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Effect of Processing Conditions on the Quality of Fried Sweet Potato Chips

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Abstract:
This study investigated the effect of processing conditions on the quality of fried sweet potato chips. A Box Behnken Design was used to determine the effect of blanching temperature, blanching time and frying time on fried sweet potato chips in 17 runs. The moisture and oil content were used as indices of product quality. Increase in blanching temperature and frying time, decrease the moisture content of the fried sweet potato chips, while increase in blanching temperature and frying time, increases the oil content of the fried sweet potato chips. The processing condition for fried sweet potato chips were blanching temperature of 70^0C, blanching time of 5mins and frying time of 6mins.

Keywords: *Fried sweet potato chips, processing conditions, quality*

1. Introduction

Sweet potatoes were first introduced outside the Andes region four centuries ago and have become an integral part of much of the world's cuisines (Garaya and Moreira, 2002). It arrived late in Africa around 20th century. The decade's production has been a continual expansion, rising from 2million tonnes in 1960 to a record of 16.7million in 2007 (Falsetto, 2008). Potato tuber has two varieties, Irish potato and sweet potato. The sweet potato is a starchy tuberous crop from the perennial *Ipomoea batatas*. They have the shortest growing period out of all the major root crops. Many varieties of sweet potatoes are available ranging in colour of the flesh from orange to purple. Sweet potatoes are fairly drought resistant and are relatively free from disease (Krokida *et al*, 2001). Sweet potato is best known for its carbohydrate content. The predominant form of its carbohydrate is starch. The orange and yellow cultivars have the highest nutritional value because of the high carotenoid content which are precursor of vitamin A (FAO,2002), sweet potatoes contains other vitamins and minerals as well as an assortment of phytochemicals such as carotenoids and natural phenols (Downey, 2002). Sweet potatoes are used to brew alcoholic beverages such as vodka, potche or akvavit. The potato tubers can also be processed into products like chips, snacks, french fries and dehydrated potato products such as potato flakes, potato granules and potato starch. They are well known for their use in culinary dishes (Vitrac *et al*, 2002).

Deep fat frying is a simultaneous heat and mass transfer process which leads to a succession of physical and chemical changes in the product (Hindra and Baik, 2006).The fried products have an attractive colour (golden brown), distinctive mouth feel, pleasant taste as well as fried flavour and unique textural properties (crispy crust formation). Deep frying is a cooking method in which the food is submerged in hot oil or fat. This is normally performed with a deep fryer or chip pan. Industrially, a pressure fryer or vacuum fryer may be used (Moyano *et al*, 2002).

Response surface methodology is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes. Its main idea is the use of sequence of designed experiment to obtain an optimal response (Sobukola *et al*, 2007), This methodology presupposes the use of experimental design techniques to investigate and learn about the functional form of the process or system that involves one or more response variables that are influenced by various factors or independent variables (Bas and Boyaci, 2007). Most research reports that are available in the literature relate to products like tofu, french fries, irish potato, cassava chips (Gamble *et al*, 1987; Gupta *et al*, 2000; Hindra and Baik, 2006). There is no detailed information on deep fat frying of sweet potato with respect to investigating the effect of conventional blanching conditions as it affects the quality parameters. Therefore the objective of this study was to determine the effect of processing conditions (blanching temperature, blanching time, frying time) on the moisture and oil contents of fried sweet potato chips.

2. Materials and Methods

2.1. Materials

2.1.1. Blanching Operation

Fresh sweet potato tubers (*Ipomoea batatas*) were purchased from mile 12 market in Lagos, Nigeria. Tubers to be used was selected from the lot, washed and graded. Thickness of 2mm was obtained from the tubers using a slicer. Freshly cut sweet potato slices was fixed on stainless steel rods and was lowered vertically into the water bath with variability in temperature and time between 60^0C,70^0C and 80^0C at 1min,3min and 5min.Excess surface water was removed by placing the material in an electric oven for 1min at 27-30^0C (Ufheil and Escher,1996).

2.1.2. Frying Operation

A deep fat fryer with the temperature control was used. Frying temperature was set at 170^0C for each selected frying time, the slices of blanched sweet potato was drained after frying over a stainless steel basket and allowed to cool at room temperature and packaged in high density polyethylene films before analysis was carried out. The oil was pre-heated for 1hr before frying and discarded after 6hours of use (Kroikida *et al*, 2001).

