Optimizationof some processing conditions for *Kokoro* production using Response Surface Methodology

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Abstract: Deep fat frying of *kokoro* was investigated with the aim of upgrading the traditional production process by optimizing the processing conditions and improving its nutritional value by incorporation of African yam bean (AYB), an underutilized crop with high nutritional value. The effect of frying temperature, frying time and quantity of AYB flour on moisture, oil contents and crispness of the *kokoro* was evaluated by Box Behnken experimental design of Response Surface Methodology. Optimization was achieved by maximizing crispness and minimizing moisture and oil contents. Statistical analysis with response regression showed that breaking force, oil and moisture contents were significantly (p<0.05) correlated with frying temperature and time. During frying, temperature and time of frying have a significant effect on the moisture loss and fat content. The optimum conditions were frying temperature of 155°C, frying time of 11.5 min using 30% AYB flour inclusion in the flour blend. At these conditions, the moisture content was 2%, fat content was 30% and breaking force (a measure of crispness) of the product was 4.5 kg.

Keywords: maize, African yam bean, response surface methodology, deep fat frying, optimum processing condition; *kokoro*, Nigeria

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1 Introduction

Popularity of traditional maize snacks in Nigeria necessitates the need for study to improve their quality. Some of these traditional maize snacks include; *aadun* (maize pudding), *kokoro* (corn cake), *donkwa* (maize-peanut ball). Improving these snacks involves understanding and optimization of the production processes. Maize (*Zea mays* L.) is the third most important cereal in the world after rice and wheat and ranks fourth after millet, sorghum and rice in Nigeria (FAO, 2009). Global statistics for cereal consumption indicate that the average total consumption in the African diet is 291.7 g per person per day, including an average maize consumption of 106.2 g per person per day (FAO, 2009). Maize is an excellent source of energy (rich in carbohydrate, fat and fibre) for people in the tropics but low in protein. The need to enrich maize-based snacks with inexpensive quality protein therefore cannot be overemphasized.

African yam bean (AYB) (*Sphenostylis stenocarpa*) is one of the less utilized legumes that are gradually going into extinction (Klu et al., 2001); it is nutrient-dense but classified as neglected underutilized species (NUS) legume (Adewale, 2010). Its utilization varies from cooked beans to fermented sauce (Arisa and Ogbuele, 2007). AYB has attracted research interest because of their nutrient content. Amino acid profile show that most essential amino acids of AYB particularly lysine, methionine, histidine and isoleucine is higher than that of

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soybean and other tropical legumes.AYB is rich in P, Ca, Mg, K, Fe, Zn but low in Cu and Na (Ekpo, 2006). Therefore incorporating AYB into maize snack will improve the snack nutritionally.

In Nigeria, as in most developing countries, there are many food items prepared traditionally by immersion frying but information about process variables, product properties and optimal processing conditions are difficult to find in literature (Sobukola et al., 2008). The application of frying has been studied for other cereal food products like popped rice (Samatcha et al., 2009) but very scare publication on frying behavior of *kokoro*. *Kokoro* is a maize-based traditional snack commonly consumed in Southern parts of Nigeria. Studies have been done to improve the nutritional contents of *kokoro* using groundnut, soybean(Uzo-Peters et al., 2008), but literature is sparse on upgrading its nutritional quality using AYB and optimization of the processing conditions.

Deep fat frying is an established process of food preparation worldwide. It is a simultaneous heat and mass transfer process where moisture leaves the food in form of vapor bubbles, while oil is absorbed simultaneously (Lui-Ping et al., 2005). It is often selected as a method of choice for creating unique flavors and texture in processed foods (Patterson et al., 2004) and results in modification of physical, chemical and sensory characteristics of the food.

Optimization is a method used to improve the performance of a system and to increase yield without increasing the cost. An important technique in optimization process is Response Surface Methodology (RSM). RSM is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes in which a response of interest is influenced by several variables and the objective is to optimize the process (Garayo and Moreira, 2002). RSM has important application in the design, development and formulation of new products, as well as in the improvement of existing product design. The experimental methodology generates a mathematical model that describes the process. It is therefore important to find an appropriate processing condition for production of maize snacks with improved quality attributes. Studies have shown temperature and frying time as major variables controlling deep fat frying operation (Akinoso et al., 2011;Sobukola et al., 2008; Sulaeman et al., 2001). Understanding and optimization of frying process as well as incorporating a nutrient-dense material like AYB is expected to improve the quality of the traditional snack.

