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Modelling and optimization of processing variables of snack (kokoro) produced from blends of maize and African yam bean seed flour

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Abstract

Response surface methodology was used to study the effect of process variables on product quality of fried maize-based snack (kokoro). The process variables are: African yam bean seed flour (AYBSF) (20-40%) inclusion in maize flour, frying temperature (150-170°C) and frying time (8-12 min). Product's protein content, sensory quality and color parameters (L^*, a^* and b^*) were determined. High quality kokoro characterized by high protein content (>10%), high sensory quality (>6.5), and acceptable color parameters [(minimum redness (a^*), optimum yellowness (b^*) and lightness (L^*)] were obtained by using 30% AYBSF, at frying temperature, 155°C for 11.5 min. Addition of legume (AYBSF) resulted in significant increases in protein content and sensory evaluation while increasing frying temperature increased the redness and yellowness. Based on the lack of fit test and coefficient of determination, R^2, quadratic model was appropriate for protein content, sensory quality, yellowness (b^*) and lightness (L^*) while linear model was appropriate for redness (a^*). Statistical analysis with response regression showed significant (p=0.05) interactions between process variables and quality parameters measured. The optimal process variables of frying temperature 155°C, frying time 11.5 min and AYBSF level (30%) would produce AYB-maize kokoro with enhanced nutritive value, better sensory quality and consistent color parameters.

Introduction

Most maize snacks in Nigeria are prepared by frying, roasting and some by boiling. Frying is the commonest of these processing methods. Frying is a unit operation used to alter the eating quality of food products. It is often selected as a method of choice for creating a unique flavor and texture in processed foods (Patterson *et al.*, 2004). The popularity of these fried snacks necessitates the need to improve their quality.

In the tropics, maize is a common cereal crop, a good source of carbohydrate, vitamins and minerals. It can be processed into a wide range of food items and snacks (FAO, 2009). Some of these snacks include; guguru (pop-corn), aadun (maize snack), kokoro (corn cake), donkwa (maize-peanut ball). Although, these snacks and appetizers are popular food items with a long history of consumption especially among the low income populace, findings shows that there exists a paucity of information on the improvement of their quality attributes (Aletor and Ojelabi, 2007). Kokoro, like other cereal-based foods is rich in carbohydrate, but low in protein and deficient in some essential amino acids particularly lysine. This makes the product nutritionally deficient. Since these snacks are widely consumed by low income populace in Southern Nigeria, optimization of its production process to improve its quality will positively affect the people.

African yam bean seed (AYBS) *(Sphenostylis stenocarpa)*, a lesser known legume of tropical origin which has attracted research interest in recent times (Azeke *et al*., 2005). Up till now, it is classified as a neglected underutilized species of legume (Anon, 2007). It is grown throughout tropical Africa, most commonly in Central and Western Africa, especially in Eastern Nigeria. It is also reported to be cultivated in Ivory Coast, Ghana, Gabon, Congo, Ethiopia and parts of East Africa (Wokoma and Aziagba, 2001). It grows well in acid and highly leached sandy soils of the humid lowland tropics where other major food legumes do not flourish. It suffers less of pest damage than the other legumes both in cultivation and storage, and it has the potential to meet year-round protein requirement if grown on a large scale (Adewale *et al*., 2010).

AYBS has attracted research interest because of

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its nutrient contents. Lysine and methionine levels in the protein are reported to be higher than those of most of legume crops (Evans and Boulter, 1974). Despite the availability and the nutritional importance of this crop, it is still less utilized. AYBS has been processed into flour and paste used locally for "moinmoin" (cooked paste) and "akara" (fried bean balls). There is still limited information on the food uses of AYBS.

Deep fat frying is a heat transfer process combining convection within the hot oil and conduction to the surface of the food (Fellows, 1990). All surfaces of the food receive a similar heat treatment to produce a uniform color and appearance. This heat treatment results in modification of physical, chemical and sensory characteristics of the food. Studies have shown frying temperature and frying time as major variables controlling deep fat frying operation (Sulaeman et al., 2001). Frying has been reported to affect product color and sensory quality (Samatcha *et al*., 2009). Therefore, optimization of the process variables involved in frying is expected to suggest conditions for obtaining products of consistent color and consistent sensory quality.

