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Effect of processing conditions on some quality attributes of fried cassava-defatted peanut crackers

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ABSTRACT

A 2^3 full factorial design was used to investigate the effect of steaming time, dough slice thickness and frying time on some quality attributes of fried cassava-defatted peanut crackers. The sample mixture (cassava starch-75% and defatted peanut flour-25%) was worked up to a moisture content of 40.85%, formed into a sausage-like shape, steamed (40 and 80 min) and then refrigerated at 5 °C for 18 h. Refrigerated dough were sliced into different thicknesses (1 and 2 mm), dried at 60 °C for 4 h and then fried at 170 °C for between 10-20 s. Fried samples were analyzed for moisture and oil contents, expansion, texture, and colour. The effect of the variables was analyzed using ANOVA of Design expert version 12 after which regression models and response surface plots were generated. Optimized samples were obtained and sensory analyses of the sample were conducted. The regression equations were evaluated and verified to be accurate with high determination of coefficient of between 0.87 and 0.99. Linear model terms of steaming time, slice thickness and frying time significantly ($p<0.05$) affect oil content and texture while interaction of steaming time and slice thickness significantly ($p<0.05$) affect oil content. The optimized process conditions to obtain high nutritious and healthier fried cassava – defatted peanut crackers were 80 min, 1.00 mm and 10.02 s for steaming time, dough slice thickness and frying time, respectively.

Introduction

Crackers (*keropok*) are snack commonly consumed in Malaysia and other Asian countries (King, 2002) and the interest in crackers in African countries is on the rise. Several starches or flours, such as sago, rice, cassava, corn and tapioca, have been used in the production of crackers (Yu, 1993; Cheow et al., 2004; Saeleaw and Schleining, 2011; Tongdang et al., 2008). The use of pre-gelatinized starch has also been reported by Yu and Low (1992). Cassava crackers have been shown to have an outstanding expansion in contrast to crackers made from other starches or mixed starches (Tongdang et al., 2008). This attribute has been linked to high paste viscosity and clarity of cassava starch (Coker et al., 2017). Cassava (*Manihot esculenta Crantz*) is extensively grown across the world for food and raw materials and can be further processed into flour or starch (Sriroth et al., 2000). Cassava cracker is conventionally made by shaping dough initially obtained from cassava starch, seasonings, and water and protein ingredients mixed together (Nor et al., 2015). Heat is applied to the dough either by boiling or steaming in water in order to gelatinize the starch. Thereafter, the gelatinized dough is cut into slices, and then dried to reduce the moisture content before the crackers are packaged and sold. Before consuming as snacks, crackers are fried in hot oil which swells into a porous and crispy product (Kyaw et al., 1999; Murtuza et al., 2016).
The global savoury snack sales are predicted to top \$138 bn by 2020 and will continue to increase as the 'snackification' trend continues to grow (Food Manufacture, 2020) Consumers derive pleasure from the flavour and texture of fried snacks (Tettweiler, 1991). Snacks are convenient and readily available for

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consumption by all age groups, hence they are often consumed to satiate hunger for a short period of time. Despite the fact that they are filling, their nutritional benefits are significant. Owing to consumer's consciousness of eating healthy food, there has been an increase in the demand for healthy snacks. Even though fish or shrimps are usually used as a source of protein in crackers (Taewee, 2011), the use of plant proteins should be investigated. There is need for exploring cheap, nutritive and locally available raws materials in the manufacturing of food inorder to combat food security concerns in Africa. Peanut (*Arachis hypogaea*), otherwise known as groundnut, is a good source of protein for the diet of humans. The protein content of peanut is relatively high (about 28%) (Woodroof, 1983), has a pleasant flavour and a light colour that facilitates its incorporation into the production of a wide range of food (Prinyawiwatkul et al., 1995). Diet high in peanuts can reduce low density lipoprotein (LDL) susceptible to oxidation and consequently reduce the chances of arteriosclerosis (Sabate, 1999). Raw peanuts contain 45% oil, and mechanical extraction leaves 12-14% fat in the press cake. Peanut press cake is rich in protein and relatively low in fat. Defatted peanut flour is highly nutritional and very low in saturated fats and cholesterol. It is also a very good source of protein, dietary fibre, thiamin, folate, potassium, magnesium phosphorous, copper and manganese. Based on this fact, exploring defatted peanut flour as a highly nutritious, abundant, cheap and with low saturated fats and cholesterol is a prospect.

