



RESEARCH ARTICLE

OPTIMIZATION OF MIXTURE FLAKES AND NUTS TO FORMULATE READY TO EAT BREAKFAST BAR USING RESPONSE SURFACE METHODOLOGY

Nazni, P. and Bhuvaneshwari, J.

Department of Food Science, Periyar University, Salem-11, TamilNadu, India

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ABSTRACT

A breakfast cereal is a food made from more or less processed grains often but not always eaten with the first meal of the day. Cereal flakes are cheapest source of energy and protein in human diet. For the present study the mixture of flakes such as (rice flakes, oats flakes, corn flakes and wheat flakes), groundnut and chocolate chips are selected and used to prepare Ready To Eat (RTE) breakfast bar and analyzed the physiochemical properties and nutritive value of the raw flakes and developed breakfast bar and determining the optimal levels of mixture flakes, groundnuts and chocolate chips using Response Surface Methodology (RSM) was applied for optimization, the multiple regression was used to get optimum levels and it was found that desirable values of weight (25.23g), diameter (4.12cm), width (1.15cm), calorie (423.1kcal), protein (8.65g), fat (14.14g), carbohydrate (51.4g) and over all acceptability (8.31) for a 100g was obtained with the corresponding optimum condition of 24g of mixture flakes, 11g of groundnut, 8g of chocolate chips and 48g of the rest of the breakfast bar ingredients. Hence it is concluded that RSM was used successfully to optimize the level of mixture flakes, groundnut and chocolate chips for the development of Ready to Eat (RTE) breakfast bar.

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*Corresponding author: naznip@gmail.com

INTRODUCTION

Breakfast is often referred to as the most important meal of the day. Evidence suggests that breakfast contributes to well-being in a number of areas. First, it is a central component of nutritional well-being, contributing to total daily energy and nutrient intake. Breakfast consumption is a marker

for an appropriate dietary pattern in terms of both macro- and micronutrient, particularly if breakfast cereals explain the objectives of the study before starting. All are included in the meal. Today the world demands foods with specific nutrients that can help human beings to stay in good health and enjoy extended life span. A breakfast cereal (or just cereal) is a food made from more or less processed grains often but not always eaten with the first

for the brain and improves learning. The effect of glucose deprivation is noticeable by a fall in blood glucose level of sufficient degree, which is rapidly followed by disturbance in cerebral function (Wurtman et al., 1977).

Breakfast cereals have been defined as "Processed grains for Human consumption" (Fast, 1990). Cereal grains are cheapest source of energy and protein in human diet. The word *cereal* derives from *Ceres*, the name of the Roman goddess of harvest and agriculture. Corn is a multipurpose crop, provides food for human, feed for animals and poultry and fodder for livestock. It is a rich source of raw material for the industry where it is being extensively used for the preparation of cornstarch, corn, dextrose, corn syrup, corn flakes etc. Rice flake is a food item prepared from paddy. It is consumed either after frying in oil or soaked in milk or curd. Rice flakes are nutrition as they contain carbohydrates and proteins. Since it is made from paddy, it is easily digestible. Wheat (*Triticum* spp.) is a grass and is the leading source of vegetable protein in human food, having higher protein content than either maize (corn) or rice, and it is a concentrated source of vitamins, minerals, and protein.

The peanut, or groundnut (*Arachis hypogaea*), is a species in the legume "bean" family (Fabaceae). Peanuts are rich in nutrients, providing over 30 essential nutrients and phytonutrients. Peanuts are a good source of niacin, folate, fiber, magnesium, vitamin E, manganese and phosphorus. They are naturally free of trans-fats and sodium, and contain about 25% protein (a higher proportion than in any true nut) (<http://www.weightlossforall.com/protein-nuts.htm>). The chocolate chips are used to ensure the breakfast bar smooth texture and it will give the glossy look. It is the good emulsifier in the development of breakfast bar.

The present study was undertaken with the objectives to assess the physiochemical properties of the raw flakes and the developed breakfast bar and to determine the optimal levels of mixing the mixture flakes, groundnuts and chocolate chips for

variables.

MATERIALS AND METHODS

Sources of materials

Mixture flakes (Corn flakes, wheat flakes, rice flakes and oat flakes in 1:1:1:1 ratio), groundnut, chocolate chips, butter, sugar, vanaspathi, essences, glycerin, sodium bi carbonate and sesame seeds were purchased from local market of Salem.

Physical parameters of selected flakes

The physical parameters such as thousand flakes weight was determined by the method of Riechert *et al.*, (1982). The water absorption capacity, oil absorption and Bulk Density (BD) were determined by using Ige, (1984). Texture was determined by using a manual penetrometer. The sogginess was determined by the method of cruzi *et al.* (1996).

Experimental design for optimization of breakfast bar

Response surface methodology was applied to the experimental data using a commercial statistical package (Design expert, Trail version 7.0, State Ease Inc., Minneapolis, IN statistical software) for the generation of response surface plot and optimization of process variables. The experiments were conducted according to Central Composite Rotatable Design (CCRD) (Khuri, al and Cornell. JA,1997). A 3³ factorial experiment was used to study the effects of mixture flakes (X₁), groundnut (X₂) and chocolate chips (X₃) on the response variables such as over all acceptability (Y1), weight (Y2), diameter (Y3), width (Y4) calorie (Y5), protein (Y6), fat (Y7), carbohydrate (Y8) of the developed breakfast bars.

