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Research Article

A Blended Approach of Mango Seed, Peel and Pulp through Statistical Modeling for Development of Mango Bar

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Abstract

Fruit bars are dehydrated fruit products which are eaten as snacks. They are flexible sheets with concentrated fruit flavor and enriched nutritional aspects. Investigation was carried out to obtain mango bar optimized through selection of varied ranges for mango seed powder (0.35 - 0.75%), mango peel powder (0.35 - 0.75%) and sugar (25 - 40%) as independent variables. Central Composite Rotatable Design (CCRD) of Design Expert 7.0 (DX 7.0) was selected for optimization on to the frozen Amrapali variety pulp fed with peel and seed powder, evaluated lastly by means of various physico-chemical and organoleptic characteristics. % contribution of final ranges for mango seed powder (0.55%), mango peel powder (0.55%), table sugar (30%) along with 0.5% citric acid governs the best solution in terms of optimization. Progress of analytical results revealed the extent of possibility for optimized mango bar with higher values of vitamin A (2540 µg/100g) and protein (2.74%) and optimum level of sugar (58.90%) and acidity (0.07%) characteristics.

Keywords: Bar; Mango; Optimization; Response Surface Methodology; Statistics

Introduction

Fruits and fruit products are the key source to get vitamins, minerals, fibers and phenolics. They have therapeutic values in terms of metabolic regulators owe to the availability of bioactive components. Their regular consumption could help in the reduction of risk of various chronic diseases such as cancer, alzheimer, cataracts and cardiovascular disease [1,2]. Mostly fruits have a short harvest season and are prone to deterioration even when stored under refrigerated condition. As per the present prevalence of post-harvest losses (20 - 30%) [3] for fresh produce, there is need to improve post-harvest handling procedures and processing up gradations too. To minimize these losses to some extent and gives better returns to the farmers during glut seasons. Moreover, blending preservation and value addition is the other advantageous aspects that tackle the present needs of customer [4].

Among list of available processed fruit products obtained from fruits; fruit bar is one of its kind that is palatable, pleasant and dried. It is also called as fruit leather or fruit slab. It is chewy and flavorful, naturally low in fat, high in fiber and is energy dense. Fruit bars are the restricted convenient and economic substitute as value added natural fruit products made from fresh fruit pulp or a mixture of fruit juice concentrates and other ingredients after complex operation. With these ideas in mind present investigation aimed to produce fruit bar with good sensory profile and also with elevated nutritional value. Mango fruit possesses all these features of exotic flavor, delicious taste and attractive colour thus selected along with mango seed and peel powder to achieve the targeted task.

Mango by-products, such as peel and seeds are enriched in various health promoting constituents, i.e. phenolic, vitamin C and dietary fiber [5,6]. Fortification of eatables with mango seed and peel powder as food additive could generate economic gains for industry, contributing in reduction of nutritional deficiencies, health promotion and also in reduction of environmental implications through generated waste. Upgradation of innovative technologies in food processing, fabrication of equipments and by-product utilization are the way that demands zero wastage [7]. Statistical control is the last mean for improved development through optimization steps. It is mostly exploited mainly in the situation where several input variables (independent variables) influence potentially the quality characteristics (response variables) of product or process.

Materials and Methods

Materials

The basic ingredients used in mango fruit bar were mango pulp, mango seed powder, mango peel powder, citric acid and sugar. The mangoes were procured from the mango orchard of Aam khas bagh, Sirhind (Punjab) during the peak season of June (2017).

Methods

Sample preparation

Procured samples were cleaned and washed to away dirt and dust. Afterwards, they were processed to peeling and deseeding, extracted pulp was stored in deep freezer. Separated seed and peel were processed separately to powder and oven dried, stored throughout in zip lock high density polyethylene laminates of 80µ thickness till further use.

Mango seed powder (MSP) processing

Mango seeds were washed and dried in hot air oven at 60°C for 3 - 4h. The dried material was grounded into powdery form and sieved to 60µ mesh sieve size.

Mango peel powder (MPP) processing

Extracted peels were washed with tap water to make it clean, dried at 55°C for 12 hrs using hot air oven. Dried peels were finely crushed to powder and passed through sieve (60µ). Milled flour was stored in zip lock bags (HDPE, 80µ) and stored at room temperature.

