Original article

Utilization of peanut fines in the optimization of peanut polvoron using mixture response surface methodology

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Summary Percentages of peanut fines, sugar and butter in a peanut polvoron formulation were optimized using mixture response surface methodology (RSM). A consumer panel evaluated colour, appearance, flavour, texture and overall acceptance of a control and 15 experimental formulations of peanut polvoron containing various levels of peanut fines, sugar and butter. Texture was found to be the limiting factor for the optimization of peanut polvoron. Formulations with a 9-point hedonic scale score minima of ≥6 for overall acceptance and acceptance of colour, appearance, flavour and texture were considered optimum. Optimum formulations can be obtained in all blends containing 22–36% peanut fines, 24% butter and 40–54% sugar.

Keywords Appearance, butter, colour, flavour, formulation, sensory evaluation, sugar, texture.

Introduction

Polvoron is a Philippine ethnic product classified under the desserts and candy category and is composed of milk powder, toasted flour, sugar and butter. Polvoron is usually prepared plain or with ground nuts added as an ingredient to vary flavour and texture properties. The most common flavouring ingredients added are nuts such as peanut, pili and cashew; toasted rice or pinipig and butter.

Peanut fines are a by-product of the roasted peanut manufacturing industry. Fines refer to particles that pass through a mesh opening of 0.75 mm and are discarded during the grinding process of roasted peanuts, resulting in large losses. Tons of these by-products are produced resulting in losses to the food company. Utilization of peanut fines as an ingredient in the formulation of peanut polvoron will provide added flavour, resulting in an additional product line and would help solve the problem of its disposal and subsequent economic loss.

Optimization studies on peanut polvoron can be conducted as a mixture experiment to optimize consumer acceptance of the product. Mixture experiments involve blends of two or more ingredients to form a product. In mixture experiments, the independent or controllable variables represent proportionate amounts of a mixture, rather than unrestrained amounts, where the proportions are expressed as volume, weight or mole fraction (Cornell, 1983). In the optimization procedure, the optimal formulation maximizes consumer acceptance given a fixed combination of ingredients (Fishken, 1983). Ingredients (factors) of the product are combined in various proportions according to an experimental design to determine the most liked or most preferred products.

Response surface methodology (RSM) is a statistical technique that can be used to systematically determine the effects of multiple variables on response variables (such as quality attributes) while minimizing the number of evaluations that must be conducted (Henika, 1982). RSM is a designed regression analysis used to predict the value of a response or dependent variable based on controlled values of the experimental factors, or independent variables (Meilgaard *et al.*, 1991).

This study was conducted to optimize consumer acceptance of a peanut polvoron using different proportions of the formulation components: peanut fines, sugar and butter. The specific objectives were to: (1) determine overall acceptance, and acceptance of appearance, colour, flavour and texture of peanut polvoron that vary in levels of peanut fines, sugar and butter using consumer affective tests; (2) identify levels of peanut fines, sugar and butter that would produce an acceptable peanut polvoron; and (3) verify prediction models of selected attributes.

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Materials and methods

Experimental design

A three-component constrained simplex lattice mixture design as described by Cornell (1983) was used to optimize the formulation for the manufacture of peanut polvoron that is acceptable to consumers. Preliminary experiments were conducted to identify high impact ingredients (Fishken, 1983) of peanut polvoron. High impact ingredients are those which when varied have a strong influence on the overall sensory properties and/or cost of the product. The ingredients that had the most influence on its quality when altered were determined and these were found to be peanut fines, sugar and butter, while flour and milk powder did not contribute to the change in quality of peanut polvoron. Initially, the formulation used by a peanut polvoron manufacturer was used as the basis for varying the levels of the ingredients. Samples of peanut polvoron with the highest and lowest percentages of the ingredients that would result in a product were prepared. These proportions were used as constraints in the mixture experiment where the highest and lowest levels were identified as the extreme vertices in the constrained region. Based on the components to be studied, thirteen formulations were prepared. In addition, three replicates of the centre point formulations 13, 14 and 15 were studied.