Response surface methodology (RSM) is a statistical-mathematical method that uses quantitative data in an experimental design to determine and simultaneously solve multivariate equations to optimize processes and the products (Myers and Montgomery, 1995; Akinoso *et al*., 2011). Studies have been done on optimization of some other food products (Olapade, 2010) (Tripathi and Mishra, 2009). However, little insight is provided for the optimization of maize snack to improve nutritional content, sensory quality and physical quality (color).

The objective of this study therefore, was to optimize the process variables involved in producing kokoro from blends of Maize Flour (MF) and African Yam Bean Seed Flour (AYBSF) and evaluate the effect of the process variables (frying temperature, frying time and quantity of AYBSF in the flour blends) on the protein content, color parameters and the sensory quality of the snack.

Materials and Methods

Materials

Yellow maize (variety, BR 9928-DMR-SY) was procured from the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria, while the African yam bean seeds (Tss-30) were purchased from a retail market (Umuaiha), Abia state, Nigeria. They were stored at temperature, 4-8^{o}C and relative humidity, 65-100% prior to further processing. Refined vegetable oil, salt and onions were obtained from a retail market in Ibadan, Oyo State, Nigeria.

Experimental design

A Box Behnken design with three variables was used to optimize the processing conditions (Box and Behken, 1960). The three independent variables in this study were frying temperature (X_1), frying time (X_2) and quantity of AYBSF (X_3). The variables considered in this study and their levels were chosen based on information from literature and preliminary laboratory investigation. Protein content, overall acceptability (sensory quality) and color parameters were the main quality parameters evaluated for the maize snacks.

Frying temperature (X_1), frying time (X_2) and quantity of AYBSF inclusion in the flour blend (X_3) were considered as independent variables. While protein content (Y_1), overall acceptability (Y_2), lightness (Y_3), redness (Y_4) and yellowness (Y_5) as dependent variables. The three levels of each of the three independent variables were: 150^{o}C, 16^{0o}C and 170oC (-1, 0, 1); 8, 10 and 12 min (-1, 0, 1) and 20%, 30% and 40% (-1, 0, 1) for frying temperature (X1), frying time (X_2) and quantity of AYBSF inclusion in the flour blend (X_3) respectively. Thirteen combinations and four center points were performed in random order.

Preparation of Maize-AYBS flour samples and the kokoro

Maize samples were sorted and milled in a hammer mill (model ED-5 Thomas Wiley, England) and sieved using 750µm mesh size. The African yam bean seeds were sorted, weighed, washed, soaked in water, dehulled manually and dried (60^{o}C) in an oven. The dried seeds were milled in a hammer mill (model ED-5 Thomas Wiley, England) and sieved with 500µm mesh size. Parts of the maize flour were substituted with 20, 30 and 40% AYBSF by weight. Each blend was properly mixed thoroughly using a Kenwood mixer (OWHM, England) for 3 min to obtain homogenous samples and packaged separately in high density (100 µm) polyethylene bags and airtight plastic containers prior to further processing.

Kokoro was prepared by using the method of Uzo-Peters *et al.* (2008) with slight modifications. The Maize- AYBS flour blends were divided into two equal parts. The first half was mixed with measured quantity of salt and onions while the second half was mixed in hot water to make a paste. The two halves were pre-gelatinized together by continuous stirring for about 3 min to form homogenous dough. The dough was allowed to cool to a temperature of 40^{o}C and kneaded on a chopping board. The kneaded dough was cold extruded into uniform sizes and deep-fried in hot oil (specific gravity 0.918) at temperature 150°C, 160°C and 170°C for 8, 10 and 12 min as reported in our previous work (Idowu and Aworh, 2014). The fried snacks were drained, left to cool and packaged in polyethylene bags (100µm) and stored at ambient conditions (Temperature-24±3oC, 61±3 % Relative humidity).