Sensory evaluation

Optimized mango bar was subjected to sensory evaluation by 20 trained panelists of food concern (faculty and students) of the department using 9 point hedonic scale. The panelists were requested to rate the samples for their sensory profiles according to the following description: dislike extremely (1 point) and like extremely (9 points). Samples scored below 7 points were treated as subnormal by sensory panels. Sensory responses namely tartness or brix acid ratio, colour and appearance, mouth feel and texture and overall acceptability were evaluated.

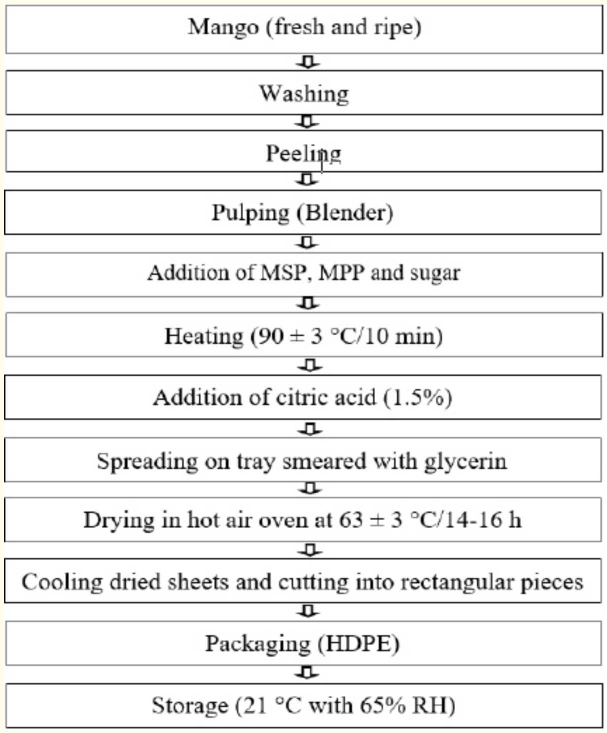

Figure 1: Process flowchart for preparation of mango bar.

Chemical analysis

The sample of optimized mango bar were analysed by standard methods of analysis for moisture content [8], TSS (Erma-hand refractometer), Titratable acidity [9], Total sugars [10], reducing sugar [11], vitamin A [12], Protein [13] and Fat [14].

Experimental design

A CCRD approach of DX 7 was used for the selection of predecided level of input variables to investigate the probable effect of independent variables on to the responses. The selected range of independent variables were mango seed powder, mango peel powder and sugar assessed against vitamin A, % moisture, colour and appearance, mouth feel and texture and overall acceptability responses (Table 1).

Independent Variables	Notations	Levels	
		-1	+1
MSP, %	A	0.35	0.75
MPP, %	B	0.35	0.75
Sugar, %	C	20	40

Table 1: Experimental variables and their coded values.

MSP: Mango Seed Powder; MPP: Mango Peel Powder.

Mathematical models describing the relationships among the process-dependent variable and the independent variables in a second-order polynomial equation terms [15] as follow:

$$y = \beta_0 + \sum_{i=1}^{4} \beta_i X_i + \sum_{i=1}^{4} \beta_{ii} X_i^2 + \sum_{i=1}^{3} \sum_{j=i+1}^{4} \beta_{ij} X_i X_{ij} + \epsilon$$

Where, y is the response, X_i and X_j are the coded independent variables that are linearly related to A, B and C, β_0 is the constant, β_i is the coefficient of the linear terms, β_{ii} is the coefficient of the quadratic terms, and β_{ij} is the coefficient of the interaction terms. ϵ is a random experimental error assumed to have a zero mean.

The stat ease design expert software (version 7.0) was used for the experiment's design. The regression and graphical analysis of the data were depicted by the software. Validity of models was tested and the effect of variables on the sensory characteristics was interpreted. 3-D graphs were generated to show the effect of mango seed powder, mango peel powder and sugar on overall acceptability of mango bar. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. In order to do this, a second-degree polynomial model was fitted; however, this model was easy to estimate and apply, even when little was known about the process (Myers., *et al*. 2009).