The objective of this work therefore was to optimize the processing condition of *kokoro* and to investigate the effect of frying temperature, frying time and % AYB flour incorporation on the moisture content, oil content and textural quality of maize snack using RSM.

2 Materials and methods

The maize cultivar used (BR-9928-DMR-SY) were obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Oyo state, Nigeria. While the African yam bean seeds (*Sphenostylis sternocarpa*) (Tss 30) were purchased from a local market (Umuaiha) in Abia state, Nigeria and classified at the IITA genetic resource centre as variety, Tss-30. Refined vegetable oil, salt, and onions were obtained from a retail market (Bodija), Ibadan, Oyo State. The African yam bean seeds were sorted, weighed, washed, soaked, dehulled manually and dried (60^{o}C) in an oven. The seeds were milled using hammer mill (model ED-5 Thomas Wiley, England) and sieved with 500 μm mesh sieve. The maize samples were also sorted and milled using 750 μm mesh size. Parts of the maize flour (MF) were substituted with 20%, 30% and 40% African yam bean flour (AYBF) by weights. Each blend was separately mixed in a Philip blender (HR2611 model) for three minutes at high speed. The various blends were packed separately in 100 μm polythene bags and kept in airtight plastic containers till needed.

2.1 Experimental design

Three independent variables: frying temperature (X_1), frying time (X_2) and %AYB flour in the flour blend (X_3) were studied. And three response variables (moisture, oil contents and crispness of the snack) were measured for optimization of the process. A Box Behnken design was adopted (Montgomery, 2005). Using the plan provided for three variable cases, seventeen experimental runs were carried out with four replications. Three levels of each of the three independent variables were chosen for the study based on preliminary experiments. The three levels of each of these independent variables were: frying temperature (X_1) of 150, 160 and 170°C (-1, 0, 1); frying time (X_2) of 8, 10 and 12 min (-1, 0, 1), and % AYB flour in the flour blend (X_3) of 20%, 30% and 40%. The coded and the actual values for the independent variables are shown in Table 1.

Table 1 Design matrix

Exp. runs	Coded variables			Actual variables	Values	Responses
	X_1	X_2	X_3	X_1/°C	X_2/min	X_3/%
1	-1	-1	0	150	8	30
2	-1	1	0	150	12	30
3	0	0	0	160	10	30
4	-1	0	1	150	10	40
5	0	-1	1	160	8	40
6	1	0	1	170	10	40
7	1	0	-1	170	10	20
8	0	1	-1	160	12	20
9	0	-1	-1	160	8	20
10	0	0	0	160	10	30
11	0	0	0	160	10	30
12	0	0	0	160	10	30
13	0	1	1	160	12	40
14	1	1	0	170	12	30
15	-1	0	-1	150	10	20
16	1	-1	0	170	8	30
17	0	0	0	160	10	30

2.2 Preparation of maize snacks

Maize snacks (*kokoro*) were produced as described by Uzo-Peters et al. (2008) with a slight modification in the recipe used as onion and salt were used in place of sugar and salt.

Half of each blend was mixed and stirred in boiled water to make a paste and the remaining half was mixed with salt and onion and then added to the paste with continuous stirring for about 3 min to form homogenous dough. The dough was allowed to cool to a temperature of 40°C and kneaded by hand on a chopping board. The kneaded dough was cold extruded into uniform sizes using a locally fabricated extruder and deep-fried in hot vegetable oil, (specific gravity 0.918) at temperatures 150°C, 160°C and 170°C for 8, 10 and 12 min, as indicated in the design matrix (Table1). The maize snacks were left to cool, then packed in polythene bags (100µm) and stored at ambient conditions (24.2±3°C, 61±3% relative humidity).