2.1.3. Experimental Design

A response surface methodology technique was used to optimize the deep fat frying conditions. Data obtained was analyzed by multivariate statistical analysis. The three independent variables in this procedure were blanching temperature($X_{1)}$, blanching time(X_2) and frying time(X_3). Three levels of each of the three independent variables were chosen for the study. Seventeen combination including five replicates of the centre point were performed in random order according to Box-Behnken rotatable experimental design configured for three factors. The coded value of the three independent variables and the treatment schedule are presented in Table 1and 2.

Variables	**Levels**		
	-1	**0**	**+1**
X_1 (^{o}C)	60	70	80
X_2 (min)	1	3	5
X_3(min)	2	4	6

Table 1: Coded Levels for the Response Surface Design

X_1=Blanching Temperature
X_2=Blanching Time
X_3=Frying Time

Blanching Temperature (X_1)	**Blanching Time (X_2)**	**Frying Time (X_3)**	**Moisture content (Y_1)**	**Oil content (Y_2)**
60	1	4		
80	1	4		
60	5	4		
80	5	4		
60	3	2		
80	3	2		
60	3	6		
80	3	6		
70	1	2		
70	5	2		
70	1	6		
70	5	6		
70	3	4		
70	3	4		
70	3	4		
70	3	4		
70	3	4		

Table 2: Treatment Schedule for Three Factors of Box-Behnken Design

2.2. Analysis

2.2.1. Moisture Content Determination

This was determined according to the method described by AOAC (2000). The sample was weighed into flasks and dried at 105^0C for 5hrs, cooled in dessicator and weighed again according to the method number.

2.2.2. Oil Content Determination

Oil content was determined according to method described by AOAC, (2000) by soxhlet extraction. The dried samples were ground in a blender and extracted with petroleum ether for 4hrs.Petroleum ether was removed under vacuum at 60^0C using a rotary evaporator. The recovered oil was left for 24hrs in a vacuum oven at 70^0C and weighed.

2.3. Statistical Analysis

Second order polynomial model was fitted to determine relationship between dependent variable (Y), moisture content (Y_1) and oil content. The following equation was used:

$$Y = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{12}X_1X_2+ \beta_{13}X_1X_3 + \beta_{23}X_2X_3$$

Where β_0, β_1- β_3, β_{11}- β_{33} and β_{12}- β_{23} are regression coefficients for interception, linear, quadratic and interaction coefficients, respectively, X_1-X_3 are coded independent variables and Y is the response (Sobukola, and Shittu, 2008). An Anova test was carried out using Design Expert 6.0.8 (Stat-Ease Inc., Minneapolis, USA) to determine the significance at different levels (0.1%, 1% and 5%) (Stat-Ease, 2002).

3. Results and Discussion

3.1. Effect of Blanching Temperature and Frying Time on Moisture Content of Fried Sweet Potato Chips

The effects of blanching temperature and frying time on the moisture content of fried sweet potato chips are presented as 3D surface plots in figure1. As the blanching temperature increases, the moisture content of the fried sweet potato chips decreases. As the frying time also increases, decrease in moisture content was observed. The model for the moisture content (R^2=0.99) had a positive quadratic terms (frying time) and a negative quadratic terms (blanching temperature and blanching time). It also has a negative linear terms (blanching temperature and frying time) and a positive linear terms (blanching time).The moisture content was significantly (p>0.05) affected by frying time(X_3) and a quadratic effect of frying time (X_3^2). Blanching has been reported to increase the permeability of cytoplasmic membrance, allowing the blanch water to penetrate cells and intercellular spaces, driving out gases and other volatile compounds (Canet and Hill, 1987), causing losses of soluble substances such as vitamins, salts and sugars, and increasing the moisture content of the samples (Fermandez *et al.,* 2006). After blanching the sweet potato chips, the slices appeared swollen but moisture was rapidly released when placed in hot oil in response to loss of osmotic integrity and cellular damage as a result of blanching (Alvarez *et al*, 2000).