The three mixture components studied were sugar (x_1), peanut fines (x_2) and butter (x_3) consisting of a total of 72.5% of a peanut polvoron formulation. The remaining 27.5% of the peanut polvoron consists of milk powder and flour, which was a fixed amount in the formulation, consisting of 15.0% flour and 12.5% milk powder. The constraints or ranges of the components in the mixture, based on preliminary experiments, were determined to be 0–80% sugar, 10–95% peanut fines and 5–50% butter, adding to a total of 100% in the mixture.

In this design, the number of points (n) necessary to run a mixture experiment is

$$n = 2^q - 1$$

where q is the number of components being studied. Therefore, the minimum number of points to be studied is $2^3 - 1$ or seven points (Scheffé, 1963) as shown in Fig. 1. The constrained region consisted of the following points: five points representing the five extreme vertices (formulations 1, 3, 5, 7 and 9) outlining the constrained region, four midpoints (formulations 2, 4, 6, and 8), a centre point (formulation 13) or overall centroid (Snee, 1975) and replicated as formulations 14 and 15. Three other points were selected to support the second-order polynomial (formulations 10, 11 and 12). The thirteen formulations and two replications of the thirteenth formulation are shown in Table 1.

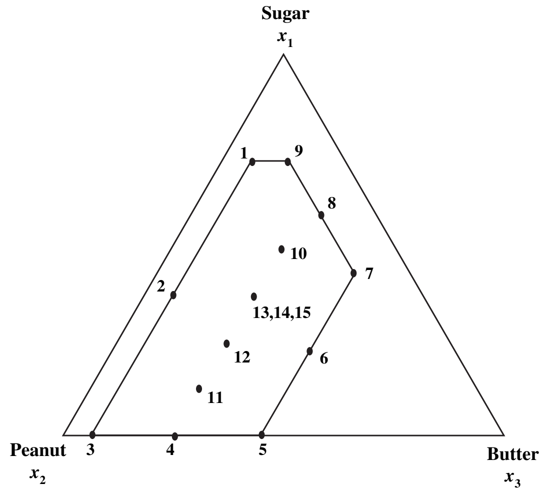

Figure 1 Constrained region in the simplex coordinate system defined by the following restrictions: $0.12 \le x_1 \le 0.80$, $0 \le x_2 \le 0.95$, $0.05 \le x_3 \le 0.50$ for sugar, peanut fines and butter, respectively.

Table 1 Composition of peanut polvoron used in a three-component constrained simplex lattice mixture design

	Component proportion (%)[a]		
Formulation no.	**Sugar (x_1)**	**Peanut fines (x_2)**	**Butter (x_3)**
1	80.0	15.0	5.0
2	40.0	55.0	5.0
3	0	95.0	5.0
4	0	72.5	27.5
5	0	50.0	50.0
6	20.0	30.0	50.0
7	40.0	10.0	50.0
8	60.0	10.0	30.0
9	80.0	10.0	10.0
10	54.0	22.0	24.0
11	12.0	64.0	24.0
12	26.0	50.0	24.0
13	40.0	36.0	24.0
14	40.0	36.0	24.0
15	40.0	36.0	24.0

[a]The three components total 72.5% of the peanut polvoron formulation. Flour and milk powder are the ingredients added in a fixed amount in the different formulations.

Processing of peanut polvoron

Peanut polvoron was prepared following a procedure developed by the FDC-NFA (1992) as shown in Fig. 2. Flour (Gold Medal; Liberty Commodities Corp., Cupang, Muntinlupa City, Philippines), refined sugar (NFA; FTI Complex, Taguig, Metro Manila, Philippines), full cream milk powder (Nido; Nestle Philippines, Inc., Cabuyao, Laguna, Philippines) and peanut