Results and Discussion

Experimental data for response surface method

The experimental data for vitamin A, moisture content, colour and appearance, mouth feel and texture and overall acceptability are presented in table 2. The second order polynomial response surface model was fitted to each response variable. Regression analysis and ANOVA were calculated for the significance of fitted model and examined it statistically. The computed regression coefficients of the second order polynomial models for the response variables along with the corresponding R^2 and coefficient of variance (CV) are given in table 3. As a general rule, the coefficient of variance (CV) should be less than 10% [16] and in the present study, the coefficient of variation was found to be in range of 0.411% to 4.34% for all the responses (Table 3). Least value for coefficient of variation indicates better exactness and trustworthiness of the executed trials. Analysis of variance favors the significance of model ($P \leq 0.001$) for all the studied responses (Table 3). The high value of coefficient of determination ($R^2 > 0.97$), indicating high proportion of variability was explained by the data and the RSM models were adequate [17,18] (Table 3).

Run	Factor 1 A: Mango seed powder (%)	Factor 2 B: Mango peel powder (%)	Factor 3 C: Sugar (%)	Response 1 Vitamin A (μg/100g)	Response 2 Moisture content (%)	Response 3 Colour and appearance	Response 4 Mouth feel and texture	Response 5 Overall acceptability
1	0.45	0.65	35	2600	10.25	6.5	6.5	6.5
2	0.45	0.45	25	2520	9.5	6	6.5	6
3	0.45	0.65	25	2600	10.21	6.5	6	6
4	0.45	0.45	35	2520	9.53	6	6.5	7
5	0.55	0.55	30	2540	9.81	7	6.5	8
6	0.55	0.55	38.4	2530	9.85	7	6.5	6
7	0.71	0.55	30	2570	9.93	6	6.5	6.5
8	0.55	0.55	30	2560	9.81	7	7	6.5
9	0.55	0.55	21.59	2540	9.65	7	6	6
10	0.65	0.45	25	2530	9.72	6.5	6	6
11	0.55	0.38	30	2525	9.45	6	6.5	6.5
12	0.65	0.65	25	2615	10.26	6	6	6.5
13	0.55	0.55	30	2560	9.86	7	7	7
14	0.65	0.65	35	2610	10.11	6.5	6.5	6.5
15	0.55	0.55	30	2540	9.75	7	7	7
16	0.65	0.45	35	2550	9.65	6	6.5	7
17	0.55	0.55	30	2540	9.75	6.5	7	7
18	0.38	0.55	30	2540	9.65	6	7	6.5
19	0.55	0.55	30	2540	9.73	7	7	7
20	0.55	0.71	30	2630	10.34	6.5	6.5	6

Table 2: Variables and responses for optimization of different ingredients for mango bar.

Variables	DF	Vitamin-A (µg/100g)		Moisture content (%)		Colour and appearance		Mouthfeel and texture		Overall acceptability	
		F Value	p-value	F Value	p-value	F Value	p-value	F Value	p-value	F Value	p-value
Model	9	21.33	< 0.0001	20.87	< 0.0001	9.12	0.0009	6.59	0.0034	3.37	0.0360
A-MSP	1	9.34	0.0121	5.84	0.0363	0.0810	0.7818	4.03	0.0726	0.1972	0.6664
B-MPP	1	158.69	< 0.0001	171.19	< 0.0001	5.46	0.0416	0.7854	0.3963	1.85	0.2041
C- Sugar	1	0.0022	0.9636	0.3784	0.5522	1.006E-08	0.9999	11.33	0.0072	5.69	0.0383
Lack of fit	5	1.08	0.4688	4.44	0.0637	0.8240	0.5815	0.6961	0.6497	2.85	0.1372
R^2		0.9505		0.9494		0.8914		0.8558		0.7520	

Table 3: ANOVA table showing interaction terms with their coefficient values.

MSP: Mango Seed Powder; MPP: Mango Peel Powder.