The final quality of a finished product is regulated by the processing conditions, such as temperature and time, mixing and thickness (Panghal et al. 2009). On the other hand, raw material characteristics, ingredient formulations, dough thickness and ratio/type of flour mixtures affect the quality of crackers (Coker et al., 2017), especially their expansion rate. Several authors have reported the effects of different processing conditions on the final quality of different types of crackers (Kyaw et al., 1999; Tongdang et al., 2008; Wang et al., 2013; Saeleaw and Schleining, 2011). Steaming process during crackers production allows the starch in dough to gelatinize and a gel is formed (Yu, 1993). A number of irreversible modifications take place in the starch granule such as uptake of water, swelling, and dissociation of hydrogen bonding during gelatinization (Taewee, 2011). Few authors have linked the expansion of crackers with the degree of starch granules swelling during gelatinization (Kyaw et al., 2001a; Cheow et al., 2004; Noranizan et al., 2010).

Steaming temperature and time were, among other factors, responsible for full gelatinization (Kyaw et al., 1999; Tongdang et al., 2008). Kyaw et al. (1999) reported that poor linear expansion was observed in fish crackers produced using extreme steaming time. On the other hand, reduction in linear expansion of crackers can also be attributed to partial gelatinization of starch granules during steaming (Murtuza et al., 2016). Steaming of cracker dough at an optimum time during the production of fish cracker gave the hardest texture of the steamed gel which resulted in the best linear expansion (Cheow et al. 1999). The degree of expansion in crackers is equivalent to their crispness and it is a crucial sensory parameter that determines the quality of crackers (Nurul et al., 2009).

Frying is a very crucial step during the production of crackers, because colour, flavour and taste greatly depend on the frying process (Tongdang et al., 2008). During frying, whichever changes occur in the product structure and composition will influence the quality attributes of the fried product (Sobukola et al., 2013). Deep fat frying involves immersing any food material in hot oil for a period of time in order to develop unique colour and texture. There is a simultaneous transfer of heat from the frying medium into the product, which consequently changes the structure and composition of the product (Saeleaw and Schleining, 2011). Crackers expand during frying due to moisture vapourization in the starch particles and pores are formed (Bhat and Bhattacharya, 2001). Although, frying time and temperature, type of oil and many other factors affect the puff process (Alvis et al., 2009), slice thickness also plays a crucial role in fish crackers expansion (Ibrahim et al, 2003). According to Peranginangin et al. (1996), when crackers are sliced into thicknesses greater than 2 mm, it results in final products with lower expansion.

Processing of crackers is often done to create unique quality attributes and improve their overall consumer acceptance. Apart from the final oil content and moisture, colour and texture are very important sensory characteristics of fried products (Krokida et al., 2001). These quality attributes often establish the basis for consumer's acceptance or rejection of the product. The processing conditions often have a negative effect on the quality characteristics of crackers. Consequently, an excellent understanding of steaming time and temperature, frying time and temperature and slice thickness during the processing of crackers are crucial. These will help in controlling the quality factors for a more acceptable final product. Hence, determining the optimum processing condition is the key in obtaining quality acceptable final cracker products. Therefore, this study was conducted to determine how steaming time, dough slice thickness and frying time affect some quality attributes of cassava – defatted peanut crackers after which the optimum processing conditions was ascertained.