3.2. Effect of Blanching Temperature and Frying Time on Oil Content of Fried Sweet Potato Chips

The effects of blanching temperature and frying time on the oil content of fried sweet potato chips are presented as 3D surface plots in figure 2. As the frying time increases there was an increase in the oil content of the fried sweet potato chips. As the blanching temperature increases, the oil content also increases. The model for the oil content (R^2=0.98) had the positive quadratic effects (blanching temperature, blanching time and frying time) and there was positive linear terms (blanching temperature and frying time) and a negative linear term (blanching time).The oil content was significantly (p>0.05) affected by frying time (X_3) and a quadratic effect of frying time (X_3^2). When sweet potato slices are placed in hot oil, the free water was rapidly lost in the form of bubbles. As frying continues, the outer surface dries out, improving hydrophobicity and oil may adhere to the chips. When the chips are removed from the fryer, the vapour inside the pores condenses and the difference in pressure between the surrounding tissue and the pores causes the adhering oil on the surface to be absorbed into the pores spaces (Sobukola *et al.,* 2007).

4. Conclusion

During deep fat frying, as the blanching temperature and the frying time increases, the moisture content of the fried sweet potato chips decreases, while the oil content increased with increasing frying time and blanching temperature.

Response surface methodology showed that the blanching temperature, blanching time and frying time significantly affected moisture and oil content of the fried sweet potato chips. Therefore, the processing conditions for fried sweet potato chips suggested were blanching temperature of 70^0C, blanching time for 5mins and frying time of 6mins.

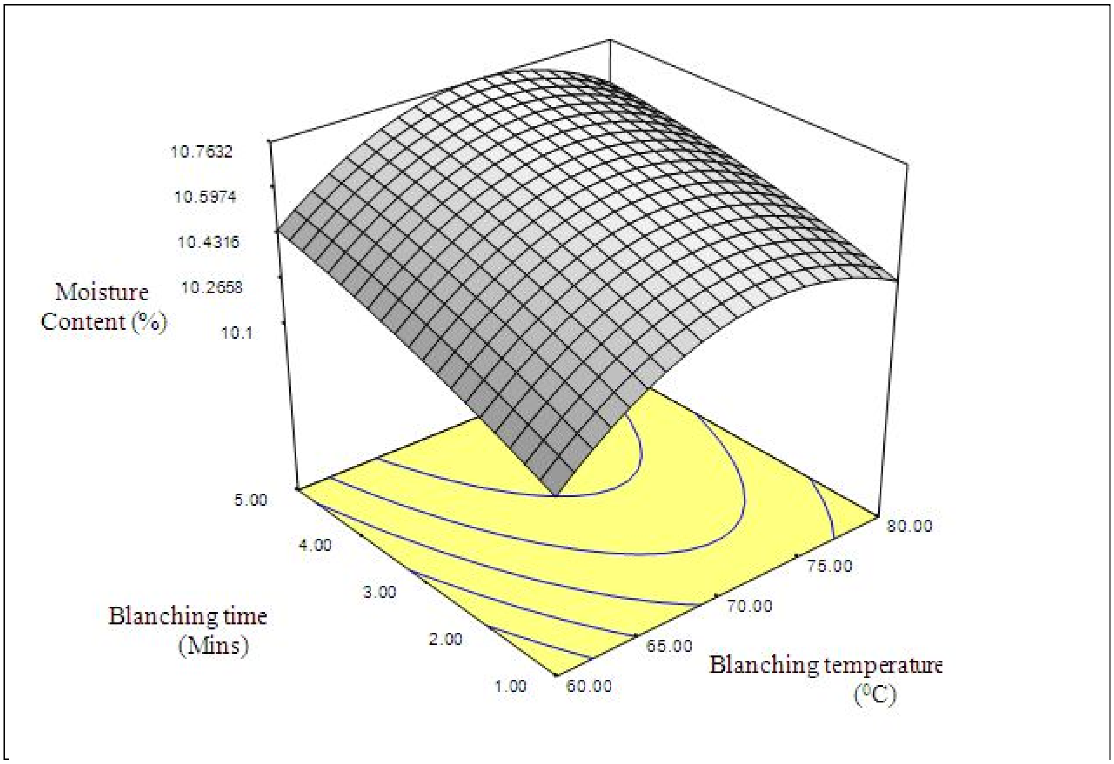

Figure 1: Effect of blanching temperature and blanching time on the moisture content of fried sweet potato chips at constant frying time