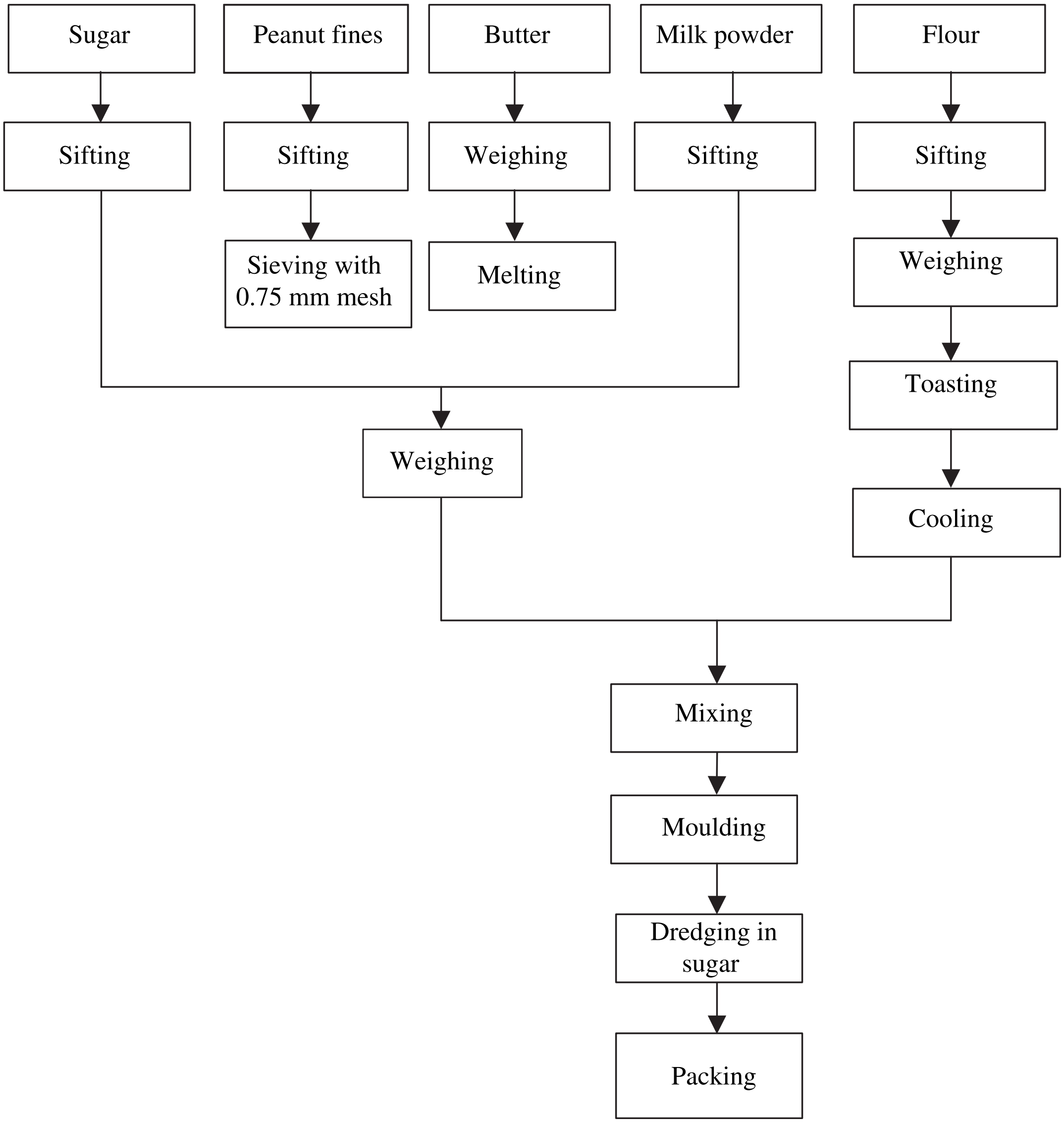

Figure 2 Flow diagram for the preparation and processing of peanut polvoron.

fines from a peanut polvoron manufacturer were sifted individually to remove lumps and aerate the ingredients using a strainer (EKCO; Elmira, New York, USA) with a mesh screen of 1 mm. Peanut fines were sifted a second time using a sieve (Tsutsui, Tokyo, Japan) with a mesh screen of 0.75 mm to obtain finer peanut fines.

