Optimization of Ingredients Level in Low Calorie-High Protein Papaya Fruit Bar using Response Surface Methodology

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Abstract

Low calorie high protein papaya fruit bar was developed using defatted soy flour for protein enrichment, stevia as sugar replacer and maltodextrin for imparting body and texture. Central composite rotatable design was used for selecting the levels of ingredients in the experimental run. The product was evaluated for sensory characteristics namely colour, taste, body and texture, aroma and overall acceptability. Second order mathematical model was used for optimization and showing the effect of ingredients on sensory characteristics. Results exhibited that the sensory scores ranged between 6.35–8.35, 6.5–8.1, 6.8–8.2, 7.98–8.35 and 6.3–8.2 for colour and appearance, taste, body and texture, aroma and overall acceptability, respectively. Mathematical models predicted all responses quite well with coefficient of determination more than 85% except aroma. Defatted soy flour affected all the responses both at linear and quadratic level. Stevia and maltodextrin had significant effect on taste and body and texture. The optimum levels of ingredients for low calorie-high protein papaya bar were 24.47, 1.98 and 2.68% of defatted soy flour, stevia and maltodextrin respectively.

Keywords: Papaya fruit bar; Defatted soy flour; Stevia; Maltodextrin; Low calorie; Optimization; Sensory properties

Introduction

Papaya or paw-paw is a popular tropical fruit. It was originated in America but is now common world wide in tropical region. Papaya is cultivated as nutritious fruits which are consumed as table fruits as well as in processed forms. Papaya fruit is an important and economical source of certain vitamins and minerals and it has therapeutic values. It is used for the treatment of piles, dyspepsia of spleen and liver, digestive disorders, diphtheria and skin blemishes [1].

Various products such as canned fruits, frozen slices, beverages, fruit leather, fruit bars are developed from fruits which are inherently perishable in nature and for value addition. Several types of fruit bars have been developed using different fruits, singly or in combination [2-4]. The fruit bars or fruit-slabs or fruit-leather are the terms used for the products prepared by dehydration of fruit pulps [2].

During the last few decades major transformations have taken place in life style, which in turn have markedly affected dietary habits. Consumers are willing to pay more for wholesome health food with low calorie and high protein and fibre content. As this healthy eating trend continues, it is likely to further increase the future demands for low calorie products, which are being marketed by the food industry. Products such as sugar free soft-drinks, frozen desserts and confectionery items have become much common. When it comes to confectionery, low calorie and dietetic products are becoming common among consumers, looking for tasty snacks but which are still part of healthy eating patterns [5].

Synthetic sweeteners as sugar replacers are used in the manufacture of low calorie products. However, synthetic sweeteners pose many health hazards such as tiredness and even mental disorders after prolonged use. Therefore, there is a need to use natural sugar replacers. Low calorie sweeteners are widely used in concept of using artificial sweeteners based on the principle of energy balance. They provide equivalent sweetness of sugar without contributing significantly calories intakes. Diabetic patients have the same liking for sweet taste that others do. Substituting low-calorie artificial sweeteners for sugar decreases the total amount of carbohydrate intake [6] and enhance weight loss. They satisfy the hedonic need for sweeteners as effectively as sugar itself resulting in decreased energy consumption. Thus, they promote long term weight maintenance by satisfying the increased sensory responsiveness found in obese subjects who have to reduce their body weight and by satisfying the desire for sweet taste without additional energy [7]. Whether a person compensates for the energy reduction of artificial sweeteners either partially or fully depends on the several factors, including the person’s motivations. Using artificial sweeteners will not automatically lower energy intake. To control energy intake successfully, a person needs to make informed diet and activity decisions throughout the day. Presently, low calories sweeteners used as table-top sweeteners are found in a wide variety of foods and drinks such as dairy products, jams, pickles, sauces, fruit preserves, chewing gum, cakes, ice-creams, puddings, chocolates, pharmaceutical products, several soft drinks, tooth paste and mouth wash [8].

Stevia is a natural sweet herbal plant from the Chrysanthemum family. It has a long history of safe use. It is a natural dietary supplement extracted from the Stevia rebaudiana herbal plant. It has a pleasant taste, no calorie, no artificial coloring or flavoring and ideal for health and weight conscious individuals. It has been used for decades in Japan, Korea, China and many South American countries in a wide variety of beverages and food products. Since stevia extract has no calorie, it is good for diabetic, over-weight and health conscious people as part of calorie controlled diet [9].

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Soybean is a cheap and excellent source of quality protein (40-42%) and fat (18-20%). It holds a great promise for protein enriched products, especially the fruits which normally lack protein and fat [2]. Soybean contains less carbohydrate and more proteins and therefore, it forms one of the best food for diabetic patients. Presence of abundant phosphorous and protein in soy bean is made use in curing nervous disorders, rickets, pulmonary diseases and anemia. Soy bean is lactose-free so useful for lactose intolerant people. Defatted soy flour contains about 9.0% moisture, 48% protein, 7.2% ash on dry basis and 1.5% fat [2].