Model F-value for vitamin A, moisture content, colour and appearance, mouth feel and texture and overall acceptability are 21.33, 20.87, 9.12, 6.59 and 3.37 respectively, which implies that model is significant "Prob > F" (0.05). The lack of fit didn't result in significant F value in case of all responses, indicating accurate of models for predicting those responses.

Vitamin A

Mango bar was analysed for their contents of vitamin A and data obtained are tabulated in table 2. The results indicated that the fitted quadratic models accounted for more than 90% of the variation in the experimental data, which were highly significant ($R^2 > 0.90$). The magnitude of P values from table 3 revealed that all the linear and interaction terms except sugar have significant effect at 5% level of significance (P < 0.05) on vitamin-A constituents. The quadratic term of sugar has non-significant effect at 5% level of significance (P > 0.05). The model F-value is 21.33, which implies the model is significant. The relative magnitude of β values (Table 3) indicates the maximum positive effect of mango peel powder (β = 72.40) followed by mango stone powder (β = 17.57) and sugar (β = - 0.266) on vitamin A constituents of prepared mango bar.

The vitamin-A constituents (Figure 2a) shows increasing trend with increase in mango seed powder and mango peel powder. This may be due to the carotenoid content of peel and seed. It was also found that the content of carotenoid increased from 5 to 84 µg/g of macroni with 7.5% constituents with mango peel powder and sugar has also been observed in figure 2b, which revealed that no changes were observed in vitamin A constituents of prepared mango bar due to the incorporation of sugar. Thus, the result suggests that by incorporating mango seed and peel powder, it is possible to enhance the nutritional quality of mango bar without affecting its cooking.

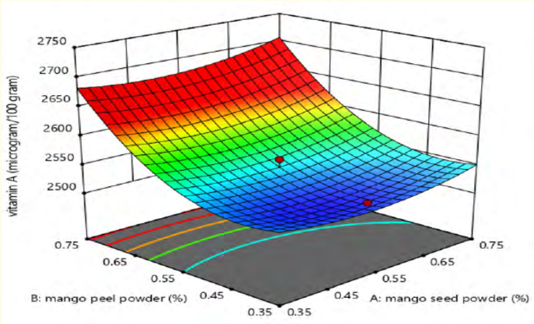

Figure 2a: Interaction effect of MSP and MPP with vitamin A

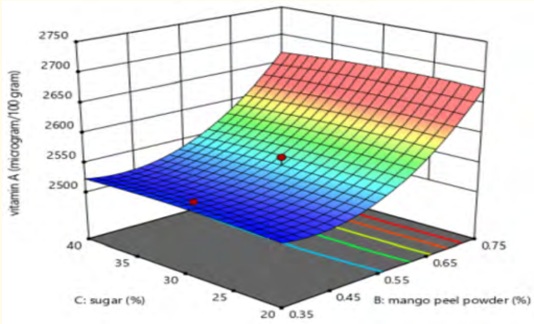

Figure 2b: Interaction effect of sugar and MPP with vitamin A.

Moisture content (%)

The table 3 indicates that the quadratic effect of mango seed powder and mango peel powder and their interaction have significant effect on moisture content in mango bar (P < 0.05). On the other hand, the sugar has non-significant effect on the moisture content of the prepared bar (P > 0.05). The model F-value (20.87) implies the model is significant. The magnitude β values indicates the maximum positive effect of mango peel powder (β = 0.585) followed by mango seed powder (β = 0.108) and sugar (β = 0.027).

Moisture content increased with increase in mango peel powder and mango seed powder (Figure 3a) is mainly because of the increased water absorption of crude fiber present in mango seed and peel. The result revealed that the water holding capacity of mango peel powder is higher than mango seed powder. Figure 3b revealed that increase in moisture content with sugar was not more remarkable but due to its hygroscopic nature sugar helps in binding the actual moisture content of the prepared bar.

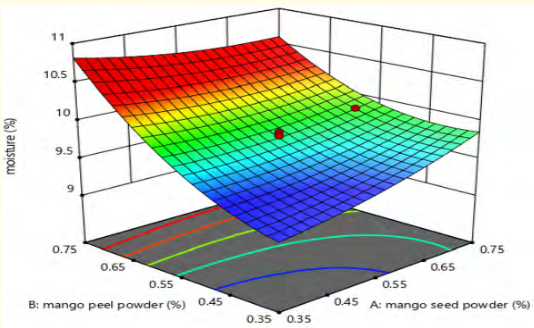

Figure 3a: Interaction effect of MSP and MPP with moisture content.