Table 1. Process variables and their levels of experimental design

Variables	Symbols	Coded levels				
		-1.68	-1	0	+1	+1.68
Mixture flakes	X ₁	25	24	25	26	33.41
Groundnut	X ₂	16.59	11	11.5	12	11.5
Chocolate chips	X ₃	11.5	7	7.5	8	25

Observed values of dependent variables for different runs of optimization experiments

Design	Uncoded			Coded		
	X ₁	X ₂	X ₃	x ₁	x ₂	x ₃
1	24	11	7	-1	-1	-1
2	26	11	7	+1	-1	-1
3	24	12	7	-1	+1	-1
4	26	12	7	+1	+1	-1
5	24	11	8	-1	-1	+1
6	26	11	8	+1	-1	+1
7	24	12	8	-1	+1	+1
8	26	12	8	+1	+1	+1
9	16.59	25	11.5	-1.682	0	0
10	33.41	25	11.5	+1.682	0	0
11	25	16.59	11.5	0	-1.682	0
12	25	33.41	11.5	0	+1.682	0
13	25	11.5	1.32	0	0	-1.682
14	25	11.5	4.68	0	0	+1.682
15	25	11.5	3	0	0	0
16	25	11.5	3	0	0	0
17	25	11.5	3	0	0	0
18	25	11.5	3	0	0	0
19	25	11.5	3	0	0	0
20	25	11.5	3	0	0	0

X₁ = Mixture flakes, X₂ = Groundnut and X₃ = Chocolate chips; x = coded value, X = uncoded value

Each design point consists of the replicates. For the statistical analysis the numerical levels are standardized to -1, 0 and +1. The experiments were carried out in randomized order (Gacula and Singh, 1984). The relationship between standardized variables values is given as follows

$$X_1 = \frac{\text{Mixture flakes} - 25}{1}$$

$$X_2 = \frac{\text{Groundnuts} - 11.5}{0.5}$$

$$X_3 = \frac{\text{Chocolate chips} - 7.5}{0.5}$$

The standard scores were fitted to a quadratic polynomial regression model for predicting individual Y responses by employing at least square technique (Wanasaundara and Shahidi, 1966; SPSS, 2007). The second order polynomial equation was fitted to the experimental data of each dependent variables as given. The model proposed to each response of Y was

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

coefficient terms. X_i and X_j are independent variables. The model permitted evaluation of quadratic terms of the independent variables on the dependent variable. The response surface and contour plot were generated for different interactions of any two independent variables, where holding the value of third variables as constant at central level. The optimization of the process was aimed at finding the optimum values of independent variables (Parmjit, 2009).

Development of breakfast bar

The breakfast bar development procedure reported by Fast and Caldwell (1990) was adopted for producing the breakfast bar. Following this method twenty different formulations of breakfast bar in triplicate varying cereal flakes, groundnut and chocolate chips concentration were developed.

Analysis of physical parameters of the developed breakfast bar

The variable parameters like the weight, diameter, width and cooking time of the bar and also the nutrients like energy (Kcal) was calculated by using calculation method, the protein (g) was calculated by Lowry’s method, and the fat (g) was by soxhlet method and carbohydrate by Anthrone method.

Sensory Evaluation

The sensory quality for all the developed breakfast bar was evaluated for their acceptability by a semi trained panel of ten judges. The developed breakfast bar was evaluated for sensory quality on the basis of appearance, colour, flavour, texture, taste and over all acceptability using a 9 point Hedonic rating scale card with scores ranging from 9 to 1 representing like extremely and dislike extremely respectively.

Statistical Analysis

The statistical significance of the regression coefficients was determined by students ‘t’ test and

The selected flakes physical parameters like thousand flakes, size and thickness, texture and sogginess were given in the Table 2. 100 numbers of flakes showed a 138.5g (corn flakes), 37.2g (rice flakes), 120.4g (oat flakes) and 117.5g (wheat flakes)

Table 2. Physical characteristics of the selected flakes

Physical characteristics	Corn flakes	Rice flakes	Oat flakes	Wheat flakes
Thousand flakes (g)	138.5	37.2	120.4	117.5
Size of flakes (mm)	11.15	6.12	12.3	10.4
Thickness of flakes (mm)	1.24	0.71	0.94	1.05
Sogginess (mins)	5.1	4.7	4.8	4.2

Table 3. Oil Absorption, Water Absorption and Bulk Density ratio of flakes

Methods	Corn flakes	Rice flakes	Oat flakes	Wheat flakes
Oil Absorption (ml)	1.39	1.20	3.21	2.51
Water Absorption (ml)	3.81	4.52	3.01	3.61
Bulk Density (g)	3.2	1.82	3.14	2.14