Fruit bar prepared by dehydration of apricot pulp supplemented with soy slurry, had increased protein and fat, decreased titratable acidity and ascorbic acid content. Product having 70% apricot pulp and 30% soy slurry with 15.3% moisture, 7.8% protein and 16.5 mg/100 g ascorbic acid was found best in sensory qualities. The product had good flavour, texture and taste [2].

Mango fruit bar was prepared from alphonso fruits by adding 20% sugar, 0.2% citric acid and 700 ppm potassium metabisulphite individually and in different combinations. Addition of sugar increased the drying time and yield of the fruit bar whereas considerable reduction in nonenzymatic browning was observed due to the addition of potassium metabisulphite. Fruit bar prepared by the addition of sugar, citric acid and metabisulphite in combination was good in sensory quality [10].

The compositional changes required to attain reduced calorie status create special problems in achieving acceptable flavour, mouthfeel, body and texture and heat shock protection [11].

The use of intense sweeteners in the manufacture of low calorie desserts has brought about the need to add bulking agents to replace the sugar in such products. A bulking agent acts as filler and reproduces the physical properties of sugar, but not its sweetness and caloric content [12]. Maltodextrin is a sweet, easily digested carbohydrate made from cornstarch. The starch is cooked, and then acid and/or enzymes are used to break the starch into smaller chains (3-20 chains in maltodextrin) a process similar to that used by the body to digest carbohydrates. These chains are composed of several dextrose molecules held together by very weak hydrogen bonds [13].

Response Surface Methodology(RSM) is a useful statistical technique to select optimum levels of parameters in a process by conducting considerably fewer number of experiments as compared to full factorial experimentation. It is more efficient since it provides minimum time and cost of experimentation required to arrive at the optimum conditions. The RSM technique gives the effect of an individual parameter and interactive effect of the parameters on the response. This has been successfully used to optimize a process [14] and to develop a product [15,16]. Polynomial regression model could be used to decide optimum operating conditions based on individual response or multiple responses [17,18]. The aim of the present study was to develop a low calorie-high protein papaya fruit bar using defatted soy flour, stevia and maltodextrin and select the optimum level of these ingredients using response surface methodology.

Materials and Methods

Materials

The basic ingredients used in papaya fruit bar were papaya pulp, defatted soy flour, stevia and maltodextrin. Defatted soy flour increased the protein content of the fruit bar while stevia substituted sugar for giving sweet taste. Maltodextrin replaced sugar in imparting body and texture to the product.

Experimental design: A central composite rotatable design was used in selecting the levels of parameters in the experiments and to investigate the effect of independent variables on the response. The independent variables were defatted soy flour , stevia and maltodextrin. The five levels of these variables used are reported in table 1. The responses were colour and appearance, taste, body and texture, aroma and overall acceptability.

The variables were standardized to simplify computation and to deduce the relative effect of variables on the responses. The magnitude of the coefficient in second order polynomial shows the effect of that variable on the response.

The relationship between standardized and real variables was as follows:

\[
x_i = \frac{DSF - 30}{5} (1)
\]

\[
x_i = \frac{Stevia - 2}{0.5} (2)
\]

\[
x_i = \frac{Maltodextrin - 3}{0.5} (3)
\]

where \(X_1, X_2\) and \(X_3\) are coded variables

Methods

Experimental procedure for papaya bar processing: Fresh good quality papaya pulp was pasteurized, concentrated and cooled. Potassium metabisulphate and citric acid were added to maintain color and flavor along with defatted soy flour, stevia and maltodextrin as per the experimental design. These ingredients were mixed, dried and converted to papaya bar.

Sensory evaluation: Low calorie high protein papaya dried fruit bars were subjected to sensory evaluation by 10 trained sensory panels consisting of post graduate students and staff members of the department using nine-point hedonic scale ranging from 1 to 9, where 1 represented dislike extremely and 9 represented like extremely [19]. Samples scored below 7 were treated as subnormal by sensory panels. Sensory responses namely color and appearance, taste, body and texture, aroma and overall acceptability were evaluated.

Chemical analysis: Low calorie high protein papaya dried fruit bars developd by using optimized levels of ingredients were analysed by standard methods for fat [20], protein [20], ash [21], moisture [21] and titratable acidity [20].

