniak 1987). Correlation does not imply causation. Finding correlation between two variables only means that two variables are related. Pearson's correlation coefficients between the textural parameters, color and sensory attributes are shown in Table 6. There was a high and positive correlation between instrumental hardness and adhesiveness ($P < 0.001$). Correlation between instrumental hardness and sensory hardness was negative and not significant ($P > 0.05$). Similar results were observed by Mazaheri-Tehrani *et al.* (2009). Meullenet *et al.* (1998) reported that instrumental and sensory hardness of 21 food samples from a wide variety of foods highly correlated with each other. Similar to hardness, sensory and instrumental adhesiveness had nonsignificant correlation ($P > 0.05$). Textural parameters evaluated by taste panel had not a significant correlation with each other. Among sensory attributes, color acceptance and aroma significantly correlated with overall acceptability ($P < 0.05$). Correlation between color parameters obtained by the digital camera and taste panel were investigated. A highly negative and significant correlation ($P < 0.01$) was observed between color

TABLE 6. PEARSON'S CORRELATION COEFFICIENTS BETWEEN THE TEXTURAL PARAMETERS, COLOR AND SENSORY ATTRIBUTES

	Hardness	Adhesiveness	Color intensity	Color acceptance	Aroma	Flavor	Hardness (s)	Adhesiveness (s)	Spreadability (s)	Overall acceptability	L^*	a^*
Adhesiveness	0.923***											
Color intensity	0.706**	0.584*										
Color acceptance	−0.758***	−0.707**	−0.85***									
Aroma	−0.089	−0.225	−0.17	0.47								
Flavor	−0.702**	−0.694**	−0.623*	0.796**	0.443							
Hardness (s)	−0.189	−0.226	0.125	0.032	0.25	0.206						
Adhesiveness (s)	0.418	0.513	0.526	−0.678*	−0.459	−0.37	−0.33					
Spreadability (s)	0.262	0.226	0.492	−0.077	0.465	0.137	0.2	0.133				
overall acceptability	−0.335	−0.484	−0.209	0.62*	0.677*	0.501	0.269	−0.689*	0.479			
L^*	−0.686*	−0.549	−0.822**	0.813**	0.019	0.507	−0.129	−0.518	−0.371	0.358		
a^*	0.146	0.142	0.507	−0.189	0.232	−0.071	0.529	−0.13	0.745**	0.357	−0.362	
b^*	0.065	0.205	−0.361	−0.053	−0.472	−0.062	−0.273	0.191	−0.638*	−0.496	0.371	−0.629*

* Significant at $P < 0.05$, ** Significant at $P < 0.01$, *** Significant at $P < 0.001$.

TABLE 7. SUMMARY OF MODEL EQUATIONS FOR EACH RESPONSE (X_1 = SOY FLOUR, X_2 = SESAME PASTE, X_3 = MONO- AND DIGLYCERIDES)

Response	Equation	Model	R²	$P < 0.05$
Hardness	$Y = 0.13\ X_1 + 0.12\ X_2 + 1.98\ X_3 - 0.09\ X_1X_2* - 1.37\ X_1X_3 - 1.5\ X_2X_3 + 14.06\ X_1^2X_2X_3* + 3.72\ X_1X_2^2X_3 - 149.8\ X_1X_2X_3^2*$	Special quartic	0.98	0.03
Adhesiveness	$Y = 2.35\ X_1 + 1.96\ X_2 + 16.84\ X_3$	Linear	0.67	0.006
$L*$	$Y = 50.11\ X_1 + 50\ X_2 - 1.1\ X_3$	Linear	0.21	0.33
$a*$	$Y = -6.41\ X_1 - 3.68\ X_2 + 11.23\ X_3$	Linear	0.51	0.04
$b*$	$Y = 23.05\ X_1 + 20.72\ X_2 + 12.88\ X_3$	Linear	0.68	0.005
ES 20	$Y = 93.6\ X_1 + 93.15\ X_2 + 133.37\ X_3$	Linear	0.59	0.02
ES 30	$Y = 91.47\ X_1 + 89.77\ X_2 + 1{,}306.77\ X_3 - 1.49\ X_1X_2 - 1{,}253.14\ X_1X_3 - 1{,}213.13\ X_2X_3 + 1{,}292.65\ X_1^2X_2X_3* + 584.54\ X_1X_2^2X_3* - 2{,}0192.56\ X_1X_2X_3^2*$	Special quartic	0.97	0.02
ES 40	$Y = 90.91\ X_1 + 87.51\ X_2 + 930.31\ X_3 - 4.1\ X_1X_2 - 904.87\ X_1X_3 - 821.19\ X_2X_3$	Quadratic	0.51	0.38
Color intensity	$Y = 4.51\ X_1\ 0\ 5.72\ X_2 - 49.97\ X_3 - 8.09\ X_1X_2 + 1{,}247.52\ X_1^2X_2X_3* - 1{,}3494.79\ X_1X_2X_3^2*$	Special quartic	0.79	0.04
Color acceptance	$Y = 6.61\ X_1 + 7.26\ X_2 - 42.19\ X_3 - 765.38\ X_12X_2X_3 + 1{,}2097.52\ X_1X_2X_3^2*$	Special quartic	0.71	0.04
Aroma	$Y = 4.79\ X_1 + 6.01\ X_2 - 6.09\ X_3 - 413.27\ X_1X_2^2X_3* + 6{,}738.38\ X_1X_2X_3^2*$	Special quartic	0.84	0.005
Flavor	$Y = 6.08\ X_1 + 6.64\ X_2 - 515.42\ X_3 + 0.41\ X1X_2 + 516.1\ X_1X_3 + 511.94\ X_2X_3 - 373.13\ X_1^2X_2X_3 - 28.21\ X_1X_2^2X_3 - 6{,}547.08\ X_1X_2X_3^2$	Special quartic	0.96	0.04
Sensory hardness	$Y = 5.23\ X_1 + 3.89\ X_2 + 38.85\ X_3$	Linear	0.54	0.03
Sensory spreadability	$Y = 4.96\ X_1 + 6.53\ X_2 - 851.83\ X_3 - 2.85\ X_1X_2* + 915.83\ X_1X_3* + 905.13\ X_2X_3* + 88.02\ X_1X_2X_3*$	Special cubic	0.95	0.003
Sensory adhesiveness	Mean is the better predictor. Mean = 6.03	–	–	–
Overall acceptability	$Y = 5.47\ X_1 + 6.77\ X_2 + 4.69\ X_3$	Linear	0.44	0.07