2.3 Frying of maize 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 is equipped with a 2 kW electric heater. Isothermal conditions was observed during frying by keeping the maize snacks-to-oil weight ratio as low as possible (~0.0035) (Krokida et al., 2001; Pedreschi et al., 2005) and the frying temperature monitored using a digital thermometer. After each frying test, the oil level was checked and replenished; the oil was changed after about 2 h of frying (Blumenthal, 1991). The samples were fried for 0, 2, 4, 6, 8, 10 and 12 min for each set of experiment to determine the amount of moisture and oil contents in snacks as a function of frying time. The experiments were carried out in triplicate hence results presented are the mean values.

2.4 Analytical procedures

2.4.1 Moisture content

Moisture content of the samples was determined using standard gravimetric method (Equation (1)). About 3 g of sample was weighed into a pre-weighed clean dried dish, after which the dish was placed in a well-ventilated oven (draft air Fisher Scientific Isotemp R Oven model 655F) maintained at 103 ± 2°C for 24 h. The lost in weight was recorded as moisture (AOAC, 2005).

$$\%\text{ Moisture content} = \frac{M_1 - M_2}{M_1 - M_0} \times 100\% \quad (1)$$

where, Mo = Weight in g of dish; M_1 = Weight in g of dish and sample before drying; M_2 = Weight in g of dish and sample after drying. Note that $M_1 - M_0$ = weight of sample prepared for drying

2.4.2 Oil content

Oil content of the sample was determined using the method of AOAC (2005). The fried samples were grounded in porcelain mortar and pestle after drying the samples in an oven (draft air Fisher Scientific Isotemp R Oven model 655F) at temperature of 60± 2°C for about 2 h after each frying experiment. Crude fat was extracted from 3 g of the sample with hexane using a fat extractor (Soxtec System HT2 fat extractor), and the solvent evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content. The oil content of the sample was represented by the crude fat content obtained (Equation (2)).

$$\% \text{ Fat} = \frac{(\text{Wt of flask+fat})\text{-}(\text{Wt of sample after drying})}{\text{Wt. of sample}} \times 100 \quad (2)$$

2.4.3 Crispness

A texture analyzer was used to determine the breaking force of the samples. Each sample was placed over the end of a hollow cylinder. A stainless steel ball probe (P/0.25 s) moving at a speed of 2.5 mm min^{-1} was used to break the maize snack. All numerical results were expressed in km.

2.5 Statistical analysis

Response surfaces are represented mathematically by second order polynomial equation. For three variables, the Equation (3) is;

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{23}X_2X_3 \quad (3)$$

where, Y is predicted responses for moisture content (Y_1), oil content (Y_2) and crispness (Y_3). $X_1 - X_3$ are coded independent variables and β_0, $\beta_1 - \beta_3$, $\beta_{11} - \beta_{33}$ and $\beta_{12} - \beta_{23}$ are the equation regression coefficients for intercept, linear, quadratic and interaction effects respectively. The polynomial equations were fitted to the data to obtain regression equations (Equation (3)). The significance of the equation parameters for each dependent variable was assessed by F-test. The analysis was carried out using Statistical Analysis System (SAS version 9.2; SAS Institute Inc., Cary, NC). Data were analyzed at p=0.05.

2.6 Optimization and validation

The optimization of this study was carried out by minimizing the moisture and oil contents, and maximizing crispness. Then the coefficients of determination, R^2 were fitted into the regression equation shown in Equation (3). Optimum conditions for *kokoro* preparation was obtained using computer software package (Design expert version 6.0.6 Stat. Ease Minneapolis, USA). The suitability of the model used for predicting the optimum conditions for *kokoro* production was tested by comparing the experimental and predicted values obtained. Standard errors were calculated for each of the parameters.

3 Results and discussions

3.1 Effect of frying time on the moisture loss and fat contents of the maize-based snack

Figure 1 and Figure 2 show the influence of frying time on the moisture contents and fat contents of the maize-based snack respectively during deep fat frying. The moisture loss during the frying experiments exhibited a classical drying profile, which usually has three distinct periods. The first is the heat-up period during which the wet solid material absorbs heat from the surrounding media. The product was then heated up from its initial temperature (room temperature of about 27-30°C) to a temperature (boiling point of water about 100°C) where moisture begins to evaporate from the food (Garayo and Moreira, 2002). This period was observed to be short as is shown in Figure 1. This is because the process occurs at an extremely fast pace due to high specific heat of water. During the heat-up period, once the water inside the product reaches its boiling point, it vaporizes. When the pores are filled with gaseous vapor, the temperature and the pressure increases at a fast rate due to high temperature differential with the oil. The capillary pressure was negligible during this period hence no driving force for the oil to flow into the pores of the maize snack. Moisture loss was found to increase as the temperature increased from 150°C to 170°C with an earlier rapid fall when the products were fried at higher temperatures of 150°C to 170°C. The constant rate period (second stage of drying) was not observed distinctly in this work. This period is where the rate of moisture loss is limited by the rate at which heat is transferred from the frying medium to the product. During the falling rate period, the rate of moisture loss from the interior of the food to the surface falls below the rate at which water evaporates to the surrounding air. The surface therefore dries out.