Statistical analysis

A second order polynomial of the following forms was fitted to the data of all the responses

<table>
<thead>
<tr>
<th>Ingredients Per 100g papaya pulp</th>
<th>Coded Variables</th>
<th>Coded levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSF, g</td>
<td>X₁</td>
<td>-2.0, -1.0, 0, 1.0, 2.0</td>
</tr>
<tr>
<td>Stevia, g</td>
<td>X₂</td>
<td>21.64, 25, 30, 35, 38.41</td>
</tr>
<tr>
<td>Maltodextrin, g</td>
<td>X₃</td>
<td>1.16, 1.5, 2, 2.5, 2.84</td>
</tr>
<tr>
<td>DSF-Defatted soy flour</td>
<td>X₄</td>
<td>2.16, 2.5, 3, 3.5, 3.38</td>
</tr>
</tbody>
</table>

Table 1: Experimental variables and their coded values.
y = $\beta_0 + \sum_{i=1}^{4} \beta_i x_i + \sum_{i=1}^{4} \beta_i x_i^2 + \sum_{i=1}^{4} \sum_{j=1}^{4} \beta_{ij} x_i x_j$ \hspace{1cm} (4)

Where $y$=response, $x_i$= defatted soy flour, $x_j$= stevia and $x_k$= maltodextrin.

Analysis of variance, regression constants and coefficient of determination (R²) were obtained by the regression analysis. Validity of models was tested and the effect of variables on the sensory characteristics was interpreted. Multiple response optimization software was used to determine optimum condition. Contour plots were generated to show the effect of defatted soy flour, stevia and maltodextrin on overall acceptability of papaya fruit bar.

**Results and Discussion**

**Effect of ingredients on sensory properties of papaya fruit bar**

Sensory score of color and appearance, taste, body and texture, aroma and overall acceptability ranged between 6.35-8.35, 6.5-8.1, 6.8-8.2, 7.98-8.35 and 6.3-8.2, respectively.

This shows that an acceptable papaya fruit bar could be developed using all ingredients, combination of defatted soy flour, stevia and maltodextrin. It was found that in general minimum sensory score was of the product made with a combination of defatted soy flour, stevia and maltodextrin as 38.4, 2.0 and 3.0 g per 100 g papaya pulp and maximum at 21.64, 2.0 and 3.0 g per 100 g papaya pulp, respectively [22].

**Analysis of variance for sensory responses**

Analysis of variance is reported in table 2. It shows that the coefficient of determination, R², was higher than 0.80 except that of aroma suggesting more than 80% variability could be explained by the predictive models. They were significant at p<0.05 except aroma. The F value was higher than the table 2 F value. Lack of fit was nonsignificant for colour and appearance, body and texture and aroma. However, it was significant for taste and overall acceptability. Considering R², F value and subjective evaluation of the responses, all the models except that of aroma were adequate for prediction of the responses and deducing the effect of variables on the responses therefore aroma was not considered for further analysis.

**Regression of coefficients and their significance**

Regression coefficients and their significance are reported in table 3. The sign and the magnitude of the coefficient indicate the effect of the variable on the response. Negative sign of a coefficient at linear level indicates decrease in response with an increase in level of the variable whereas at interactive level, level of one variable could be increased while that of other decreased to get the same response. In case of quadratic term, negative sign of a variable indicates the minimum is at centre point and increases with increase or decrease towards the α level. Positive sign indicates maximum response at centre point.

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Sum of squares</th>
<th>Color and appearance</th>
<th>Taste</th>
<th>Body &amp; texture</th>
<th>Aroma</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>9</td>
<td>4.414*</td>
<td>3.061 *</td>
<td>3.323 *</td>
<td>0.114</td>
<td>3.848 *</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>10</td>
<td>0.2437</td>
<td>0.196 NS</td>
<td>0.047</td>
<td>0.355</td>
<td>0.1599</td>
<td>0.095</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>5</td>
<td>0.047</td>
<td>0.011 NS</td>
<td>0.011</td>
<td>0.127NS</td>
<td>0.024</td>
<td>0.013</td>
</tr>
<tr>
<td>Pure error</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of determination, R²</td>
<td>5</td>
<td>94.8</td>
<td>89.6</td>
<td>95.7</td>
<td>54.4</td>
<td>86.1</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>20.13</td>
<td>9.58</td>
<td>24.47</td>
<td>1.32</td>
<td>6.89</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at P<0.05; NS=non-significant; DF=Degree of freedom