Deep fat frying operation of the snacks

A deep fat fryer (Model S-516, Hong Kong, China) with temperature control of ±1°C was used. The fryer holds 2.5 L of oil and it is equipped with a 2 kW electric heater. Isothermal conditions were observed during frying by keeping the snacks-to-oil weight ratio as low as possible (~0.0035) (Pedreschi *et al*., 2005) (Krokida *et al*., 2001) and the frying temperature monitored using a digital thermometer. After each frying test, the oil level was checked and replenished with oil; and changed after every 2h of frying (Blumenthal, 1991).

Analysis of quality parameters

Crude protein content, color and overall acceptability were analyzed as quality parameters of the snacks, using the procedures discussed below.

Determination of Crude protein content of samples

The kokoro snacks were grounded with porcelain mortar and pestle after drying the samples in the oven for about 2h after each frying operation. Crude protein was determined using Kjeldahl method, (AACC, 2005) method 46-12.01.

Determination of Color parameters

Color parameters (L^*, a^* and b^*) were measured using a color meter (ColorTec-PCM TM, Omega Engineering Inc. Stanford, CT). The instrument was standardized each time with a white and a black ceramics plate. Samples scanned at five different locations to determine the L^*, a^* and b^* values as the average of five determinations (Lui-Ping *et al*., 2005).

Determination of Overall acceptability

The overall acceptability of the product was determined using Hedonic scale ranking of sensory analysis. A ten-member semi-trained panel on a nine point Hedonic scale ranking 1 for ‘dislike extremely’ and 9 for ‘like extremely’ (Iwe, 2002) was used. The average values of the sensory attributes were computed and analyzed statistically at p=0.05.

Statistical analysis

A second order polynomial equation was used to fit the experimental data given in Table 1. It could be fitted to the following equation:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{23}X_2X_3 \quad \ldots\ldots 1.$$

Where Y is predicted responses for protein content (Y1), overall acceptability (Y_2), lightness, l^* (Y_3), redness, a^*(Y_4) and yellowness, b^* (Y_5). X_1 - X_3 are coded independent variables and β_0, β_1- β_3, β_{11}- β_{33} and β_{12}- β_{23} are the equation regression coefficients for intercept, linear, quadratic and interaction effects respectively (Garayo and Moreira, 2002).

Optimization and validation

In order to optimize the processing variables during the frying process whilst retaining high quality kokoro snack, the protein content and overall acceptability were maximized, redness was minimized while lightness and yellowness were kept at a recommended acceptable range (Sobukola *et al*., 2008). Then the coefficients of determination, R^2 were fitted into the regression Equation 1. Optimum conditions of process variables for kokoro preparation was obtained using computer software package (design expert version 6.0.6 Stat. Ease Minneapolis, USA). The suitability of the model developed for predicting the optimum response was tested by comparing the experimental and predicted values obtained. Standard deviations were calculated for each of the parameters.

Results and Discussion

Effect of process variables of kokoro on its quality

The obtained empirical data was used to predict the effect of the process variables (frying temperature, frying time and quantity of AYBSF in the flour blend) on protein content, overall acceptability and color parameters (L^*, a^* and b^*) of kokoro. Based on the lack of fit test and coefficient of determination, R^2, quadratic model was appropriate for lightness (L^*), yellowness (b^*), protein content and overall acceptability while linear model was appropriate for redness (a^*). This is similar to the result obtained for optimization of fried yam chips (Sobukola *et al*., 2008).