Materials and methods

Materials

Cassava starch used in this study was procured from MATNA Food Company Limited, Akure, Ondo state. Peanut, vegetable oil, table salt, packaging material were obtained from a local store at Osiele, Abeokuta, Ogun state. Raw and clean peanuts purchased from a local market in Abeokuta, Nigeria were peeled and tempered at 10±5 °C for 12 h. A mechanical oil expeller was used to de-oil the peanuts after which the pressed cake was dried at 50±5 °C for 8h. The dried cake was then dry milled to obtain the defatted peanut flour (DPF).

Ingredient combination and production of cassava-defatted peanut crackers

Optimum ratio of cassava starch to defatted peanut flour, 75% and 25%, respectively obtained from preliminary experiments was used. Sample preparation began by ensuring the moisture content of the kneaded dough was 40.85%. Moisture content of the dried ingredients; cassava starch (CS) and Defatted Peanut Flour (DPF) were determined initially to know the amount of water to be added to form the dough. Moisture content of the dry ingredients was determined by drying in a hot air oven at 105 °C for 24 h to a constant mass. In preparing the dough, 250 g of defatted peanut flour, 750 g of cassava starch and 4 g of table salt were weighed accurately into a beaker. About 599 g of water at 40 °C was added gently at intervals to ensure 40.85% moisture content of the dough was obtained. The ingredients were thoroughly mixed and kneaded before forming into eight pieces sausage-like shape to give a spherical shape after slicing. The slices were then steamed in the steam chamber within the experimental conditions outlined. The steam samples were allowed to cool to room temperature (±35 °C) before refrigerating at 5 °C for 18 h to reduce stickiness. Refrigerated samples were then cut into1 mm and 2 mm slices with the aid of a sharp stainless-steel kitchen knife and oven dried at 60 °C for 4 h resulting in a half-finished product. An electric deep fat fryer (model 614 SAISHO, China) containing about 6 l of frying oil heated to a temperature of 170 °C was used for frying the samples for between 10 to 20 s as outlined in Table 1.

Table 1. Experimental condition of samples based on the design used

Steaming time (minutes)	Dough slice thickness (mm)	Frying time (seconds)	Sample code
40	1	10	$S_{40}D_1F_{10}$
40	1	20	$S_{40}D_1F_{20}$
40	2	10	$S_{40}D_2F_{10}$
40	2	20	$S_{40}D_2F_{20}$
80	1	10	$S_{80}D_1F_{10}$
80	1	20	$S_{80}D_1F_{20}$
80	2	10	$S_{80}D_2F_{10}$
80	2	20	$S_{80}D_2F_{20}$

Analysis of physico-chemical properties of fried cassava-peanut crackers

Determination of linear expansion

The methods described by Yu et al. (1981) was used in determining the percentage linear expansion of the fried cracker. It was calculated using the equation below where the unpuffed and puffed samples are referred to as dried without frying and dried and fried samples.

$$\text{Calculated as} = \frac{\text{length after puffing - length before puffing}}{\text{Length before puffing}} \times 100$$

Determination of moisture content

Triplicate samples of about 5 g of blended cassava-defatted peanut cracker were dried in a hot air oven at 105±1 °C for 16 h gravimetrically using the modified AOAC standard methods (950.6 and 934.01). Thereafter, dried samples were cooled using a desiccator and the moisture content was determined on wet basis.

Determination of oil content

About 2 g of dried cassava-peanut cracker samples was extracted for oil content using Soxhlet extraction method of AOAC (2000) with petroleum ether as the solvent. Mean values of triplicate samples were reported.