Table 2: ANOVA for Sensory responses.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>DF</th>
<th>Colour</th>
<th>Taste</th>
<th>Body &amp; texture</th>
<th>Aroma</th>
<th>OAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defatted soy flour</td>
<td>4</td>
<td>4.33 ***</td>
<td>2.09 ***</td>
<td>2.655 ***</td>
<td>3.190 ***</td>
<td></td>
</tr>
<tr>
<td>Stevia</td>
<td>4</td>
<td>0.082</td>
<td>0.709 **</td>
<td>0.60 *</td>
<td>0.634 *</td>
<td></td>
</tr>
<tr>
<td>Maltodextrin</td>
<td>4</td>
<td>0.026</td>
<td>0.306</td>
<td>0.532 ***</td>
<td>0.038</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>3.834 ***</td>
<td>1.866 ***</td>
<td>2.616 ***</td>
<td>2.474 ***</td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>3</td>
<td>0.554 **</td>
<td>1.149 ***</td>
<td>0.682 ***</td>
<td>1.360 ***</td>
<td></td>
</tr>
<tr>
<td>Interactive</td>
<td>3</td>
<td>0.026</td>
<td>0.046</td>
<td>0.025</td>
<td>0.014</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at P<0.05; ** Significant at P< 0.01; ***Significant at P=0.001 OAA-Over all acceptability

Table 3: Regression coefficients for full second order model of sensory characteristics.

Analysis of variance, regression constants and coefficient of determination (R²) were obtained by the regression analysis. Validity of models was tested and the effect of variables on the sensory characteristics was interpreted. Multiple response optimization software was used to determine optimum condition. Contour plots were generated to show the effect of defatted soy flour, stevia and maltodextrin on overall acceptability of papaya fruit bar.

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Table 4 shows that defatted soy flour affected all the responses significantly (P<0.001) at linear as well as at quadratic level. The effect was negative suggesting that with increase in the level of defatted soy flour decreased colour and appearance, taste, body and texture and overall acceptability. Stevia did not have significant effect on colour and appearance of papaya fruit bar. However, it affected taste (P<0.01), body and texture (P<0.05), and overall acceptability (P<0.05) at quadratic level. This shows the concentration of stevia at centre point would give minimum sensory score. It affected taste significantly at linear level. The effect was positive. Maltodextrin had a significant effect on body and texture both at linear (P<0.05) and quadratic (P<0.01) level.

Table 5: Optimum conditions for various responses.
sensory responses is show in table 5. The table also shows the effect of these at linear, quadratic and interactive level in the predictive models. Level of defatted soy flour was the most significant (P<0.01) independent variable affecting colour and appearance, taste, body and texture and overall acceptability. Stevia affected taste (P<0.05) and body and texture (P<0.10) significantly. Maltodextrin had significant (P<0.01) effect on body and texture. This validates the use of maltodextrin as bulking agent. Table 4 indicates that there was no interaction between the defatted soy flour, stevia and maltodextrin that affected the sensory characteristics significantly. Total effect of these variables at linear and quadratic level was significant.

Optimization of ingredient

All the responses were optimized using multiple response optimization software [18]. The software is used to optimize individual response as well as compromise optima considering more responses. To get compromise optima, the software takes into account individual optimum conditions and tries to get the compromise optimum. However, it is always not possible to get compromise optimia since the optimum conditions of the individual responses vary widely. Table 4 reports the results of optimization. The compromise optimum conditions could not be obtained as the individual optimum conditions vary widely. Therefore, optimum conditions of overall acceptability were considered as it was sum total of all quality attributes.

The optimum conditions were: defatted soy flour 24.47%, stevia 1.98% and maltodextrin 2.7%. Papaya fruit bars prepared using these optimum conditions were evaluated for sensory characteristics. It was observed that the sensory scores were higher than 8.0 on hedonic scale. The samples were analysed for proximate composition which resulted into moisture(18.69%), protein(12.55%), fat(0.36%), titratable acidity as citric acid(1.33%) and ash(2.96%) [23].

Effect of variables on overall acceptability

Contour plots were generated, keeping the third independent variable at optimum point, to show the effect of variables on the response- overall acceptability. Contour graphs are shown in figure 1a, b, c.

Effect of deatted soy-flour and stevia on overall acceptability is shown in Figure 1a. It is observed that overall acceptability increased when the level of defatted soy-flour is low and that of stevia is high. Figure 1b gives the effect of defatted soy flour and maltodextrin. Maltodextrin did not affect the overall acceptability. However, defatted soy flour showed maximum overall acceptability in the range 25 to 30g per 100g of papaya pulp. Contour plot between stevia and maltodextrin (Figure 1c) shows that maltodextrin had no effect on overall acceptability. Stevia in the range 2-2.5 g per100 g of papaya pulp gave the maximum response. Thus, defatted soyflour and stevia are important ingredients in preparation of papaya pulp fruitbar [24].

Conclusions

An acceptable low calorie-high protein papaya fruit bar as health food was developed by optimizing the levels of 24.47% defatted soy flour, 1.98% stevia and 2.7% maltodextrin. Low level of defatted soy flour and relatively high level of stevia gave the product with higher overall acceptability. In view of this study, it is recommended that food industry should manufacture low calorie-high protein papaya fruit bar for the benefits of the society for the health conscious customers.

References