From Figure 1, it is obvious that the moisture loss during the frying of the maize-AYB snack was similar to the falling rate period of drying (Lui-Ping et al., 2005), (Garayo and Moreira, 2002). The moisture content of the maize snack was still about 10% after frying for 6 min, the rate of drying decreased slowly after frying for 8 min.

The moisture content of the snack decreased to below 2% after frying for 10 min and thereafter decreased slightly. The moisture content reduces with higher frying temperature and higher frying time. During deep fat frying, little expansion may be produced by the superheated vapor trying to escape the pore space (as the water is heated, then vapor expands), this expansion happens when the product is immersed in the oil. As it is heated, starch gelatinizes, producing a barrier for the saturated vapor to escape (Kawas and Moreira, 2001). An increase in oil temperature decreased the frying time of the snacks, thereby improving the rate of drying. Frying time significantly affected (p<0.05) the moisture content; the higher the temperature, the lower the moisture content. This result is in agreement with the work of Lui-Ping et al. (2005) who reported that the higher the temperature, the lower the moisture content during vacuum frying of carrot chips.

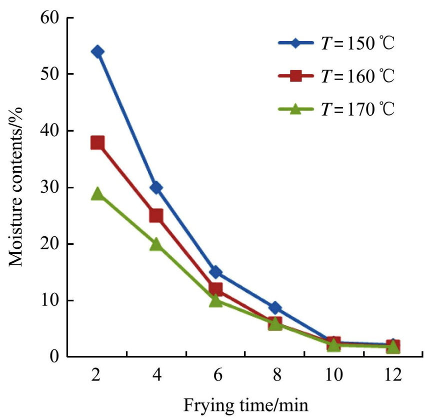

Figure1 Effect of frying temperature on rate of moisture loss of AYB-maize snack during deep fat frying

Figure 2 shows fat contents of the maize snack during deep frying at 160°C. The fat contents of the snack increased with the increasing temperature and time. This increase in fat content coincided with the period of moisture evaporation from the maize snack. The fat content appears to be related to moisture content. The changes in the water and fat contents are in agreement with the works of Rice and Gamble (1989) and Krokida and Orepoulou (2000). When the snacks were placed in hot oil, the free water was rapidly lost in form of bubbles. As frying continued, the outer surface dried out, improving its hydrophobicity and some oil were adhered to the surface. When the products were removed from the fryer, the vapor inside the pores condensed and the differences in pressure between the surrounding tissue and the pore caused the oil adhering to the surface to be absorbed into the pore space. This result is similar to the report of Awoyale et al. (2011) who reported that fat content of maize snack supplemented with distillers' spent grain increased at higher frying temperature.

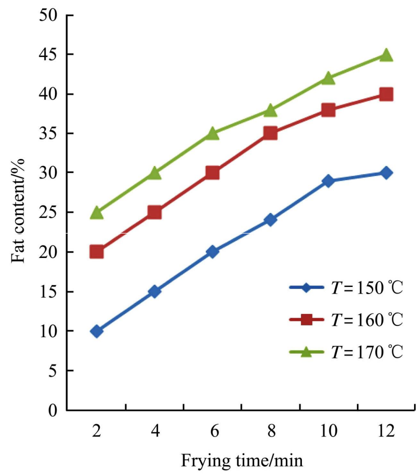

Figure 2 Effect of frying temperature on fat content of AYB-maize snack during deep fat frying

The curves showing the effect of frying temperature on fat content of AYB-maize snack during deep fat frying in Figure 2 may be of interest to the manufacturers of the maize snack who want to know if the actual oil content of the final product may be controlled through selection of appropriate processing conditions. Too much oil in the product may be costly to the manufacturers and may also contribute to some coronary heart diseases for the consumers (Singh, 2000). From the curves, it was shown that samples fried at higher frying temperature had higher fat content compared to those fried at lower temperature at the same frying time. This implies that with close interaction with temperature and time of frying, optimum processing conditions for lower fat content can be attained.