* Significant at $P < 0.05$.

intensity and $L*$ value, while correlation between $a*$ or $b*$ value with color intensity was not significant ($P > 0.05$). Color acceptance was positively correlated with $L*$ value ($P < 0.01$). There was no significant correlation between color acceptance and $a*$ or $b*$ values. Reasons for poor correlations between sensory and instrumental parameters are improper accomplishment of taste panel, inadequate knowledge of what the instrumental tests actually measure, sampling errors and heterogeneity of food products, and interpretation of the meaning of the correlation coefficient (Szczesniak 1968).

Model Establishment

Table 7 indicates the predicted models, the R^2 values and significance of the predicted models obtained for responses. The coefficient of determination, denoted by R^2, is the proportion of the total variation in the response variable explained by the regression model and was suggested that for a good fitted model, R^2 should not be less than 80%. When R^2 approaches to the unity, signifies the suitability of fitting empirical model to the actual data. The lower value of R^2 shows the inappropriateness of the model to explain the relation between variables (Mendenhall 1975; Little and Hills 1978). A positive interaction coefficient in a model means that the corresponding terms are synergistic, while a negative interaction coefficient in a model means that the corresponding terms have antagonistic blending effects. R^2 values of the predicted models for hardness, ES 30, aroma, flavor and sensory spreadability were higher than 0.80, indicating that they were adequate for the prediction purpose. Except ES 40, $L*$ and overall acceptability, the linear portion of the predicted models were significantly different ($P < 0.05$). Elimination of highly insignificant terms from ES 40, color intensity, color acceptance and aroma models through backward model reduction improved R^2 and P value of the three models color intensity, color acceptance and aroma. A slight improvement of R^2 and P value could not persuade us to remove insignificant terms of ES 40 model. Predicted linear model for $L*$ and overall acceptability were also insignificant and X_1, X_2 and X_3 were forced terms. No model was fitted for sensory adhesiveness data.

Optimization

In order to optimize halva formulation using the Design Expert software, the amount of each component was set in range. Depending on the responses' importance, their goals were minimized, maximized and or set in range. To find out which group of responses are the most effective in desirability increase, numerical optimization was carried out using all responses, the significant responses, the sensory responses and nonsensory responses, respectively. Each

TABLE 8. SOLUTIONS WITH THE HIGHEST VALUE OF DESIRABILITY FOR NUMERICAL OPTIMIZATION OF TOTAL, SIGNIFICANT, SENSORY AND NONSENSORY RESPONSES

	Soy flour (%)	Sesame paste (%)	Emulsifier (%)	Desirability
All responses	0.512	18.732	0.756	0.58
Significant responses	8.821	10.344	0.835	0.56
Sensory responses	0	20	0	0.75
Nonsensory responses	0	19	1	0.62

generated solution met all our criteria, with varying degrees of desirability. Ideal desirability value is one. In optimization process, formulations containing very small amount of soy flour had the highest desirability except significant responses group (Table 8). Because elimination of the insignificant responses (ES 40, L^* and overall acceptability) caused a slight decrease in desirability value and a small change of formulation, we did not remove them fromoptimization process. The highest value for desirability was obtained using sensory responses. The range of optimum combination was determined by superimposing the contour plots of the all responses. Figure 2a–d present the overlaying contour plots for the all responses, significant responses, sensory responses, and nonsensory responses. These plots illustrate the determination of the best combination. A yellow area, namely overlay area of the responses, is assigned as the optimum area of responses that represents a higher desirability for formulation.