Table 4. Organoleptic and physiochemical parameters of the Breakfast Bar

Variables	Un coded			Over all acceptability	Weight (g)	Diameter (cm)	Width (cm)	Calorie (k.cal)	Protein (g)	Fat (g)	CHO (g)
	X ₁	X ₂	X ₃								
1	24	11	7	9	25.3	4.15	1.1	415.23	8.03	19.5	51.9
2	26	11	7	8	25.1	4.1	1.02	420.4	8.6	21.8	52.2
3	24	12	7	8	25.8	4.1	1.06	417.5	7.67	20.7	51.3
4	26	12	7	9	25.4	4.3	1.3	423.4	9.4	20.1	55.4
5	24	11	8	9	25.3	3.8	1.05	415.2	8.6	19.4	51.2
6	26	11	8	8	25.1	3.8	1.02	420.4	8.7	21.3	51.4
7	24	12	8	7	25.13	3.2	1.3	420.1	8.2	20.7	55.3
8	26	12	8	9	24.8	3.6	1.1	418.2	9.4	24.3	55.2
9	16.59	25	11.5	8	25.12	3.4	1.2	423.5	6.4	18	51.3
10	33.41	25	11.5	8	24.6	3.9	1.4	421.5	9.6	24.7	51.4
11	25	16.59	11.5	9	24.8	4.2	1.3	423.6	8.2	19.1	51.4
12	25	33.41	11.5	8	25.3	3.9	1.05	423.8	8.3	19.4	52.3
13	25	11.5	1.32	9	24.3	3.8	1.2	420.5	8.1	20.3	51.8
14	25	11.5	4.68	8	25.1	3.4	1.3	421.1	8.2	20.1	51.3
15	25	11.5	3	9	24.8	3.3	1.4	418.6	8.5	20.3	51.4
16	25	11.5	3	7	24.1	3.6	1.02	418.6	8.1	20.1	51.2
17	25	11.5	3	8	24.3	3.4	1.05	418.5	8.6	19.3	51.1
18	25	11.5	3	6	24.5	3.4	1.06	418.5	8.3	20.3	51.6
19	25	11.5	3	8	24.1	3.5	1.05	418.2	8.4	20.4	51.4
20	25	11.5	3	8	24.3	3.6	1.08	418.6	8.6	20.3	51.3

X₁= Mixture flakes, X₂= Groundnut, X₃= Chocolate chips

flakes) of weight and its size were 11.15mm (corn flakes), 6.12mm (rice flakes), 12.3mm (oat flakes) and 117.5mm(wheat flakes) and its thickness were 1.24 mm (corn flakes), 0.71mm (rice flakes), 0.94mm(oat flakes and 1.05mm (wheat flakes) and the value of sogginess for the selected flakes showed that 5.1mins (corn flakes), 4.7min (rice flakes), 4.8mins (oat flakes) and 4.2mins (wheat flakes) respectively. The oil absorption capacity of the flakes were found to be 1.39ml (corn flakes,

1.20ml (rice flakes), 3.21 ml (oat flakes) and 2.51ml (wheat flakes) respectively. Regarding water absorption, it was found that 3.81ml for corn flakes, 4.52ml for rice flakes, 3.01ml for oat flakes and 3.61ml for wheat flakes and about bulk density corn flakes, rice flakes, oat flakes and wheat flakes had 3.2g, 1.82g, 3.14g and 2.14g respectively. Similar responses were observed by Eck (1991) with sorghum grain and by Zinn (1990) with corn.

Optimization of developed breakfast bar

The breakfast bar was developed with the help of mixture flakes, groundnut and chocolate chips as main ingredients and it was characterized for its physiochemical and organoleptic properties. The over all acceptability (Y1), weight (Y2), diameter (Y3), width (Y4) calorie (Y5), protein (Y6), fat (Y7), carbohydrate (Y8) were measured as response variables.

X₁= Mixture flakes, X₂= Groundnut, X₃= Chocolate chips

Table 4 shows that the over all acceptability of breakfast bar was ranged from 7 to 9. Regarding nutrients calorie content was found between 415.23 to 423.4 k.cal, protein 6.4 to 8.4g, fat 18 to 22.3 and carbohydrate 46.3 to 55.3g respectively.

Diagnostic checking of fitted model and surface plot for various responses

Regression analysis indicated that the fitted quadratic model accounted that above 80% for protein, 80% for fat, 80% for carbohydrate and 40% for over all acceptability of the developed breakfast bar. The values of regression coefficients, sum of squares, F values and P values for coded form of process variables are presented in Table 5.

appearance. The F value of the model is 2.77 and lack of fit is not significant.

Width

The width of the developed bar was ranged from 1.1 to 1.8. The coefficient of determination R^2 was 32% of the regression model predicting the width of the bar. The F value of the model is 0.52 and lack of fit is not significant.