3.2 Response surface analysis of variables and responses

Table 2 showed the results of response surface analysis of the variation of moisture content (Y_1), fat content (Y_2), and texture (Y_3) with frying temperature, frying time and % African yam bean flour (AYBF) in the maize-AYB flour blend using the design matrix of Table 1.

Table 2 Process variables and values of quality parameters (responses) for production of *kokoro*

Process variables			Responses		
Frying temperature/°C	Frying time/min	Quantity of AYBSF/%	Moisture content/%	Fat content/%	Breaking force/kg
150 (-1)	8(-1)	30(0)	2.69	31.04	1.50
150 (-1)	12(+1)	30(0)	1.99	27.61	2.10
160 (0)	10(0)	30(0)	1.76	34.01	1.80
150 (-1)	10(0)	40(+1)	2.32	35.01	2.10
160 (0)	8(-1)	40(+1)	2.42	30.94	1.80
170 (+1)	10(0)	40(+1)	1.97	29.58	1.30
170 (+1)	10(0)	20(-1)	2.13	34.25	1.90
160(0)	12(+1)	20(-1)	1.84	31.04	1.50
160(0)	8(-1)	20(-1)	2.42	31.53	1.80
160(0)	10(0)	30(0)	1.76	34.01	1.80
160(0)	10(0)	30(0)	1.76	34.01	1.80
160(0)	10(0)	30(0)	1.76	34.01	1.80
160(0)	12(+1)	40(+1)	1.78	32.71	1.55
170(+1)	12(+1)	30(0)	1.72	29.96	1.50
150(-1)	10(0)	20(-1)	1.40	27.35	2.45
170(+1)	8(-1)	30(0)	2.11	33.33	1.45
160(0)	10(0)	30(0)	1.76	34.01	1.80

Table 3 showed the coefficient of regression of the developed model obtained from Equation (3). The high coefficients of determination; R^2 indicates that the variables were adequately fitted to the regression equation shown in Equation (3) above.

3.3 Moisture content and fat content

The moisture content (Y_1) of the snack was significantly (P<0.05) affected by X_1, X_2, X_3 and X_2X_2 and the fat content (Y_2) was significantly (P<0.05) affected by X_1, X_2, X_3 and X_3X_3 (Table 3). The moisture content (Y_1) of the snack decreased with increasing temperature (X_1) and time (X_2) of frying and decreasing % AYB flour in the flour blend (X_3) (Figure 3). The fat content increased with the increasing temperature and time of frying and decreasing % AYB flour in the flour blend (Figure 4). Acceptable fried snack in terms of sensory attributes and storage stability should contain <3% moisture content and <35% oil content (Krokida et al., 2001); (Garayo and Moreira, 2002). As is shown in the contour plots (Figure 4), when X_3 was fixed at 30% (X_3=0), the moisture content of the snack decreased below 3% and the fat content was below 35% for a frying temperature of 155-160°C and 11.55 min. For a frying temperature of below 155°C and frying time <11.55 min, the moisture content was above 3%. However, the fat content was above 35% when the frying temperature was above 160°C and the frying time above 11.55 min. Obviously, to attain the high quality snack in terms of lower moisture content (<3%) and lower fat content (<35%), frying temperature of between 155-160°C, frying time of about 11.5 min and 30% AYB flour in the flour blend will be appropriate.

Table 3 Coefficients of regression of developed model

Coefficients	Y_1	Y_2	Y_3
B_0	1.81	34.01	210.71
β_1	-0.38*	0.79**	-167.21*
β_2	-0.16**	9.64*	-182.51**
β_3	0.41	3.22*	-151.72
β_{11}	1.4	1.33	42.41
β_{22}	0.75*	-0.35	14.21**
β_{33}	0.53	-1.15	130.22
β_{12}	0.43	-0.09	159.17
β_{13}	-0.65	-0.01	22.06
β_{23}	0.12	0.28	55.17
R^2	0.957	0.891	0.861

Note: *P<0.05, **P<0.01.