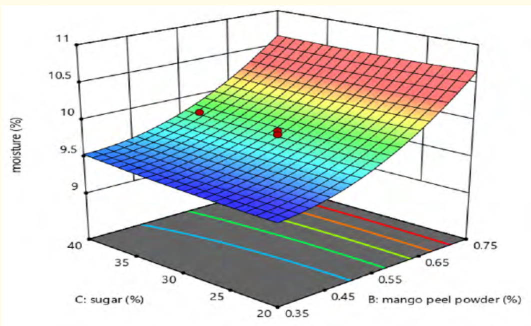

Figure 3b: Interaction effect of MPP and sugar with moisture content.

Colour and appearance

It can be seen that mango peel has significant effect ($P < 0.05$) on colour and appearance of prepared mango bar (Table 3), while mango seed powder and sugar has non-significant effect ($P > 0.05$). The model F-value 9.12 implies the model is significant. The magnitude β values indicates the maximum positive effect of mango peel powder (β = 0.248) followed by mango seed powder (β = - 0.030) and sugar (β = - 0.000).

The increasing range of mango seed and peel powder improves the colour and appearance (Figure 4a) of the prepared mango bar up to some extent. On the other hand, increase in % proportion of mango peel and seed reduces the sensory score in context to colour and appearance. Increase in colour and appearance value with raised sugar level was not much remarkable in high concentration as in composition with reduced concentration (Figure 4b).

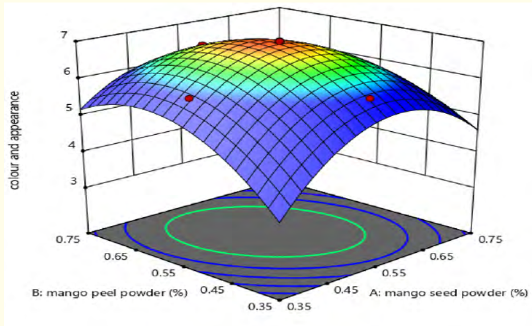

Figure 4a: Interaction effect of MSP and MPP on colour and appearance.

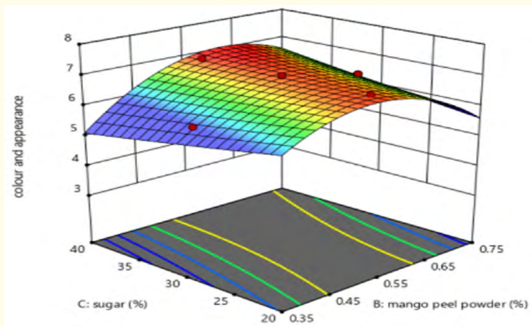

Figure 4b: Interaction effect of MPP and sugar on colour and appearance.

Mouthfeel and texture

The magnitude of P-value indicates that all the linear and interaction terms have significant effect on mouth feel and texture of mango bar, while mango peel powder and mango seed powder has non-significant effect ($P > 0.05$). The model F-value 6.59 implies the model is significant. The magnitude β values indicates the maximum positive effect of sugar (β = 0.342) followed by mango seed powder (β = - 0.206) and mango peel powder (β = - 0.091).

It has been noticed in the study that the sensory of sample first increased and then decreased with mango peel powder and mango stone (Figure 5a). The sensory has its maximum value when the proportion of mango peel and seed powder were in the range of 0.55% and 0.55%. However, at the higher level of incorporation of MSP and MPP the bar had slight bitter taste which may be due to high polyphenols content. Besides that the effect of sugar on sensory score is shown in figure 5b. This implies that the overall acceptability of the prepared mango bar depends upon the concentration of mango peel powder, mango seed powder and sugar.