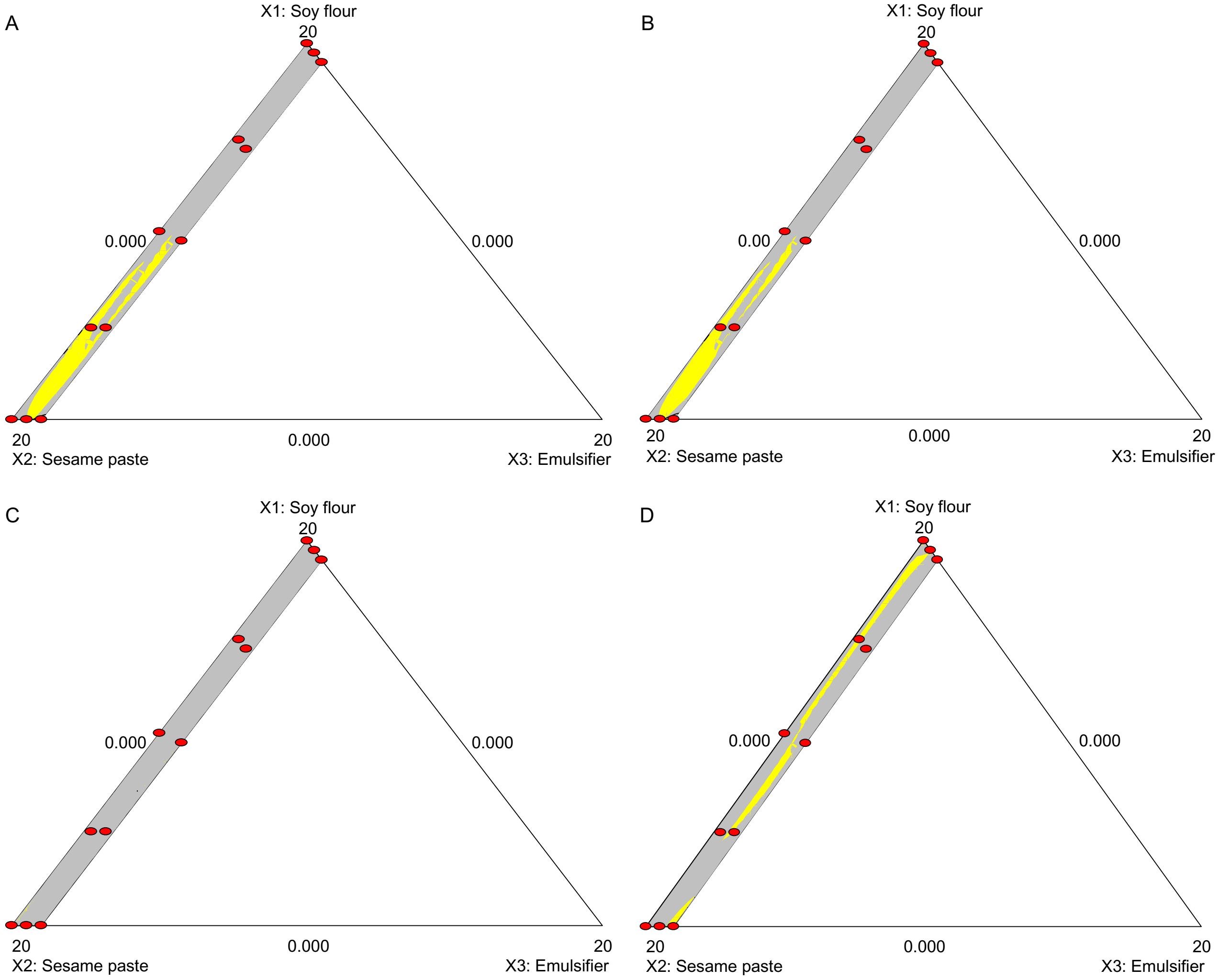

FIG. 2. THE OPTIMUM REGION FOR FORMULATION BY OVERLAYING CONTOUR PLOTS OF THE (A) ALL RESPONSES, (B) SIGNIFICANT RESPONSES, (C) SENSORY RESPONSES, AND (D) NONSENSORY RESPONSES

CONCLUSIONS

Spreadable sesame-based halva fortified with soy flour was developed successfully in order to provide more convenience for consumers and utilize health-giving effects of soy. A mixture design was used to study effects of soy flour, and mono- and diglycerides addition on the halva properties. Mono- and diglycerides imparted high ES to spreadable halva. Addition of soy flour caused appreciable reduction in color intensity of halva samples. Incorporation of oil prevented hardening effect and adhesiveness of soy flour on the halva samples. For this reason, hardness and adhesiveness of most samples were not significantly different from each others. Based on taste panel results we can conclude that all halva samples were accepted by panelists and samples in all evaluated attributes received scores 4 to 7. Results of optimization process indicated that addition of soy flour into spreadable halva negatively influenced the physical and sensory properties of the halva. However, high nutraceutical value of soy flour can partly compensate the negative effects of it and justifies fortification of the halva with soy flour.

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