Dry ingredients and butter, unsalted pure and creamy butter (Magnolia Gold, Philippine Dairy Products Corp., Pasig, City, Philippines) were weighed using a top loading balance (Model E5500S; Sartorius AG, Goettingen, Germany) according to the proportions in the experimental design (Table 1). The weighed flour was toasted in a 304.5 mm diameter aluminium alloy frying pan (SEB, Ecully Cedex, France) over moderate heat to a uniform light brown colour (L-value = 94) measured using the SZ-80 II Colour Measuring System (Nippon Denshoku Kogyo Co., Ltd, Tokyo, Japan). The flour was stirred constantly while toasting to prevent burning that may result in a burnt or bitter flavour. After toasting, the flour was cooled immediately and small pockets of flour that agglomerated during the toasting operation were removed. The weighed butter was melted in a stainless steel container over low heat.

Dry ingredients were mixed together in a stainless steel container and sifted twice using a strainer to evenly disperse and distribute the ingredients. The melted butter was added to the mixture and manually stirred until all the dry ingredients were thoroughly moistened and the butter was evenly dispersed. Portions of the mixture (10–12 g) were moulded using a fabricated aluminium polvoron moulder (C.S. Barrera Corp., Tondo Manila, Philippines) to produce compact oval cakes 10 mm in height then dredged in sugar. The products were stored in plastic cups (30 mL capacity) with cover's, coded, and stored in a storage freezer (−18°C, Sanyo, Model SRF-T681A; Moriguchi-shi, Osaka-fu, Japan) until time of use.

Sensory evaluation

A central location test was conducted at the National Food Authority (NFA), Central Office, Quezon City, Philippines. Panellists were recruited based on the following criteria: (1) had no food allergies; (2) were between the ages of 18 and 70 years; (3) had satisfied gender balance requirement consisting of 50% male and 50% female (only one of each gender per immediate family); and (4) had eaten peanut polvoron or other related products at least three times a month.

A total of fifteen formulations (formulations 1–13, 14 and 15) were tested in each of two replications. Twenty-five consumer responses is close to the minimum required for consumer acceptance tests (Institute of Food Technologists Sensory Evaluation Division, 1981). A total of 115 consumers were used in the study. Attributes evaluated were overall acceptance and acceptance of appearance, colour, flavour, and texture using a 9-point hedonic scale, where 1, dislike extremely; 5, neither like nor dislike; and 9, like extremely. A control sample, which was a popular commercial peanut polvoron was also evaluated by each panellist.

Tables were lined with white paper and set up in one part of an open room for evaluation. Separate tables were also set up which were used by the panellists to fill-out demographic questionnaires prior to the test. The ballots were given to panellists in the order of evaluation. The evaluation order of the eight peanut polvoron samples was randomized for each panellist. Panellists were instructed to evaluate four samples, then take a 1 min break before evaluating four more samples. Panellists were asked to place at least one-fourth of the sample in their mouths when evaluating. The panellists were also instructed to drink water after every sample and not to make comments during evaluation to prevent influencing other panellists.

Statistical analysis and modelling

All analyses were performed using the Statistical Analysis System (SAS Institute Inc., 1985). Development of prediction models and model fitting were as outlined by Cornell (1981). Analysis of Variance using the General Linear Models (GLM) Procedure was performed on the data of each sensory attribute. A response surface model, using Scheffé second-order polynomial (Scheffé, 1958),

$$\eta = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3$$

was used to fit the treatment means where: η = a sensory quality attribute; β_1, β_2, β_3, β_{12}, β_{13}, β_{23}, β_{123} = the corresponding parameter estimates for each linear and cross product term produced from the prediction models; and x_1, x_2, x_3, x_{12}, x_{13}, x_{23}, x_{123} = the linear terms of sugar, peanut and butter and the cross-product terms of sugar × peanut, sugar × butter, peanut × butter and sugar × peanut × butter.