Table 5. Regression coefficient (coded variables) from quadratic model and their significance

Coefficients	Over all acceptability	Weight (g)	Diameter (cm)	Width (cm)	calorie (k.cal)	Protein (g)	Fat (g)	CHO (g)
β_0	4.14	4.54	1.51	0.03	72.77	7.98	41.09	62.59
β_1	0.99	0.027**	6.139	2.23	3.20	6.31	30.98	45.17
β_2	0.99	5.266	0.06**	2.87	1.23	0.30	1.20	3.19
β_3	0.29	0.01**	3.40	9.761	1.81	0.06**	0.54	0.16
β_{12}	0.50	1.25	1.25	1.398	5.01	0.48	0.55	10.81
β_{13}	0.50	1.25	1.25	1.12	34.74	0.06**	0.36	0.10
β_{23}	0.50	0.15**	0.026**	7.81	24.75	2.000	0.91	0.10
β_1^2	0.02**	2.03	1.08	3.12	0.72	5.346	1.87	0.83**
β_2^2	0.02**	1.67	0.38	2.23	1.11	0.66	4.16	2.29
β_3^2	0.30	1.50	0.17	0.01	0.61	0.17	1.69	0.41
F-value	0.98	12.96	2.77	0.52	0.84	7.72	6.09	6.49
R^2	0.46	0.92	0.71	0.32	0.71	0.87	0.84	0.85
Adj R^2	0.007	0.84	0.45	0.29	0.13	0.76	0.70	0.72
Pred R^2	0.78	0.65	0.62	1.50	10.48	0.06	0.17	0.07**
Adeq precision	3.79	8.9	4.64	2.65	10.48	10.54	8.44	9.24
Lack of fit	NS	NS	NS	NS	NS	NS	NS	NS

** - 1% significant level; NS = Not Significant

Over All Acceptability

The overall acceptability of the developed breakfast bar was ranged from 4 to 9. The coefficient of determination R^2 was 46% of the regression model predicting the appearance. The F value of the model is 0.98 and lack of fit is not significant.

Weight

The weight of the developed bar was ranged from 24.0 to 25.6. The coefficient of determination R^2 was 92% of the regression model predicting the appearance. The F value of the model is 12.96 and lack of fit is not significant.

Diameter

The diameter of the developed bar was ranged from 3.5 to 4.2. The coefficient of determination R^2 was 71% of the regression model predicting the

OVER ALL ACCEPTABILITY

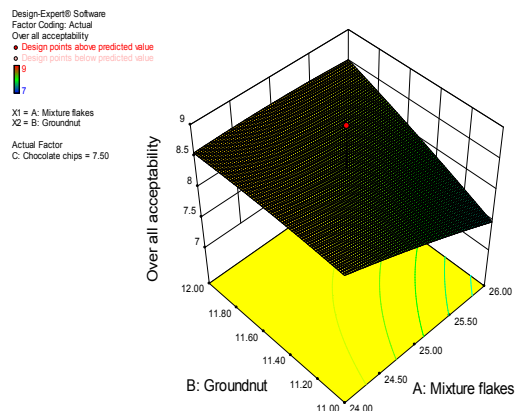


Fig.1. showed effects of mixture flakes, groundnut and chocolate chips on overall acceptability of the breakfast bar

Calorie

The calorie of the developed breakfast bar was ranged from 415 to 423.25 k.cal. The coefficient of

determination R^2 was 71% of the regression model predicting the appearance. The F value of the model is 0.84 and lack of fit is not significant.

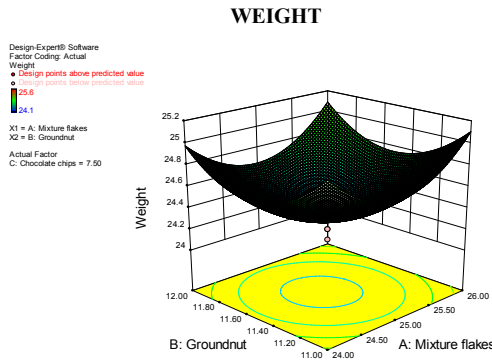


Fig. 2. showed effects of mixture flakes, groundnut and chocolate chips on weight of the breakfast bar

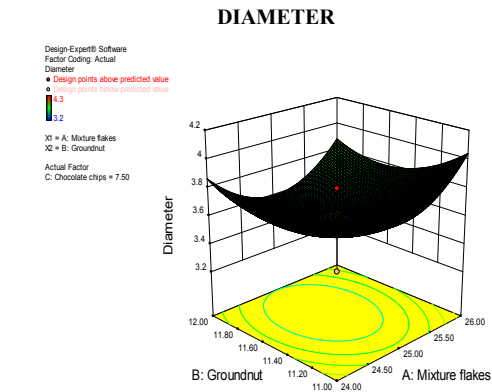


Fig.3 indicated effects of mixture flakes, groundnut and chocolate chips on diameter and width of the bar

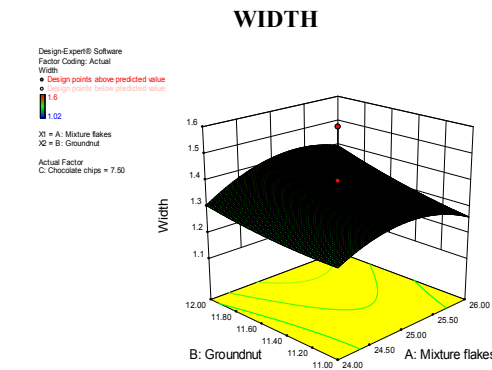


Fig.4. indicated effects of mixture flakes, groundnut and chocolate chips on width of the bar

