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Effect of processing parameters on quality attributes of fried banana chips

Wani, S. A., Sharma, V. and *Kumar, P.

Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Longowal 148106 (India)

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Abstract

Chips are the most popular variety of snacks and they are consumed round the year by people of all age groups. A central composite face cantered design was applied to determine the effects of chips thickness (mm), frying temperature (°C) and frying time (min) on moisture content, fat content, hardness, color and overall acceptability. A second-order polynomial model was used for predicting the response. Chips thickness (1.5, 2 and 2.5 mm), frying time (2.0, 2.5, 3.0 min) and frying temperature (160, 170 and 180°C) were the parameters used in the study. Result indicated that moisture content decreased whereas oil content increased with increasing frying time and chips thickness. Hardness increased with increasing chips thickness and frying temperature. Color (ΔE) of chips became darker yellow with longer frying time. Increased frying time increases the sensory characteristics of the product and vice versa for frying temperature. The optimum conditions for fried banana chips were obtained at a temperature of 160°C, time 2.69 min and slice thickness of 1.5 mm. Therefore, quality banana chips could be developed using theses optimum conditions

Introduction

Bananas are tropical fruits belonging to the genus *Musa* and the family *Musaceae* (Palmer, 1971). Bananas are popular and nutritious fruit, with a pleasant flavor. They are high energy fruit rich in carbohydrates and also good source of potassium, iron, phosphorous, vitamin C and B6. Generally, bananas are eaten raw but ripe banana is perishable and deteriorates rapidly after harvesting hence there is a need to apply an appropriate post-harvest technology to prolong the shelf life of the fruit. In order to minimize huge economic losses, banana can be preserved and processed by frying and drying (Robinson, 1996).

Deep fat frying is a conventional frying method for banana chip production, basically it includes the immersion of banana slices in a vegetable oil at temperature of around 110-160°C that causes drying by means of frying. The high temperature causes an evaporation of the water, which moves away from food and through the surrounding oil. Oil is absorbed by food, replacing some of lost water (Troncoso et al., 2009).

During the frying process, the physical, chemical and sensory characteristics of foods are modified. Banana chips produced from fully ripe bananas are popular as a snack food in many countries. Consumer acceptance of banana chips is based on quality attributes of the product (Godavari and Narayana, 1969). Textural changes during frying are the result of many physical, chemical and structural changes produced in this complex process unit operation, which includes heat and mass transfer together with chemical reactions. The aim of the work was to determine the effect of processing condition such as frying time, frying temperature and chip thickness on the quality attributes of fried banana chips, using response surface methodology (RSM).

Materials and Methods

Materials

Raw bananas were purchased from local supermarket. Prior to the start of each experiment banana was peeled and cut into slices with thickness of 1.5, 2 and 2.5 mm. Cottonseed oil obtained from local market of Sangrur, Punjab, India and its brand is Gokul brand was used for frying process. For polyphenoloxidase (PPO) inhibition banana slices was dipped in 250 ppm potassium metabisulfite for 2.5 min. before frying.

*Corresponding author.
Email: *pradyuman@sliet.ac.in,pradyuman2002@hotmail.com*
Tel: *91-1672-253399*
Fax: 91-1672-280057

Table 1. The range of the coded and uncoded variables

Variables	Code	Coded levels		
		-1	0	1
Chips thickness, mm	A	1.5	2	2.5
Frying time, min	B	2	2.5	3
Frying temp. °C	C	160	170	180

Experimental design for optimized banana chips

Response Surface Methodology (RSM) was used for optimized fried banana chips. For the optimization of process conditions, the experiments were conducted according to second order Central Composite face centred Design. The frying time, frying temperature and chip thickness were the process variables used for achieving the optimized banana chips. The responses include color, hardness and sensory evaluation. The range and levels of experimental variables investigated are presented in the Table 1. The independent variables were coded at three levels and their actual values were selected based on the results of preliminary evaluation. Experiments designs in the coded form were presented in Table 2.