Regression analysis was next performed on the means of the sensory attributes of the fitted models using the no intercept option to determine parameter estimates (Cornell & Linda, 1989). No intercept was specified due to the limitation of $x_1 + x_2 + x_3$ which must equal 100%, in a mixture design experiment. The parameter estimates from the no intercept option were used to predict the models for each sensory attribute. All models with $R^2 > 0.70$ were chosen. To determine the effects of the mixture components sugar, peanut fines and butter on the properties of peanut polvoron, response surfaces were generated using PC SAS Graph (SAS Institute Inc., 1985).

Optimization

Contour plots were generated for each sensory attribute using the significant prediction models. Ranges of acceptable formulations were determined for each attribute based on the area covered by an acceptance rating of six or greater. Acceptable regions for each attribute were outlined onto contour plots, which were then superimposed to determine a region of overlap for all attributes. This region of overlap was defined as the optimum region. All formulation within the optimum region would result in polvoron that would be acceptable, overall and in all attributes modelled.

Model verification

Model verification was performed on two replicates of the two formulations, one predicted to result in an acceptable product and another predicted to result in an unacceptable product. Twenty-five consumers evaluated each replication of each of the two formulations. Each consumer was presented with one acceptable and one unacceptable product. Samples were evaluated for overall acceptance and acceptance for appearance, colour, flavour and texture acceptance. The Student's *t*-test was performed to determine whether a significant difference existed between the predicted and observed ratings.

Table 2 Mean consumer acceptance scores observed for peanut polvoron with two replications[a]

	Factors[b]			Mean acceptance ratings[c]				
Treatment	x_1	x_2	x_3	Overall liking	Colour	Appearance	Flavour	Texture
1	0.800	0.150	0.050	5.33d	6.02ab	5.20de	5.44c	5.19e
2	0.400	0.550	0.050	5.87bcd	6.04ab	5.96bc	5.70bc	5.44cde
3	0.000	0.950	0.050	3.69e	5.13cd	5.10de	3.494c	3.92f
4	0.000	0.725	0.275	3.83e	4.70d	4.77e	3.75d	4.11f
5	0.000	0.500	0.500	3.85e	4.62d	4.61e	3.65d	3.91f
6	0.200	0.300	0.500	5.23d	5.79bc	5.72cd	5.28c	5.30de
7	0.400	0.100	0.500	5.68cd	5.83bc	6.06abc	5.60c	5.66bcde
8	0.600	0.100	0.300	5.88bcd	6.27ab	6.15abc	5.75bc	5.58bcde
9	0.800	0.100	0.100	5.75bcd	6.00ab	5.15de	5.51c	5.24de
10	0.540	0.220	0.240	6.56ab	6.46ab	6.62ab	6.50ab	6.21abc
11	0.120	0.640	0.240	5.69cd	5.72bc	5.80cd	5.48c	5.46cde
12	0.260	0.500	0.240	6.00bcd	6.08ab	6.23abc	6.06abc	6.02abcde
13	0.400	0.360	0.240	6.54ab	6.30ab	6.39abc	6.50ab	6.07abcd
14	0.400	0.360	0.240	6.82a	6.74a	6.84a	6.70a	6.56a
15	0.400	0.360	0.240	6.41abc	6.47ab	6.43abc	6.49ab	6.35ab
Control	–	–	–	**7.42**	**7.42**	**7.24**	**7.48**	**7.42**

[a]Scores are based on a 9-point hedonic scale with 1, dislike extremely; 5, neither like nor dislike; and 9, like extremely.
[b]Factors were: x_1, proportion of sugar; x_2, peanut fines; x_3, butter.
[c]Mean values in the same column not followed by the same letter are significantly different ($P < 0.05$).

Table 3 Regression equations[a] describing the response for each dependent variable (overall acceptance, and acceptance for colour, appearance, flavour, and texture) for peanut polvoron containing the proportions sugar (x_1), peanut fines (x_2), and butter (x_3)[b]