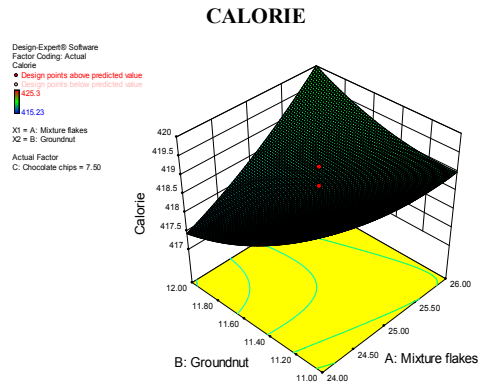


Fig. 5. indicated effects of mixture flakes, groundnut and chocolate chips on calorie content of the bar

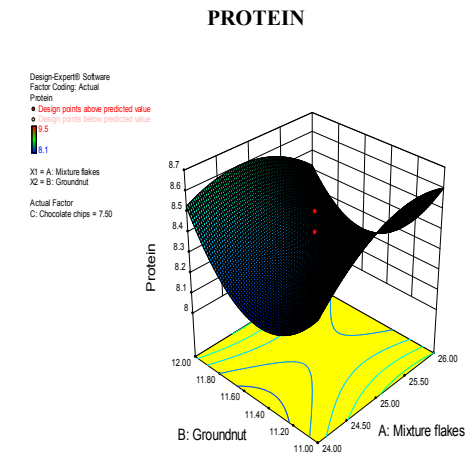


Fig.6. Indicated effects of mixture flakes, groundnut and chocolate chips on protein content of the bar

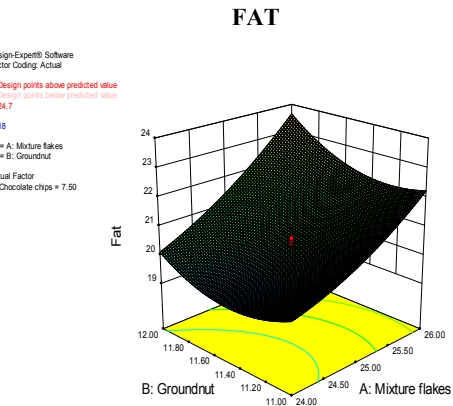


Fig.7. Indicated effects of mixture flakes, groundnut and chocolate chips on fat content of the bar

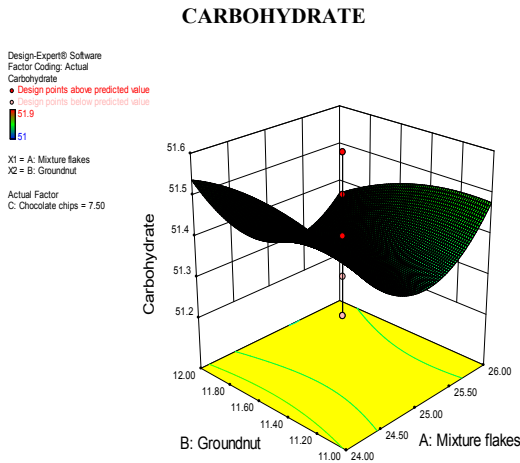


Fig. 8 . Indicated effects of mixture flakes, groundnut and chocolate chips on carbohydrate content of the bar

Table 6. Optimum value of process parameters and responses the responses

Process Parameters	Target	Experimental	Design	Importance	Optimum values	Desirability
Mixture flakes	In range	24	26	3	24	
Groundnut	In range	11	12	3	11	0.66
Chocolate chips	In range	7	8	3	8	
Responses					Predicted values	
Over all acceptability	Maximum	7	9	3	8.02	
Weight	Maximum	24.1	25.6	3	25.23	
Diameter	Maximum	3.4	4.2	3	4.12	
Width	Maximum	1.2	1.5	3	1.15	
Calorie	Maximum	418.3	425.6	3	423.1	
Protein	Maximum	8.1	9.5	3	8.65	
Fat	Minimum	19	22.8	3	14.14	
Carbohydrate	Maximum	51	51.9	3	51.4	

Table 7. Physical parameters of developed breakfast bar

Physical parameters of the bar	Quantity
Weight of the bar (g)	25.13
Diameter (cm)	4.15
Width (cm)	1.12

Protein

The protein of the developed breakfast bar was ranged from 22.1 to 26.8g. The coefficient of determination R^2 was 87% of the regression model predicting the appearance. The F value of the model is 7.72 and lack of fit is not significant.

Fat

The fat of the developed breakfast bar was ranged from 18 to 24.3g. The coefficient of determination R^2 was 84% of the regression model predicting the appearance. The F value of the model is 6.09 and lack of fit is not significant.