Determination of colour parameters

Yellowness, redness and lightness parameters of cassava - defatted peanut crackers were determined using a Hunter Lab Colorimeter Labscan XE (Hunter Associates Laboratory, Reston, VA) based on the method described by Mariscal and Bouchon (2008). Change in colour was determined using the equation below:

$$\Delta E = \sqrt{(L* - L*o)2 + (a* - a*o)2 + (b* - b*o)2}$$

Where L^*_o, a^*_o and b^*_o represent the respective readings of control sample

Texture analysis

Breaking force, an indicator of texture was determined using a texture analyzer. The method earlier reported by DaSilva and Moreira (2008) was used where fried cassava – defatted peanut cracker was placed over the end of a hollow cylinder. The ball probe (P/0.25 s) made up of stainless steel was adjusted to move at a speed of 5 mm/s)1 for a distance of 5.0 mm, thereby breaking the cracker.

Sensory analysis

Laboratory sensory acceptability of the samples in terms of colour, crispness, oiliness, aroma, taste and overall acceptability were carried out with each attribute evaluated using a 9-point hedonic scale according to Stone and Sidel (2004). Thirty panelists received each of the coded samples of cassava-defatted peanut crackers and ranked them according to intensity of colour, texture, taste, and overall acceptability.

Experimental design

A two level (2^n where n is number of factors) full factorial experimental design was used to investigate the effect of steaming time (40 and 80 min), slice thickness (1 and 2mm) and frying time (10 and 20 s) on some important quality attributes of the crackers. Data obtained were fitted with predictive models to obtain the regression equations for each response as a function of the processing parameters. Analysis of variance (ANOVA) was used to estimate the statistical significance of the model terms of the regression equations for each quality attribute. The predictive models obtained were used to generate the response surface and contour plots describing the change in the responses as a function of change in combination of the processing parameters. Optimized processing conditions of the fried crackers were carried out using the numerical technique of full factorial experimental design. The selected optimization conditions closest to one was selected based on desirability concept.

Statistical Analysis

Sensory data was statistically analyzed for significant effect of independent variable using analysis of variance (ANOVA) of SPSS version 21. The differences between the mean values were calculated using Duncan's multiple comparison tests at 95% confidence level ($p<0.05$). The effect of processing conditions and optimization procedure was carried out using Design expert version 12 based on two level full factorial design. Models were generated and significance effect of the ingredient combination at 5% level was determined.

Results

Effects of processing conditions on oil content

Table 2 show the effect of steaming time, slice thickness and frying time on some quality attributes of fried cassava-defatted peanut crackers. The highest oil content (23.77 %) was observed for sample steamed for 40 min, slice thickness of 1 mm and fried for 20 sec while sample steamed for 80 min with thickness of 1 mm and fried for 10 sec had the lowest (15.33%). Table 3 shows the regression parameters for all the responses as a function of the independent variables. The oil content was significantly ($p<0.05$) affected by linear terms of steaming time, frying time and interaction of steaming time and dough slice thickness. However, there was no effect of interaction of steaming time and frying time on oil content. The models developed for oil content has a coefficient of performance of 0.98. The oil content of crackers significantly ($p< 0.05$) decreased with increase in steaming time as observed in figure 1. During steaming, the starch granules gelatinize due to the interaction between water and temperature, hence, forming a closed matrix on the surface of the product, which inhibit the absorption of oil. This observation is comparable with the study by Manjunatha et al. (2014), who reported that oil absorption of a product during frying is related to the changes in the products surface and pore sizes. Similarly, adsorption of oil during frying is influenced by the product porosity (Wani et al., 2017).
Frying time significantly ($p<0.05$) affected the oil content of cassava-defatted peanut crackers. The longer the duration of frying, the higher the oil content in the samples. This agrees with the result of Therdthai et al. (2007) who reported on the effect of frying time on oil uptake of a similar fried product. The most important factors during frying that influences oil absorption are frying temperature, frying time and product thickness (Krokida et al., 2000). In this work, oil content of fried cassava-defatted peanut cracker decreased as the dough slice thickness increased as shown in Table 2. Decrease in oil content with an increase in dough slice thickness could be due to fact that a higher slice thickness (smaller surface area) restricts the rapid movement of water in form of vapour from the surface of the cracker during frying. This resulted in crackers with higher moisture content due to its thickness thus hindering oil from

percolating into the inner structure of the crackers. Esan et al. (2015) had earlier stated that oil content appears to be related with moisture content due to the observation highlighted above. Therefore, during frying when moisture evaporation occurs, oil is absorbed into the product capillary as a replacement.