Analysis of data and Model fitting for RSM

RSM was applied to the experimental data using a commercial statistical package (Design Expert, Trial Version 8.0, Stat-Ease INC., Mineapolis, MN statistical software) for the generation of response surface and optimization of process variables. Optimization of process parameters was done by partially differentiating the model with respect to each parameter, equating to zero and simultaneously solving the resulting functions. For the three factors, this design was made up of a full 23 factorial design. Total of twenty runs were provided by central composite rotatable design by RSM. The analysis was done by regression analysis describing the effects of variables in first order, a two-factor interaction and second order polynomial models (Altan *et al*., 2008). The data were fitted to the selected models and regression coefficients obtained. The response surfaces plots for these models were plotted as a function of two variables, while keeping other variables at the optimum values. Analysis of variance (ANOVA) was used for the determination of statistical significance of the terms in the regression equation for each response.

The second order polynomial equation was fitted to the experimental data of each dependent variable as given below,

$$Y_i = \beta_0 + \sum_{i=1}^{n}\beta_i X_i + \sum_{i=1}^{n}\beta_{ii} X_i^2 + \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\beta_{ij} X_i X_j + e_i \quad \text{.......................} (1)$$

where, Yi represents the measured response, Xi represents the independent variables, β_0 intercept terms at the central points i.e. (0, 0, 0), β_i,, β_{ij}, and β_{ii} are linear, quadratic and cross product regression coefficients respectively. The variable $X_i X_j$ represents the first order interaction between X_i and X_j for (j<i).

Frying

Continuous banana chips making machine was used in the present study. The frying chamber of the machine was made of double jacketed trapezoidal shape and it consists of a stainless steel frying chamber, insulated with glass wool, with inner dimensions of 55 cm x 25 cm x 30 cm. Deep fat frying was conducted in a continuous banana chips making machine using cottonseed oil under various time-temperature combinations. When the frying process was finished, the product was moved by conveying belt to drain the excess fat.

Moisture content

Moisture content was determined according to the method of AOAC (1995).

$$\text{Moisture (\% by mass)} = [(w_1 - w_2)/(w_1 - w)] \times 100 \quad \text{..............} (2)$$

Where,

w_1 = weight in g of dish with sample before drying

w_2 = weight in g of dish with sample after drying.

w = weight in g of sample of dish.

Fat content

Fat were determined by AOAC (1975). Two g of sample was weighed and transferred to extraction thimble (dried overnight at 1050C). The thimble was kept in extractor and fat was extracted with petroleum ether in Soxhlet Extraction Apparatus for 6 hrs. The residue was dried at 800C in an oven after removal of ether by evaporation, then cooled in dessicator and weighed. The loss in weight of thimble was estimated as loss of lipids from sample and expressed as per cent lipids in sample.

$$\% \text{ Fat} = \frac{(W_2 - W_1)}{w} \times 100 \quad \text{.............} (3)$$

Table 2. Effect of independent variables on responses value

Exp. No.	Coded variables			Responses				
	Chips thickness (mm)	Frying time (min)	Frying temp. (°C)	Moisture Content (%)	Fat (%)	Hardness (N)	Color (ΔE)	Overall Acceptability
1	1	0	0	15.66	21.99	8.1	57.26	7
2	0	0	0	41.54	26.45	60.45	56.08	4.6
3	1	1	1	5.58	29.86	12.23	47.44	7.3
4	0	0	0	22.12	33.78	71.87	58.61	5.6
5	-1	0	0	11.19	31.85	11.55	60.04	6.09
6	-1	-1	-1	27.03	31.13	82.03	52.7	6
7	0	0	0	7.09	31.89	4.15	58.04	5.1
8	-1	-1	1	18.89	39.78	83.56	61.89	5.2
9	1	-1	1	3.1	19.82	3.23	58.45	7.3
10	0	0	-1	29	24.16	99.7	60.01	6.2
11	0	-1	0	29.99	27.01	49.02	54.43	4
12	0	0	1	9.93	33.95	58.34	54.89	4.6
13	0	1	0	18.23	36.26	16.37	53.12	5.17
14	0	0	0	11.94	42.34	28.67	60	3.6
15	-1	1	1	12.63	29.38	24.82	52.45	3.9
16	0	0	0	11.23	32.39	23.86	51.51	3
17	-1	1	-1	13.43	30.12	25.82	51.23	3.5
18	1	-1	-1	11.12	30.36	22.66	53.67	3.7
19	1	1	-1	10.91	31.24	21.63	51.03	3.3
20	0	0	0	10.56	28.37	20.67	52.66	3.2