Carbohydrate

The carbohydrate of the developed breakfast bar was ranged from 47.2 to 52.2g. The coefficient of determination R^2 was 85% of the regression model predicting the appearance. The F value of the model is 6.49 and lack of fit is not significant.

Effect of variables on responses

Mixture flakes affect the weight, groundnut affects the diameter and chocolate chips affects the weight

and protein content of the developed breakfast bar at 1% level of significance. Both mixture flakes and groundnut affects the overall acceptability of the bar at 1% level of significance.

Response surface methodology optimization result

Mathematical model

Mathematical relationship generated using Multiple Linear Regression Analysis for the response variable for coded and uncoded values are expressed in equation 1 to 10.

Table 8. Nutrient composition of developed breakfast bar

Nutrient contents of the bar	Quantity
Energy (k.cal)	412.5
Protein (g)	8.05
Fatt(g)	15.5
Carbohydrate (g)	57.45
Iron (mg)	8.7
Calcium (mg)	148.6
Phosphorus (g)	124.3
Vitamin A (mcg)	60
Vitamin C (mg)	1.5
Thiamine (mg)	0.03
Riboflavin (mg)	0.05

$$Y5 = +418.08 + 9.88X_1 + 2.03X_2 + 1.17X_3 - 0.76X_1^2 + 0.85X_2^2 + 1.02X_3^2 + 1.22X_1X_2 + 1.02X_1X_3 + 1.97X_2X_3 \text{ ----- (5)}$$

$$Y6 = +8.11 + 0.68X_1 + 0.15X_2 + 0.068X_3 + 0.019X_1^2 + 0.21X_2^2 + 0.11X_3^2 + 0.25X_1X_2 - 0.087X_1X_3 - 5.00X_2X_3 \text{ ----- (6)}$$

$$Y7 = +20.22 + 1.51X_1 + 0.30X_2 - 0.20X_3 + 0.36X_1^2 + 0.54X_2^2 + 0.34X_3^2 + 0.26X_1X_2 + 0.21X_1X_3 + 0.34X_2X_3 \text{ ----- (7)}$$

$$Y8 = +51.46 + 1.82X_1 + 0.48X_2 - 0.11X_3 + 0.24X_1^2 + 0.40X_2^2 + 0.17X_3^2 + 1.16X_1X_2 + 0.11X_1X_3 + 0.11X_2X_3 \text{ ----- (8)}$$

The negative coefficient for X₁ and X₃ in equation 2 (weight) and for X₁ and X₃ in equation 3 (diameter) and X₁ in equation 4 (width) indicates

Table 9. Mean organoleptic evaluation of developed breakfast bar using Duncan multiple range tests