Effect of frying temperature and quantity of African yam bean in the flour blend on protein content of kokoro

Frying temperature is one of the factors

Table 1. Process variables and quality parameters (responses) for preparation of kokoro

Process variables			Responses				
Frying temperature (°C)	Frying time (min)	Quantity of AYBSF (%)	Protein content (%)	Overall acceptability	Lightness	redness	Yellowness
150 (-1)	8(-1)	30(0)	9.94	6.60	46.20	11.00	8.20
150 (-1)	12(+1)	30(0)	9.55	7.10	43.80	9.79	32.27
160 (0)	10(0)	30(0)	9.98	7.60	44.53	12.49	32.38
150 (-1)	10(0)	40(+1)	10.83	7.30	45.18	12.71	32.73
160 (0)	8(-1)	40(+1)	11.00	6.40	43.69	10.79	28.46
170 (+1)	10(0)	40(+1)	9.81	6.20	41.44	11.06	24.70
170 (+1)	10(0)	20(-1)	8.54	7.50	42.90	12.08	28.42
160(0)	12(+1)	20(-1)	8.39	7.50	45.33	12.00	32.80
160(0)	8(-1)	20(-1)	8.48	6.90	45.96	13.38	33.74
160(0)	10(0)	30(0)	9.98	7.60	44.53	12.49	32.38
160(0)	10(0)	30(0)	9.98	7.60	44.53	12.49	32.38
160(0)	10(0)	30(0)	9.98	7.60	44.53	12.49	32.38
160(0)	12(+1)	40(+1)	10.72	7.20	45.18	12.71	32.73
170(+1)	12(+1)	30(0)	9.67	7.50	46.84	13.44	32.14
150(-1)	10(0)	20(-1)	8.99	7.30	44.36	14.33	31.87
170(+1)	8(-1)	30(0)	9.30	6.90	47.76	13.53	34.69
160(0)	10(0)	30(0)	9.98	7.60	44.53	12.49	32.38

influencing the quality of fried product (Bilbech *et al.*, 2013). Figure 1 represents the effect of frying temperature and quantity of AYBSF inclusion in the flour blend on the protein content [at fixed frying time (X_2=0)]. The protein content obtained increased as the quantity of AYBSF increased in the maize-AYBS flour blend. Higher protein content was obtained for the snack (kokoro) fried at 150°C and 160°C. However, the protein content reduced slightly as the frying temperature increased to 170°C. Frying the maize snack at a lower temperature for longer frying time was found to retain the protein content better.

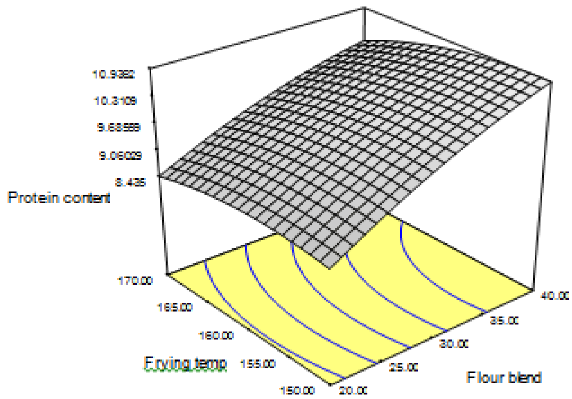

Figure 1. Surface plot of protein content of kokoro

Effect of frying temperature and quantity of African yam bean seed in the flour blend on overall acceptability

Figure 2 represents the effect of frying temperature and quantity of AYBSF inclusion in the flour blend on overall acceptability [at fixed frying time (X_2=0)]. At 20% AYBSF, maize snacks fried at 150°C showed lower overall acceptability although the overall acceptability was not significantly (p>0.05) affected by increase in temperature. At 30% AYBSF inclusion in the maize-AYBS flour blend, samples fried at frying temperature 160°C showed the peak overall acceptability. At 40% AYBSF inclusion in the flour blend, the overall acceptability reduced with increase in temperature. Therefore, similar to what was reported in Figure 2, a frying temperature around 160°C will be more appropriate to obtain better overall acceptability. This is consistent with the report on optimization of process variables for the preparation of expanded finger millet using response surface methodology (Ushakumari *et al.*, 2007)