Where,
w_1 = Weight of empty beaker (g)
w_2 = Weight of beaker with oil (g)
w = Weight of sample (g)

Color

One of the important characteristic of food material is the color. Any changes in color give information about the extent of browning reactions such as caramelization, maillard reaction, degree of cooking and pigment degradation that take place during the process. Color (L^*, a^* and b^*) was determined by Hunter CIE – Lab colorimeter (Gretag Macbeth, USA) (Wani and Kumar, 2015). All the analysis of color was carried out in triplicate. The letters L^*, a^* and b^* represents the white–black, red–green and yellow–blue ratio of the sample, respectively. For each sample, three measurements were taken and averaged. Color was also evaluated as the total color difference (ΔE)

$$\Delta E = \sqrt{(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2}$$

Where, L_o, a_o and b_o represented the standard reading and L, a and b represented the instantaneous individual reading after applying the experimental design.

Hardness

Hardness was determined in triplicates using a texture analyzer (Model TA-XT 2i, Stable Micro Systems Ltd, Vienna Court, Lammas Road, Godalming, Surrey GU71YL, UK) (Wani *et al*., 2015).

Sensory characteristics

A sensory characteristic (9 Points Hedonic Scale) was performed according to the method as described by Xu *et al*. (1999). Seventy semi trained and untrained panelists were asked to assess the product and mark on a Hedonic Rating Test (1 – Dislike extremely, 5 – Neither like nor dislike and 9 – Like extremely) in accordance with their opinion for taste, texture, color, and overall acceptability.

Results and Discussion

The F-value of moisture, fat content, hardness, color and overall acceptibility showed that the model is significant. The values of R_2, Adj R_2 and "Lack of Fit values are shown in Table 3. Result of regression analysis of different responses of fried banana chips

Table 3. Result of regression analysis of different responses of Fried banana chips

	DF	Moisture content	Fat content	Hardness	Colour	Overall Acceptability
		F value				
Model	9	11.6*	30.3*	23.3*	52.1*	3.41*
A	1	8.31*	1.67*	31.0*	0.66*	-0.43*
B	1	-5.52*	2.60*	1.85*	0.04	0.03
C	1	-2.29*	2.40*	3.61*	1.81*	-0.34*
A^2	1	1.82*	-2.89*	9.55*	2.39*	1.30*
B^2	1	3.20*	0.10	10.34*	0.78*	0.43*
C^2	1	1.48*	3.22*	-0.67	1.45*	0.46*
AB	1	-1.67*	1.0	2.02	2.9*	0.11
AC	1	-1.84*	-0.15	4.73*	-1.6*	0.51*
BC	1	2.15*	-0.81	-2.67*	1.81*	-0.38*
Lack of fit	5	2.53	1.85	3.96	0.44	3.02
R-Squared		0.98	0.94	0.99	0.97	0.94
Adj R-Squared		0.97	0.90	0.98	0.95	0.88

* Significant at $P \leq 0.05$
where A, B and C are the coded values of chips thickness (mm), frying time (min.) and frying temperature (ºC) respectively.

were shown in Table 3.

Effect of process variables on moisture content

Moisture content is a major chemical property of the fried chips. The moisture content, ranged from 3.1 to 41.54% (Table 2). The following regression equation as shown in Table 3 represents the variation of moisture content (%) with independent variables. From Figure 1a it was observed that moisture content decreases significantly ($P \leq 0.05$) with increase in the temperature, frying time of the fried chips at higher moisture levels. The decrease in moisture content with increase in temperature may be due to the evaporation of moisture from the surface of chips. Similar observations were reported by Therdthai et al. (2007). Increasing of the oil temperature decreased the frying time of chips and improved the rate of drying. Frying temperature significantly affected the moisture content. The higher the frying temperature, the lower the moisture content in banana chips. This was in line with the observation of Christopher et al. (2004). The moisture content of chips increases ($P \leq 0.05$) with increase in chip thickness as shown