Effect of processing condition on the moisture content

Moisture content, an equally important quality attribute of food (Saeleaw and Schleining, 2011) is dependent on the frying time, frying temperature, product size and ingredients composition. During frying of food product, moisture evaporation is a major phenomenon in addition to other chemical changes that occurs on the surface of the product. For deep fat fried cassava-defatted peanut crackers, moisture content varied between 3.50 and 12.50% within the experimental conditions. The regression models developed for moisture content can predict about 95% of the experimental data as shown in Table 3.
Figure 2 present the response surface plots for moisture content at different experimental conditions. The highest moisture content (12.50%) was found in sample $S_{80}D_2F_{10}$, while the lowest moisture content (3.50%) was in $S_{40}D_1F_{20}$. The values of moisture content of the fried product decreases significantly (p<0.05) frying time increases. This observation can be attributed to rapid removal of moisture from samples at higher frying rate. This observation agrees with the report of Manjunatha et al. (2004) and Tongdang et al. (2008) who submitted that the moisture loss of fried products increased with the frying time and temperature. On the other hand, steaming significantly (p<0.05) increased the moisture content of fried cassava-defatted peanut cracker. This may be as a result of changes in the starch granules and the heating medium during steaming which allows the cracker dough to take up water for gelatinization to occur. Kawas and Moreira (2001) opined that fried products that were steamed prior to frying did not let water vapour to escape, due to the puffiness caused by gelatinization. Similar observation was reported by Kyaw et al. (1999).
Furthermore, the moisture content of fried cracker increases with increase in dough slices thickness. Similar observation was reported by Kigncam et al. (2008). From the study reported by Reddy and Dias (1993), the thickness of the chips is equivalent to the present moisture content. In products that are sliced thin, moisture moves out fast because of the small distance and surface area as a result of the volume of the product (Wani et al., 2017).

Table 2. Mean values of some quality attributes of fried cassava-defatted peanut crackers

Sample codes	Oil Content (%)	Moisture Content (%)	Expansion (%)	Texture (N)	L*	a*	b*	ΔE
$S_{80}D_1F_{20}$	16.41	8.00	43.55	6.40	55.20	2.76	19.38	20.04
$S_{40}D_1F_{10}$	21.36	11.00	13.00	8.50	55.73	2.36	13.23	16.18
$S_{80}D_2F_{20}$	18.52	11.00	48.10	9.10	62.65	2.51	18.24	25.28
$S_{40}D_1F_{20}$	23.77	3.50	16.06	9.20	54.56	3.31	16.33	17.15
$S_{80}D_1F_{10}$	15.33	8.00	34.29	9.00	58.52	2.10	12.00	16.12
$S_{80}D_2F_{10}$	19.93	12.50	35.86	10.70	61.98	2.80	18.15	24.84
$S_{40}D_2F_{20}$	20.63	4.50	33.58	16.40	58.59	3.31	18.69	22.75
$S_{40}D_2F_{10}$	20.30	8.00	25.15	6.90	58.07	3.82	15.75	21.13

Values are means of triplicates

Table 3. Regression coefficient of the responses as a function of the independent variables

Coefficient	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
X_0	19.53	8.31	31.20	9.53	58.16	2.87	16.47	20.44
X_1	-1.98*	1.56	9.25*	-0.73	1.43	-0.33	0.47	1.13
X_2	0.31	0.69	4.47*	1.25	2.16	0.24	1.24	3.06
X_3	0.30*	-1.56	4.12*	0.75	-0.41	0.10	1.69	0.87
X_1X_2	1.36*	1.19	-2.94	-0.15	0.57	-0.13	0.02	0.43
X_2X_3	-0.57	0.31	1.04	1.23	0.71	-8.75^{-003}	-0.93	-0.35
X_1X_3	-	1.19	1.25	-1.80	-0.25	-0.30	0.18	0.22
R^2	0.98	0.95	0.99	0.89	0.99	0.99	0.87	0.98
Model (F-value)	16.84	2.92	250.09	1.30	15.64	11.57	1.15	7.37