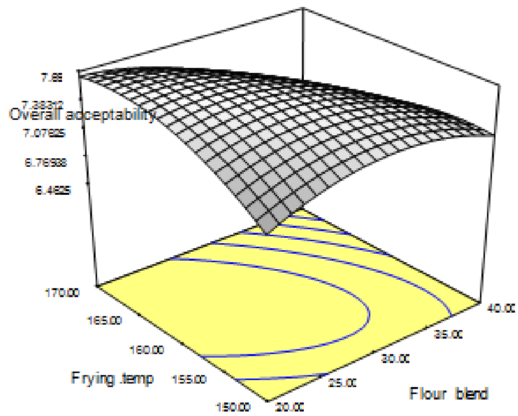

Figure 2. Surface plot of overall acceptability of kokoro

Effect of frying temperature and quantity of African yam bean in the flour blend on color parameters (l^*, a^* and b^*)

Figure 3 represents the effect of frying temperature and quantity of AYBSF inclusion in the snacks on color parameters [(lightness (^{L*}), redness (a^*) and yellowness (b^*)] respectively. Statistical analysis with response surface regression showed

Table 2. Regression coefficients for process variables

Coefficients	Protein content	Overall acceptability	lightness	redness	yellowness
β	-46.77	-80.23	15664.6	-94.92	48618.87
β_1	0.68	0.88	327.55	5.78	1043.43
β_2	-0.81	1.51	-528.88	52.69	-4652.88
β_3	0.47	0.63	-219.44	-3.86	-406.29
β_{11}	-0.02	-0.025	-1.18		-4.69
β_{22}	-0.03	-0.08	-17.81		-104.31
β_{33}	-0.002	-0.027	0.93		3.06
β_{12}	9.43	1.25	3.98		41.04
β_{13}	-0.014	-0.032	0.41		0.46
β_{23}	-0.024	2.5	8.43		11.96
R^2	0.9478	0.8895	0.7584	0.6339	0.8706
p-value	0.001	0.0122	0.1262	0.0037	0.0201

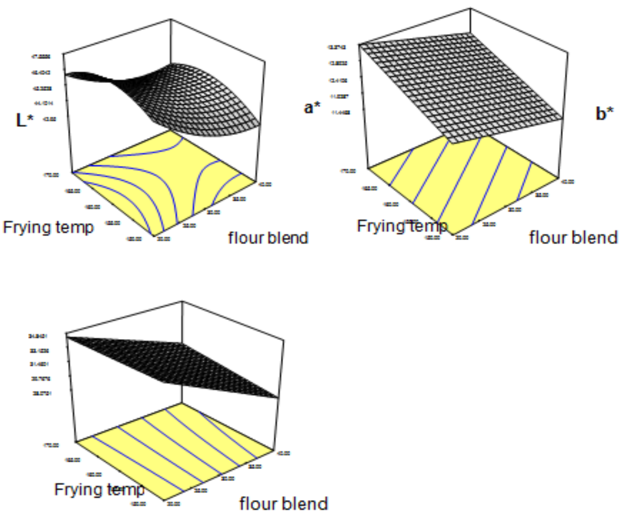

Figure 3. Surface plots for colour parameters {lightness (L^*), redness (a^*) and yellowness (b^*)} of the snack

that color parameter (a^* and b^*) were significantly correlated with frying temperature, frying time and quantity of AYBSF in the maize-AYBS flour blend. But color parameter, L^* did not show significant ($p>0.05$) correlation. This is contrary to the result for fried yam chips that color parameters (L^* and a^*) were significantly ($p<0.05$) correlated with frying temperature, initial dry matter and frying time of yam chips, but the b^* (yellowness) was not significantly ($p>0.05$) correlated (Sobukola *et al.*, 2008)

Color is an important parameter to be considered during processing to obtain high quality food products. It plays significant role in its appearance and consumers' acceptability. Color of fried products could be as a result of the maillard reaction which depends on the content of the food products such as starch, reducing sugar, amino acids or proteins at the food surface as well as the temperature and time of frying (Marquez and Anon, 1986).