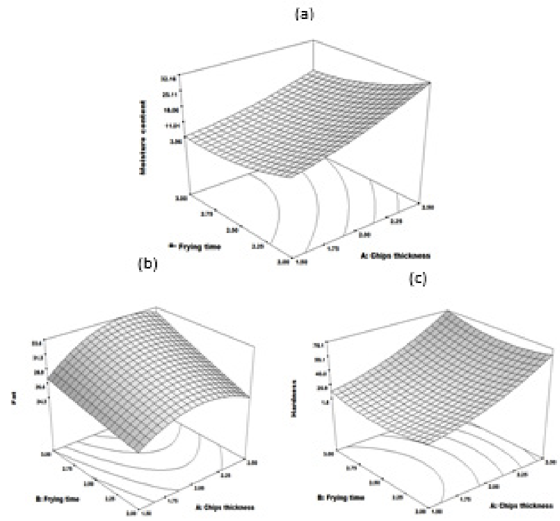

Figure 1. Response surface plot for the (a) moisture content, (b) fat content and (c) hardness of fried chips as a function of chips thickness and frying time

in Figure 1a. Here moisture from the thick slice interior is first transferred to the surface and then it gets evaporated. So, moisture loss by evaporation is governed by the diffusion rate (Rice and Gamble, 1989). In thinly sliced chips moisture travels faster due to the reduced distance and increased surface area exposed for a given volume of product. According to Reddy and Dias (1993) the thickness of chips is related to its moisture present. Moisture content increases linearly with increase in thickness (Kingcam *et al*., 2008).

Effect of process variables on product fat content

Oil content is one of the most important quality attributes of a deep-fat fried product. The texture of a low oil content product can be soft and unpleasant. However, the high oil content is costly to the processor and results in an oily and tasteless product (Moreira *et al*., 1999). Gamble *et al*. (1987) suggested that most of the oil enters the final product from the adhered oil being pulled into the product when it is removed from the fryer due to condensation of steam. The fat content ranged from 21.99 to 42.34%. The quadratic model obtained from regression analysis for fat content (FC) in terms of coded levels of the variables is shown in Table 3.

The main process parameters influencing oil uptake are frying temperature and duration (Cuesta *et al*., 2001). The most important characteristics of the product influenced are texture (Varela, 1988; Math *et al*., 2004; Kita *et al*., 2007). From the Figure 1b it was observed that fat content increases linearly ($P \leq 0.05$) with increase in frying temperature, frying time and chip thickness. Oil content of chips increases significantly during frying. Similar observation was obtained by Krokida *et al*. (2000) as the temperature of frying increases the oil content for the same frying time increases. According to the Therdthai *et al*. (2007), longer frying time increased ($P \leq 0.05$) fat content of the final product. Oil adsorption has been found to be affected by porosity of the product. Porosity was found to be increased during frying and longer frying times resulted in more uniform pore size distribution, as a result increased the overall frying.

Effect of process variables on hardness

Texture is a key quality attribute of a snack food, and hardness is an important textural characteristics. The texture of dried potato chips is reported in terms of hardness, toughness and crispness, which were indicated from the maximum breaking force, area under the force-deformation curve (Rosenthal, 1999) and the number of peaks (van Loon *et al*., 2007) respectively. The textural property of banana chips was determined by measuring the force required to break the chips. The higher the value of maximum peak force required in Newton, which means the more

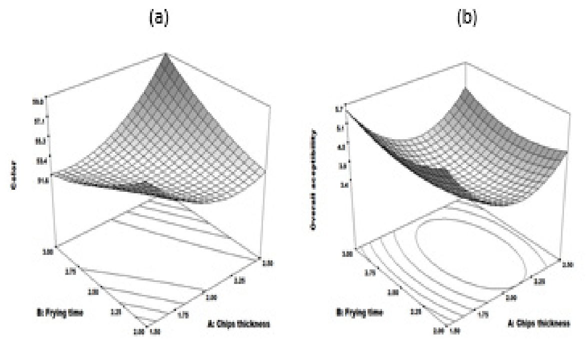

Figure 2. Response surface plot for the (a) color and (b) overall acceptability of fried chips as a function of chips thickness and frying time

force required to breakdown the sample, the higher the hardness of the sample to fracture. Hardness of fried chips varied between 3.23 and 99.7 N. The quadratic model for hardness (H) in terms of coded levels of variables is shown in Table 3.