Where, Y_1 = moisture loss, Y_2 = oil content and Y_3 = breaking force.

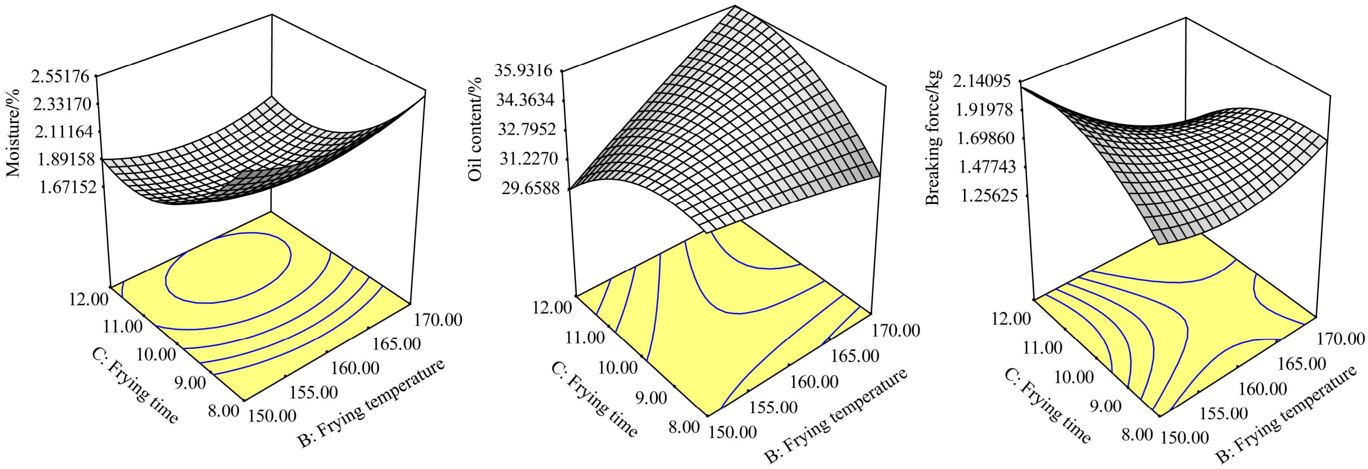

Figure 3 The surface plot for moisture, oil content, breaking force of deep fried maize snack as affected by frying temperature and frying time