Variable	Model[c]	R^2
Overall acceptance	$4.40x_1 + 3.58x_2 + 0.51x_3 + 6.58x_1x_2 + 10.30x_1x_3 + 6.84x_2x_3 + 25.39x_1x_2x_3$	0.9361
Colour acceptance	$5.72x_1 + 5.12x_2 + 3.91x_3 + 1.74x_1x_2 + 2.78x_1x_3 + 0.14x_2x_3 + 25.35x_1x_2x_3$	0.7629
Appearance acceptance	$3.91x_1 + 4.98x_2 + 2.38x_3 + 4.99x_1x_2 + 10.55x_1x_3 + 3.23x_2x_3 + 17.37x_1x_2x_3$	0.8916
Flavour acceptance	$4.45x_1 + 3.35x_2 + 0.78x_3 + 6.08x_1x_2 + 8.48x_1x_3 + 6.21x_2x_3 + 33.78x_1x_2x_3$	0.8750
Texture acceptance	$4.30x_1 + 3.84x_2 + 1.50x_3 + 4.16x_1x_2 + 7.73x_1x_3 + 4.94x_2x_3 + 31.77x_1x_2x_3$	0.8757

[a]Equations used were the full model. Consumer rating based on a 9-point hedonic scale where 1, dislike extremely; 5, neither like nor dislike; and 9, like extremely.
[b]Where x_1, x_2 and x_3 are proportions of the components sugar, peanut and butter used in the mixture to formulate peanut polvoron.
[c]All models significant at $P < 0.05$.

Results and discussion

Evaluation of peanut polvoron

Mean values for consumer acceptance scores for the attributes tested for peanut polvoron are shown in Table 2. Peanut polvoron prepared from mixtures containing 40–54% sugar, 22–36% peanut fines and 24% butter had acceptance scores of 6.0 or greater for overall acceptance, flavour and texture. Acceptance scores were low ≤5.30 for all attributes in blends without sugar. Blends without sugar (formulations 3, 4 and 5) had the lowest overall acceptance ratings and significantly lower colour ratings compared with all formulations. These and the very high sugar (formulation 1) had significantly lower appearance ratings compared with the other blends with sugar.

Modelling of sensory attributes of peanut polvoron

Results of the regression analyses are presented in Table 3, listing the coefficients of determination (R^2) and parameter estimates for the prediction models for all acceptance scores and intensity ratings of sensory attributes evaluated. Significant models ($P < 0.05$) for acceptance scores (Table 3) with high coefficient's of determination were for overall liking, and liking for colour, appearance, flavour and texture. Response surfaces representing plots produced from the parameter estimates for each of these variables were also generated (Fig. 3).

The peanut polvoron had acceptance scores of 6 or greater for overall liking, colour, appearance and flavour, and up to 6.0 for texture. Blends with increasing amounts of sugar, but with decreasing amount of peanut