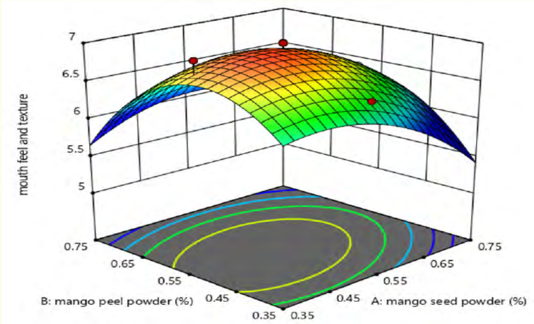

Figure 5a: Interaction effect of MSP and MPP on mouth feel and texture. .

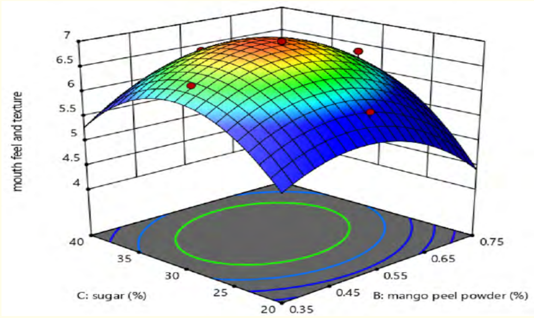

Figure 5b: Interaction effect of MPP and sugar on mouth feel and texture.

Overall acceptability

The magnitude of P-value from Table 3 indicates that all the linear and interaction terms have significant effect on the sensory score of the prepared mango bar ($P < 0.05$) at 5% level of significance. The quadratic term of mango seed powder and mango peel powder has a non-significant effect on the sensory score, i.e. quality of product, at the 5% level of significance ($P > 0.05$). The magnitudes of β values indicate that sugar had more pronounced effect (β = 0.365) on sensory score than did mango peel powder (β = -0.210) and mango seed powder (β = 0.068).

From the figure 6a and 6b it could be observed that bar incorporated 0.55% MSP, 0.55% MPP and 30% sugar showed higher scores. The lower score values of mango bar could be due to the unattractive colour and the unpleasant taste [19].

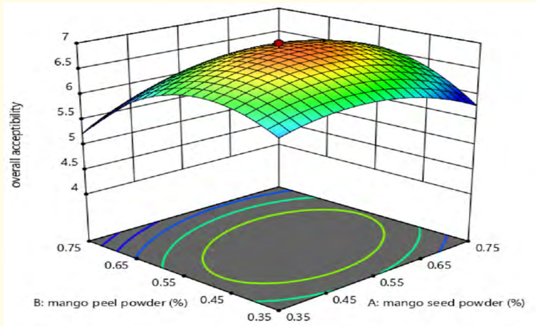

Figure 6a: Interaction effect of MSP and MPP on overall acceptability.

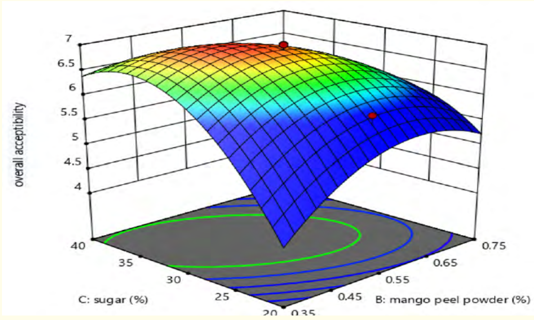

Figure 6b: Interaction effect of sugar and MPP on overall acceptability.

Conclusions

The present study clearly highlights that response surface methodology was effective in optimizing process parameters for the preparation of mango bar having different concentrations range i.e. mango seed powder (0.55%), mango peel powder (0.55%) and sugar (30%). Analysis of variance has shown that the effects of all the process variables including mango seed powder, mango peel powder and sugar were statistically significant. Second order polynomial models were obtained for predicting vitamin A, % moisture, colour and appearance, mouth feel and texture and overall acceptability. Conformance of experimental results with the empirical model was evaluated using correlation coefficient (R) which was found for the proposed model as, R = 0.9505, 0.9494, 0.8914, 0.8558 and 0.7520 for vitamin A, % moisture, colour and appearance, mouth feel and texture and overall acceptability respectively.

Conflict of Interest

The authors declare that they have no conflict of interest.

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