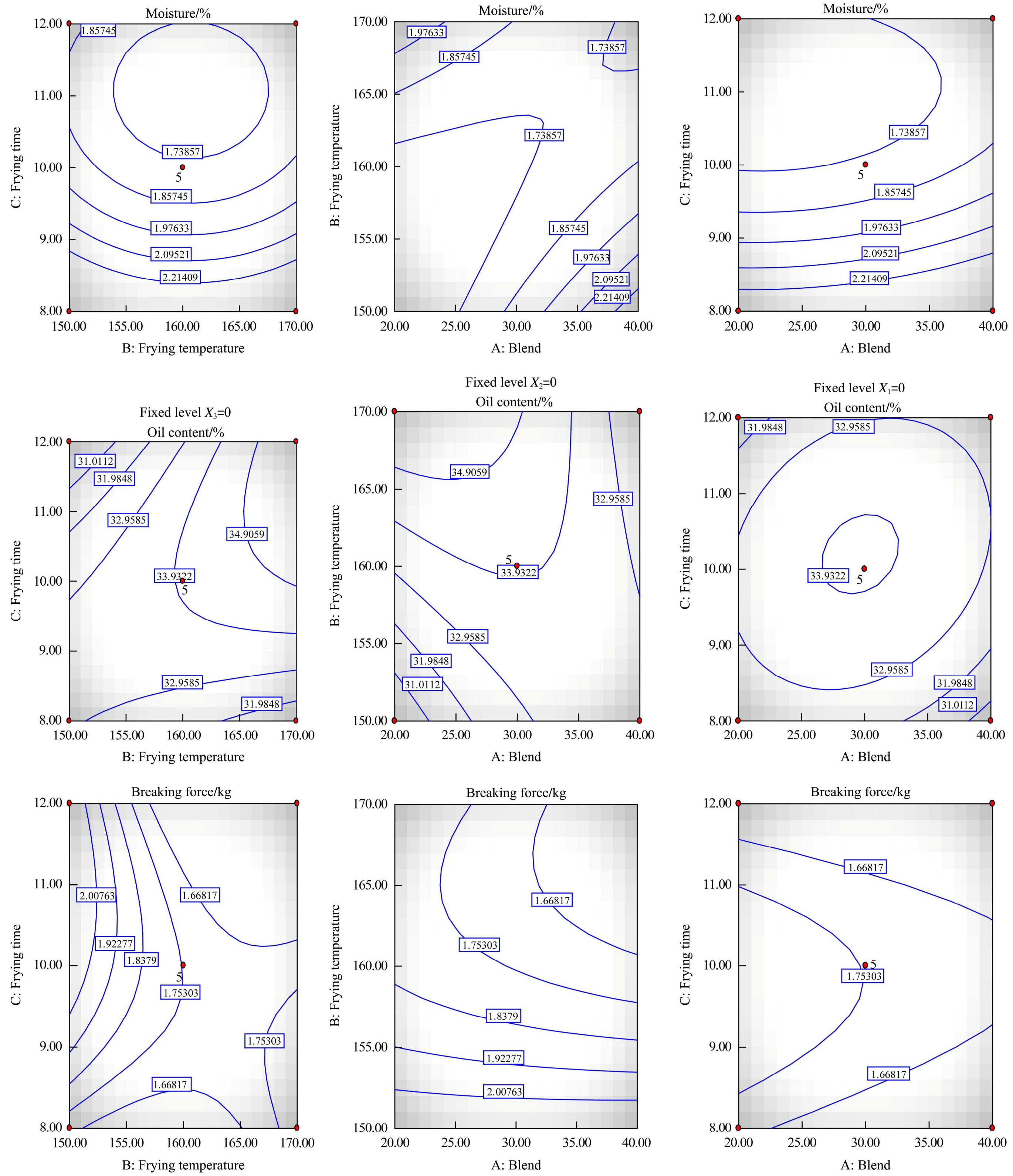

Figure 4 The contour plot for moisture, oil content, breaking force of deep fried maize snack as affected by frying temperature (X) and frying time (X_2) at fixed levels (X_3=0)

3.4 Crispness

Deep fat frying is similar to dehydration process in that water is lost from the product resulting in textural changes of the product. The textural property may reflect the crispness of the maize snack. The breaking force (kg) has been reported to be an indicator of crispness of fried product, with lower breaking force corresponding to higher crispness and hence increased acceptability. As is shown in Table 3, the breaking force was significantly (P<0.05) affected by X_1, X_2, X_3 and X_2X_2. The breaking force was reduced to below 2.0 kg when the frying temperature was above 155°C, 30% AYB flour in the flour blend and frying time was about 11.5 min (Figure 4). The contour plots showed that the breaking force decreased with the decreasing moisture content. When the moisture content was below 2%, its breaking force was reduced to below 2.0 kg.

3.5 Optimisation of parameters

The optimum conditions obtained was a frying temperature of 155°C, frying time 11.5 min and 30% AYB flour inclusion in the flour blend, having a desirability of 0.75.

3.6 Validation of results

The standard error obtained ranged between 10%-13% for all the parameters. Therefore, to produce *kokoro* of suitable quality characteristics, frying temperature of 155°C and frying time of 11.5 min and 30% AYB flour in the flour blend could be considered as optimum conditions. At these conditions, the moisture content was 2%, fat content was 30% and breaking force (a measure of crispness) of the product was 4.5 kg.

4 Conclusions

Deep fat frying was observed to be a similar process to hot air dehydration in which the rate of moisture loss was significantly affected by frying temperature and frying time. The fat content was significantly affected by frying temperature, frying time and to an extent % AYB flour in the flour blend used to prepare the product. The study revealed that with the increasing frying temperature and frying time, moisture content and breaking force decreased while oil content increased. Using the breaking force (crispness), oil content and moisture content as indicators of the maize snacks' quality, the optimum frying condition were a frying temperature of 155-160°C, using about 30% AYB in the flour blend and a frying time of about 11.5 min.

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