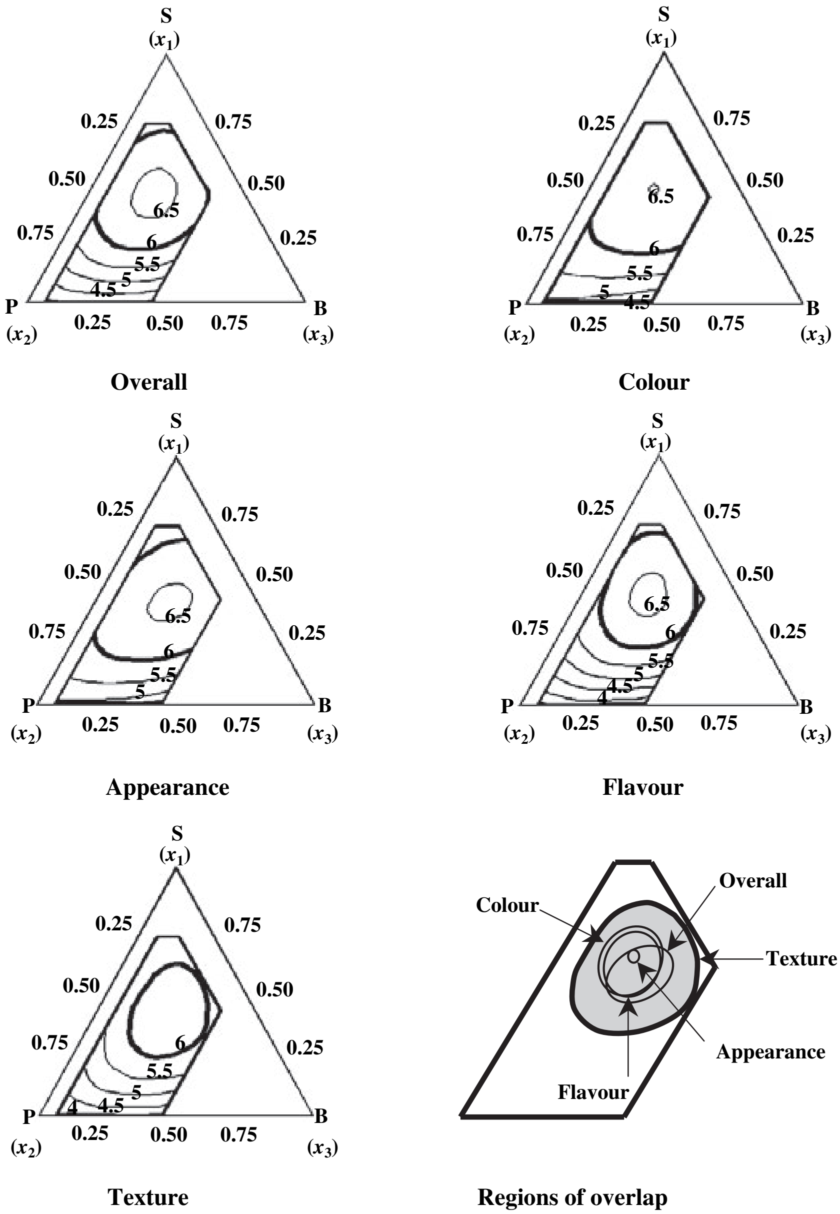

Figure 3 Contour plots for overall acceptance, colour, appearance, flavour and texture, and their regions of overlap for formulations with ratings ≥6.

fines and with 24% butter had the highest consumer acceptance scores at the centre of the constrained region for all the sensory attributes. The plots show that acceptance for the different attributes decreased when the amount of sugar was high (60–80%), low (12%) or absent in the formulation, and with increase in peanut fines and a decrease in butter.

Deriving the optimum formulation

The region of overlap for formulations that were rated 6.0 or higher for overall acceptance, colour, appearance, flavour and texture are shown in Fig. 3. Texture was the limiting factor defining the area of overlap and, therefore, outlined the optimum formulations. The optimum regions show that acceptable peanut polvoron formulations should contain 22–36% peanut fines, 24% butter and 40–54% sugar.

Model verification

The observed and predicted values for appearance, colour, flavour and texture acceptance and overall acceptance are presented in Table 4. The *t*-tests indicated

Table 4 Predicted and observed values for consumer acceptance of selected formulations of peanut polvoron for verification of the optimum region

Sensory attribute	Peanut polvoron containing 40% sugar, 36% peanut and 24% butter			Peanut polvoron containing 0% sugar, 95% peanut and 5% butter		
	Observed	Predicted	*t*-value	Observed	Predicted	*t*-value
Overall	6.19	6.41	3.48E-09NS	3.81	3.69	0.0289NS
Colour	6.23	6.47	0.0002NS	5.46	5.13	0.0970NS
Appearance	6.08	6.43	6.76E-05NS	5.46	5.10	0.0071NS
Flavour	5.96	6.49	1.92E-09NS	3.08	3.49	0.0060NS
Texture	5.58	6.35	1.11E-07NS	3.50	3.92	0.0009NS

NS, observed ratings were not significantly different ($P \leq 0.05$) from predicted ratings.

that the observed values for the selected formulation (formulation 1) were not significantly different from the predicted values at $\propto = 0.05$.

Conclusions

Mixture response surface methodology was used to determine the effects of varying the percentages of sugar, peanut fines and butter on the sensory attributes of 13 peanut polvoron formulations. Texture was the limiting sensory attribute in the manufacture of peanut polvoron. Optimum formulations could be obtained in blends containing 22–36% peanut fines, 24% butter and 40–54% sugar.

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