From Table 2, the color parameter L^* (lightness, Y_3) of the maize snack showed significant ($p<0.05$) relationship between the processing variables (X_1, X_2 and X_3) as well as their second order derivatives (X_1^2, X_2^2 and X_3^2) and their interaction X_1X_2, X_1X_3 and X_2X_3 because of the quadratic model appropriate for it. As shown in Table 2, linear model was appropriate for color parameter, a^*. Color parameter, a^* showed relationship with the processing variables (X_1, X_2 and X_3) alone, but it neither showed relationship with its second order derivatives nor the interactions between them. Redness (a^*, Y_4) parameter was therefore significantly ($p<0.05$) affected by X_1, X_2, X_3 and was observed to increase with increase in the temperature and time of frying. While the b^* (yellowness, Y_5) parameter showed significant ($p<0.05$) relationship between the processing variables (X_1, X_2 and X_3), their second order derivatives (X_1^2, X_2^2 and X_3^2) and the interaction between them, X_1X_2, X_1X_3, X_2X_3 since the quadratic model was appropriate for it. This color parameter b^* (yellowness) was significantly ($p<0.05$) affected by X_1, X_2 and X_3. An increase in temperature and time of frying resulted in increase in yellowness.

For an acceptable maize snack in terms of color, it must be lighter, yellowish and not dark (red). From the surface plots in Fig. 3, when the frying time (X^2) was fixed at 11.5 min using 30% AYBSF in the flour blend, it was observed that L^* (Y_4) decreased while a^* (Y_5) and b^* (Y_6) increased with increase in frying temperature. When the product was fried at frying time less than 11.5min and a frying temperature above 160°C, it gave a decreasing value of L^* (Y_4) but increasing values of a^* (Y5) and b^* (Y6). However, when the product was fried at the frying temperature 155°C and frying time, 11.5min using 30% AYBSF, lower values of L^*, a^* and b^* were observed. The maize snack tends to get darker (more red) as the frying proceeds due to surface non enzymatic browning reactions as shown by progressive increase in redness values with time. The higher the temperature the darker the product becomes since non enzymatic browning reactions are highly temperature-dependent. Hence, to obtain product of acceptable color parameters (higher L^* and

b^* but lower a^*), a frying temperature of between 155 and 160°C, using 30% AYBSF and frying time of about 11.5 min will be appropriate.

Optimum parameters

The computer software package (Design expert version 6.0.6, Stat. Ease Minneapolis, USA) used for optimization gave an optimum frying temperature of 155°C, frying time of 11.5 min and 30% AYBSF in the maize-AYB flour blend, with desirability of 0.75. Table 1 shows the results of response surface analysis of the dependent variables (responses) with independent variables. The regression coefficient and analysis of variance of the fried maize snack are given in Table 2. Based on lack of fit test and coefficient of determination R^2, quadratic model was appropriate for protein content (Y_1), overall acceptability (Y_2), lightness (Y_3), yellowness (Y_5) while linear model was appropriate for the color parameter, redness (Y_4).

Validation of results

The standard error obtained ranged between 10-13% for all the parameters. The frying temperature of about 155°C, frying time of about 11.5min and 30% AYBSF in the maize-AYBS flour blend could be considered as optimum as well as feasible condition for the variables studied to prepare kokoro of suitable quality characteristics.

Conclusion

Results obtained from this study showed that processing variables: frying temperature, frying time and quantity of AYBSF substitution in the flour blend has significant effect on the protein content, overall acceptability and color parameters of kokoro. Using the protein content, overall acceptability and color parameters as indicators of quality of fried maize snacks (kokoro), optimum frying conditions of 155°C, 11.5min and 30% AYBSF were recommended for frying temperature, frying time and quantity of AYBSF in the flour blend respectively. The study showed that addition of African yam bean seed improved the protein content of kokoro. It is expected that the optimum processing condition highlighted in this work will be useful for obtaining kokoro of acceptable quality attributes. This could be also a prospect to commercial producers of the snack.

Commercial production of the snack will help in reduction of protein-energy malnutrition, being widely consumed by adults and children. This will provide an avenue for greater utilization of African yam bean thereby encouraging more cultivation of the crop.

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