Varia tions	Appearance	Colour	Flavour	Texture	Taste	Over all Acceptability
V ₁	7.70 ±1.25 ^{ab}	8.40 ±0.69	7.70 ±1.56 ^a	6.70 ±2.00 ^{abcde}	8.20 ±0.63 ^c	8.20 ± 0.63 ^{cd}
V ₂	8.0 ±0.66 ^b	8.00 ±1.24 ^{cd}	8.20 ±0.78 ^a	7.20 ±1.75 ^{abc}	8.30 ± 0.82 ^{bc}	8.30 ± 0.82 ^{cd}
V ₃	8.20 ±0.78 ^b	8.10 ±0.99 ^{bcd}	7.90 ±0.73 ^a	8.20 ±0.78 ^{abcd}	8.30 ±0.82 ^{bc}	8.30 ±0.67 ^{cd}
V ₄	8.40 ±0.69 ^b	7.80 ±1.22 ^{abcd}	8.40 ±0.69 ^a	7.70 ±1.33 ^c	8.30 ±0.67 ^{bc}	8.10 ±0.56 ^{cd}
V ₅	8.10 ±0.73 ^b	7.80 ±1.22 ^{abcd}	8.30 ±0.67 ^a	7.00 ±2.00 ^{abcde}	8.10 ±0.56 ^{bc}	8.40 ±0.84 ^{cd}
V ₆	8.40 ±0.69 ^b	6.50 ±1.71 ^a	8.10 ±0.73 ^a	8.40 ±0.51 ^{ab}	8.40 ±0.84 ^{bc}	8.40 ±0.69 ^d
V ₇	8.30 ±0.67 ^b	7.40 ±1.50 ^{abcd}	8.50 ±0.70 ^a	8.10 ±0.73 ^{abcde}	8.40 ±0.69 ^a	8.30 ±0.67 ^{cd}
V ₈	7.70 ±0.48 ^{ab}	8.70 ±0.48 ^d	8.20 ±0.78 ^a	7.50 ±1.43 ^{cde}	8.30 ±0.67 ^b	8.00 ±0.66 ^{cd}
V ₉	8.40 ±0.69 ^b	7.60 ±1.83 ^{abcd}	8.40 ±0.69 ^a	8.40 ±1.28 ^{abcde}	8.00 ±0.66 ^c	8.40 ±0.84 ^{cd}
V ₁₀	8.50 ±0.70 ^b	6.70 ±2.00 ^{ab}	8.20 ±0.63 ^a	8.30 ±0.67 ^{abcd}	8.40 ±0.84 ^c	7.80 ±1.22 ^{bc}
V ₁₁	8.00 ±1.05 ^b	7.20 ±1.75 ^{abc}	8.30 ±0.82 ^a	8.00 0.81 ^{de}	8.20 ±0.78 ^{bc}	7.80 ±1.22 ^{cd}
V ₁₂	7.70 ±1.15 ^{ab}	8.20 ±0.78 ^c	8.30 ±0.82 ^a	7.70 ±1.25 ^{cde}	8.40 ±0.69 ^c	6.50 ±1.71 ^{cd}
V ₁₃	7.80 ±1.39 ^{ab}	7.70 ±1.33 ^{abcd}	8.30 ±0.67 ^a	8.0 ±0.66 ^{abcde}	8.00 1.24 ^{bc}	7.40 ±1.50 ^{cd}
V ₁₄	6.80 ±1.61 ^a	7.00 ±2.00 ^{abc}	8.10 ±0.56 ^a	8.20 0.78 ^{bcdde}	8.10 0.99 ^c	8.70 ±0.48 ^d
V ₁₅	8.00 1.56 ^b	8.40 ±0.51 ^{cd}	8.40 ±0.84 ^a	8.40 ±0.69 ^{cde}	7.80 1.22 ^c	7.60 ±1.83 ^{cd}
V ₁₆	7.70 ±1.25 ^{ab}	8.10 ±0.73 ^{cd}	8.40 ±0.69 ^a	8.10 ± 0.73 ^{bcdde}	7.80 1.22 ^c	6.70 ±2.00 ^{cd}
V ₁₇	8.20 ±1.47 ^b	7.50 ±1.43 ^{abcd}	8.30 ±0.67 ^a	8.40 ± 0.69 ^{de}	6.50 1.71 ^c	7.20 ±1.75 ^{cd}
V ₁₈	8.20 ±0.78 ^b	7.90 ±1.28 ^{abcd}	8.00 ±0.66 ^a	8.30 ± 0.67 ^{abcde}	7.40 1.50 ^{bc}	7.70 ±1.15 ^{cd}
V ₁₉	8.10 ±0.73 ^b	8.30 ±0.67 ^{cd}	8.40 ±0.84 ^a	6.80 ±1.61 ^{abcde}	7.00 2.00 ^e	7.80 ± 1.39 ^a
V ₂₀	8.10 ±1.28 ^b	8.00 ±0.81 ^{bcd}	8.20 ±0.78 ^a	8.00 ±1.56 ^a	8.40 ±0.51 ^{bc}	6.80 ±1.61 ^{ab}
F value	1.35	1.976	0.599	2.082	3.018	3.856
P value	0.158	0.012	0.904	0.007	0.000	0.000

**-Significant at 0.01% level; *-Significant at 0.05% level; NS-No significant; (Values with different superscripts are significantly different from each other on application of Duncan multiple Range test)

Coded Value

$$Y1 = +8.12 + 0.30X_1 + 0.44X_2 + 0.24X_3 + 0.063X_1^2 + 0.063X_2^2 + 0.063X_3^2 + 0.13X_1X_2 + 0.38X_1X_3 + 0.13X_2X_3 \text{ ----- (1)}$$

$$Y2 = +26.23 - 0.10X_1 + 0.02X_2 - 0.064X_3 + 0.32X_1^2 + 0.21X_2^2 + 0.13X_3^2 - 0.08X_1X_2 + 0.03X_1X_3 - 0.037X_2X_3 \text{ ----- (2)}$$

$$Y3 = +3.61 - 0.052X_1 + 0.09X_2 - 0.18X_3 - 0.051X_1^2 + 0.11X_2^2 + 0.16X_3^2 + 0.14X_1X_2 - 0.19X_1X_3 - 2.50X_2X_3 \text{ ----- (3)}$$

$$Y4 = +1.12 - 0.015X_1 + 8.45X_2 + 0.010X_3 + 0.012X_1^2 - 0.026X_2^2 + 0.012X_3^2 - 75X_1X_2 + 0.031X_1X_3 + 6.25X_2X_3 \text{ ----- (4)}$$

that linear effect of mixture flakes (X₁) and chocolate chips (X₃) decreases the weight, diameter and width of the developed breakfast bar.

Uncoded value:

$$Y1 = +17.90 + 0.44X_1 - 0.21X_2 - 1.49X_3 + 2.5X_1^2 + 2.51X_2^2 + 0.02X_3^2 + 5.00X_1X_2 + 0.037500X_1X_3 + 0.01X_2X_3 \text{ ----- (1a)}$$

$$Y2 = +36.33 - 0.58X_1 - 0.32X_2 - 0.26X_3 + 0.01X_1^2 + 8.56X_2^2 + 0.03X_3^2 - 3.50X_1X_2 + 3.00X_1X_3 - 3.75X_2X_3 \text{ ----- (2a)}$$

$$Y3 = +7.37 + 0.02X_1 - 0.33X_2 + 0.07X_3 - 2.03X_1^2 + 4.32X_2^2 + 0.04X_3^2 + 5.60X_1X_2 - 0.01X_1X_3 - 2.50X_2X_3 \text{ ----- (3a)}$$