X_0, intercept; X_1, steaming time; X_2, dough slice thickness; X_3, frying time; Y_1, oil content; Y_2 moisture content; Y_3, texture; Y_4, expansion; Y_5, lightness; Y_6, redness; Y_7, yellowness Y_8, change in colour. Significant values at p<0.05

Effect of processing conditions on linear expansion

Expansion is a determinant of fried cracker's crispiness and overall quality (Taewee, 2011). According to Rosell (2001), the concept of rapid increase in molecular volume of water during evaporation can be used to explain the expansion phenomenon during frying of foods. As shown in Table 2, expansion of fried cassava-defatted peanut cracker varied from 13.00 and 48.10% within the experimental runs. The expansion value obtained from this study was significantly lower than the value suggested by authors as a minimum expansion. For instance, Yu (1993) stated that fish crackers with excellent linear expansion should normally exceed 77%. Although, the type of flour and quantity used may affect the degree cracker expansion (King, 2002). The maximum and minimum expansion was found with samples $S_{80}D_2F_{20}$ and $S_{40}D_1F_{10}$, respectively. The regression models developed for expansion in this work has a coefficient of performance of 0.89 (Table 3). The model was subsequently used to generate the response surface plots that depicts the direction of expansion of the cracker as the independent variables' changes. The observations for expansion with different combinations of the process parameters are presented in Figure 3.

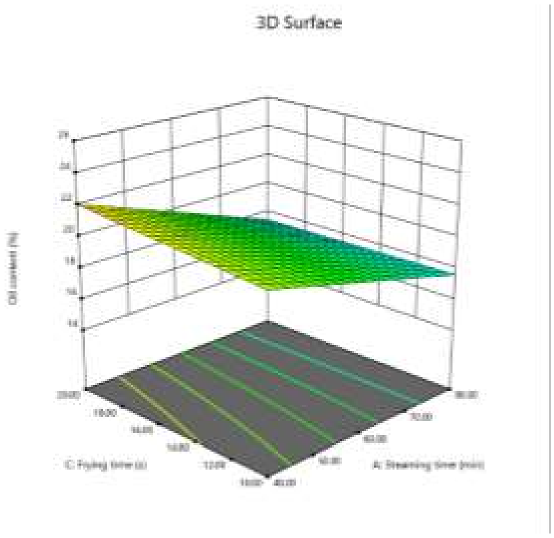

Fig. 1. A typical response surface plot showing effect of frying time (s) and steaming time (min) at constant dough slice thickness on oil content of fried cassava-defatted peanut cracker

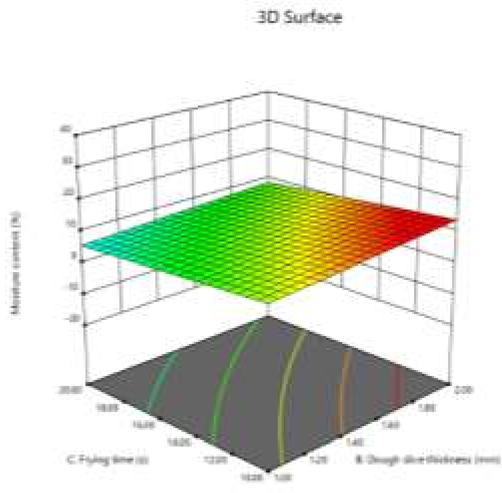

Fig. 2. A typical response surface plot for moisture content (%) of fried cassava-defatted peanut cracker showing effect of frying time (s) and dough slice thickness (mm) at constant steaming time (min)