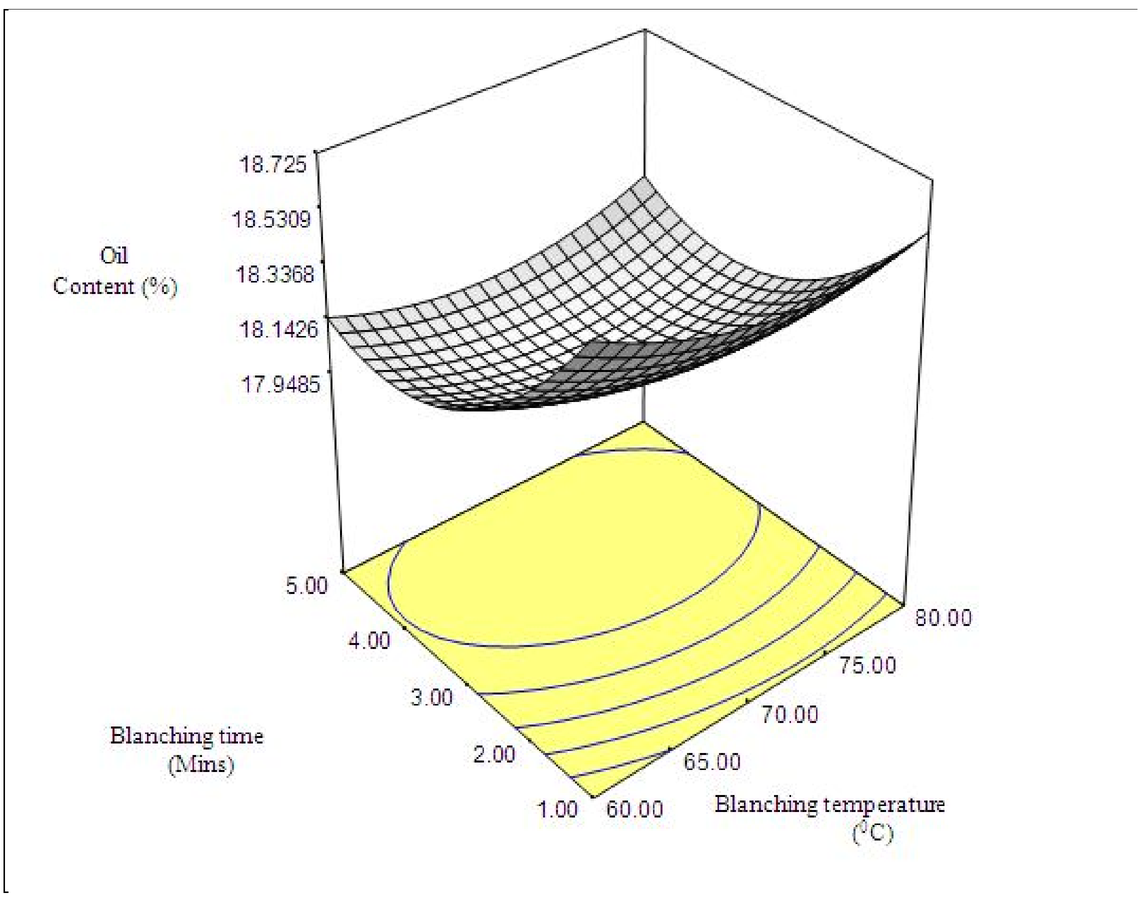

Figure 2: Effect of blanching temperature and blanching time on the oil content of fried sweet potato chips at constant frying time

Coefficient	Moisture Content	Oil Content
β_0	5.53***	24.56***
β_1	0.33	-0.17
β_2	0.29	-1.03
β_3	-2.85	-0.37
β_{11}	-0.00	0.00
β_{22}	0.00	0.07
β_{33}	0.24	0.18
β_{12}	-0.00	0.00
β_{13}	0.00	-0.00
β_{23}	-0.02	0.00
R^2	0.99	0.98

Table 3: Significant coefficients of regression equation for the responses

X_1: feed moisture, X_2: screw speed, X_3: temperature
*** Significant at the 0.1%
** Significant at the 1%
* Significant at the 5%

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