Frying time and temperature influence the product characteristics especially texture (Varela, 1988; Kita *et al*., 2007). Results showed that an increase in chips thickness, frying temperature and frying time resulted in significant ($P \leq 0.05$) increase in product hardness respectively. Response surface plot, (Figure 1c) predicting that hardness increased ($P \leq 0.05$) with increasing chips thickness and frying temperature. Similarly, in case of potato chips, it was found that initial thickness significantly ($P \leq 0.05$) influenced the hardness of potato chips. Higher degrees of starch retrogradation tended to increase the hardness of dried chips, especially in the case of chips with higher initial thicknesses (Kingcam *et al*., 2008). The increase in toughness might be due to the higher strength of the internal bonds within the product.

Effect of process variables on product color (ΔE value)

Color is an important factor influencing consumer acceptance of a fried product. It is directly related to the quality of the final product. The manufacturer generally notices the color of a product in order to determine the end of the frying process. The final color of the fried product depends on the absorption of oil and browning reaction (Baixauli *et al*., 2002). Color (ΔE) is the important physical characteristics of fried products and directly related to the acceptability of food products. Color (ΔE) of banana chips varied between 47.44 and 60.04. The quadratic model for color (ΔE) in terms of coded levels of variables is shown in Table 3.

Response surface plot (Figure 2a) showed ΔE value increased significantly ($P \leq 0.05$) with increase chip thickness and frying temperature also increase in frying time increases ΔE value. Oztop *et al*. (2006) found that the total color difference (ΔE) of potato chips increased as frying time increased. It was found that the color of chips as indicated by ΔE became a dark yellow when the moisture content was lower (longer frying time, increased frying temperature). Maillard browning reactions are believed to be source of color development. Furthermore, aldehyde groups of triglyceride molecules, derived from lipid degradation react with amino groups to form dark coloring compound. Krokida *et al*. (2001) suggested that lower thickness leads to lower lightness and higher yellow color of the product, while red color development was intense only in case of higher temperature.

Effect of process variables on product overall acceptability

Sensory evaluation indicates the acceptability of the product. Hedonic scale is used to find the different aspect of sensory evaluation. The overall acceptability of the product ranges from 3.1 to 8.2. The quadratic model for sensory (overall acceptability) in terms of coded levels of variables is shown in Table 3. Results showed that increase in chips thickness and frying temperature decreased significantly ($P \leq 0.05$) the sensory characteristics (Figure 2b). However a non-significant effect of frying time was observed on overall acceptability. The decreased effect of frying temperature on overall acceptability may be attributed to the increased darkness with higher temperature. Whereas decreased effect of chip thickness on overall acceptability may be due to the incomplete frying.

Numerical optimization

Response surface methodology was used to optimize the processing parameters like chips thickness, frying time and frying temperature to produce a quality chips. The processing parameters; chip thickness, frying temperature and frying time were kept within range as the optimization constraint. The constraints for the responses were moisture content (minimum), fat content (minimum), hardness (minimum) and sensory quality (maximum). The result provided by the RSM on the basis of above constraints were optimum values of 1.50 mm chip thickness, 2.69 min. Frying time and 160oC frying temperature with a predicted responses of 5.24% moisture content, 27.3 %, fat content 4.7 (N) hardness and 6.7 overall acceptability.

In order to verify the predictive capacity of the model, an optimum condition was used for an optimum product. The experimental results obtained were moisture content (5.9%), fat content (29.1%) and overall acceptability (7.1). The experimental results were found to be very close to the predicted one with desirability of 94.2%. This implied that there was a high fit degree between the values observed in experiment and the value predicted from the regression model. Hence, the response surface modelling could be applied effectively in achieving optimum product quality.

Conclusion

In this study, the effects of frying process on quality (moisture content, oil absorption, hardness color and sensory characteristics) of fried banana chips were studied. Chips thickness, frying time and frying temperature were the parameters used in the study. It was observed from the results that moisture content decreased and oil content increased with the increasing frying time and chips thickness. The hardness of chips increased as the chips thickness and frying temperature increased. Darker yellow color of chips was observed with longer frying time. The color development was investigated to be due to maillard browning reactions. In addition, optimum conditions for fried banana slices are at a temperature of 160ºC, time 2.69 min and slice thickness of 1.5 mm. These optimum conditions could be used for the development of acceptable quality banana chips with longer shelf life as compared to the raw banana. Further analysis is needed to determine the storage period of the banana chips.

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