$$Y4 = +1.10 - 0.03X_1 + 0.05X_2 - 0.11X_3 + 4.97X_1^2 - 1.057X_2^2 + 3.11X_3$$

$$Y5 = -1.50X_1X_2 + 3.12X_1X_3 + 6.25X_2X_3 + 422.68 + 1.87X_1 - 3.29X_2 - 8.91X_3 - 0.03X_1^2 + 0.033X_2^2 + 0.25X_3^2 \quad (4a)$$

$$Y6 = +0.04X_1X_2 + 0.10X_1X_3 + 0.19X_2X_3 + 15.28 - 0.11X_1 - 0.64X_2 + 0.05X_3 + 7.70X_1^2 + 8.548X_2^2 + 0.026X_3^2 \quad (5a)$$

$$Y7 = +9.80X_1X_2 - 8.750X_1X_3 - 5.00X_2X_3 + 47.48 + 0.76X_1 + 1.41X_2 + 2.16X_3 + 0.01X_1^2 + 0.021X_2^2 + 0.085X_3^2 \quad (6a)$$

$$Y8 = +0.01X_1X_2 + 0.02X_1X_3 + 0.03X_2X_3 + 88.11 + 1.32X_1 + 1.90X_2 + 0.95X_3 + 9.58X_1^2 + 0.015X_2^2 + 0.04X_3^2 \quad (7a)$$

$$Y = +0.04X_1X_3 + 0.01X_1X_3 + 0.01X_2X_3 + 88.11 + 1.32X_1 + 1.90X_2 + 0.95X_3 + 9.58X_1^2 + 0.015X_2^2 + 0.04X_3^2 \quad (8a)$$

In uncoded value the negative coefficients were seen in X_2 and X_3 in equation 1a and 5a, X_1 , X_2 and X_3 in equation 2a, X_2 in equation 3a and 6a, X_3 in equation 4a indicates that linear effect of mixture flakes, groundnuts and chocolate chips decreases the overall acceptability, weight, diameter, width and protein content of the developed breakfast bar.

Diagnostic checking of fitted model and surface plot for various responses

The mixture flakes, groundnut and chocolate chips of developed breakfast bar showed a maximum over all acceptability as 8.02 and the maximum weight as 25.23g were showed a maximum acceptability of the developed breakfast bar (Fig 1 and 2). The maximum diameters (4.12cm) with maximum width (1.15cm) of the developed breakfast bar were predicted in Fig 3 and 4. The maximum amount of calorie (423.11kcal), protein (8.65g), fat (19.14g) and carbohydrate (51.4g) indicated in Fig 5 to 8. In order to optimize the developed breakfast bar by numerical optimization technique, equal importance of '3' was given to all the three parameters (viz. mixture flakes, groundnut and chocolate chips) and responses (ie. Over all acceptability, weight, diameter, width, calorie, protein, fat and carbohydrate of the developed bars). The optimum operating condition for mixture flakes, groundnut and chocolate chips was 24g, 11g and 8g respectively. Corresponding to these values of process variables, the value of over all acceptability is 8.02%, weight is 25.23g, diameter of the bar is 4.12cm, width is 1.15cm, calorie 423.1kcal, protein 8.65g, fat 14.14g and carbohydrate is 51.4g (Table-6). The overall desirability was 0.66. The physical parameters of the developed breakfast bar showed that 25.13g,

4.15cm and 1.12cm were weight of the bar, diameter and width of the developed bar.

Nutrient composition of developed breakfast bar

The nutrient content of developed cereal based breakfast bar is energy 412.51k.cal, protein 8.05g, fat 15.5g and iron 8.7 (mg), calcium and phosphorus 148.6(mg) and 124.3 (g) and vitamin respectively for a developed 100 g breakfast bar.

Organoleptic evaluation of developed breakfast bar

The mean organoleptic evaluation of developed breakfast bar using Duncan multiple range tests was shown in the table 9.

Among the 20 variations of cereal based breakfast bars, V10 have scored highest mean value (8.50) the other variations in appearance. In colour attributes, V8 obtained 8.70 of highest score than V6 (6.50). Regarding flavour attributes, the highest score 8.70 is obtained by the variation V7 which is followed by the variation V18 with least score of 8.00 is obtained. In texture attributes, V6 scored highest of 8.40 than V1 which scored the least score of 6.70. Regarding taste, the highest score of 8.40 is scored by the variations of V6, V7, V10, V12 and V20 and is followed by the least score by V18 and V19 with score of 7.40 and 7.00. Regarding over all acceptability attributes, the highest score 8.40 is scored by V5, V6 and V9 followed by the least score 6.50 is obtained by V12. Results of the Duncan's test revealed that there was significant difference for all the variations.

Conclusion

It is concluded that RSM was used successfully to optimize the level of mixture flakes, groundnut and chocolate chips for the development of breakfast bar. A good quality breakfast bars can be made by the combination of 24g of mixture flakes, 11g of groundnut and 8g of chocolate chips.

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