In this study, the expansion of cassava-defatted peanut crackers increased as steaming time increased. This agrees with the observations of Kyaw et al. (1999) and Tongdang et al. (2008), who reported that increase in steaming time correlates to cracker expansion. As the starch granules swell owing to gelatinization, water is absorbed and these water molecules are trapped inside the swollen granules. As temperature increase during frying, there is a corresponding increase in volume of water that want to escape in form of vapour from the interior. As the vapour finds it difficult to escape, the product expands giving rise to increase linear expansion of the fried crackers. Tongdang et al. (2008) stated that the expansion of cracker is greatly influenced by the degree of starch gelatinization in cracker dough, If the starch is not completely gelatinized, it will result in poor expansion of the cracker (Cheow and Yu, 1997) probably due to ease of movement of water vapour through the such sample.

The cracker expansion increased with increase in dough slice thickness as shown in Figure 3. This could be as a result of increased volume or capacity of the dough to expand better. So, the expansion is dependent on the surface area during deep fat frying. Findings from this work revealed that frying time increases the expansion of the cassava-defatted peanut crackers. This phenomenon can be attributed to rapid vapourization and bubbling inside the gelatinized starch granules which result in the expansion of crackers. Taewee (2011) reported similar trend of increasing frying time and temperature with significantly increased linear expansion. According to Jirawan et al. (2009) the expansion ratio of fried rice crackers mixed with fish powder content of 15g/ 100g increased slightly with increase in frying time.

Texture (Hardness) of fried cassava-defatted peanut crackers

The texture of a fried product has been reported to be an index of its crispiness and it has a direct relationship with cellular structure of foods resulting in emission of sound (Saeleaw and Schleining, 2011). Crispness is a unique characteristic and an important sensory parameter that are perceived by the consumer, so as to either accept or reject a fried product (Pedreschi and Moyano, 2005; Thanatuksorn et al., 2007). Texture of most fried food materials can be reported as hardness measured as breaking force. This is the minimum force required to crush a product (Wani et al., 2017) and also describes the compactness of structure arrangement of starch and protein composition (Ibadullah et al., 2019). As presented in Table 2, the breaking force (N) of fried cassava-defatted peanut crackers varied between 6.5 N ($S_{80}D_1F_{20}$) and 16.4 N ($S_{40}D_2F_{20}$) within the experimental conditions. Regression coefficient (Table 3) of texture as presented shows the significant effect of the linear terms of the processing variables (steaming time, dough slice thickness and frying time) at 5%. From the table, it can be observed that interaction effects of the processing parameters do not significantly ($p>0.05$) affect texture. The developed model for texture has the highest coefficient of performance of 0.99. Response surface plots for texture at different experimental conditions are presented in Figure 4.

In this study, results showed that an increase in dough thickness and frying time resulted in significant ($p\leq0.05$) increase in breaking force of cassava-defatted cracker, respectively. Wani et al. (2017) reported a similar trend in the hardness of potato chips as influenced by slice thickness. Slices that are too thin may results into products that are oily and easily break (Bennett, 2001). Slice thickness influences the curl ability and texture of crunchy products. Thus, slice thickness should be taken into consideration during the production of crackers. There was a significant ($p>0.05$) increase in the hardness of the crackers with increase in frying time. This agrees with the fact that increase in frying time of food products will increase the hardness of the fried products (Ngadi et al., 2009). Observation from these results is comparable with the reports of Saeleaw and Schleining, (2011) and Sahin and Sumnu, (2009). Investigations have shown that processing conditions have a drastic effect on texture of crackers, which is measurable by the crunchiness or crispness of fried crackers. Kita et al. (2007) stated that frying temperature and time affects the texture of food products. The main effect of texture on food products is the starch gelatinization during heat application (Andersson et al., 1994) suggesting that steaming at high temperature results into products with higher degree of starch gelatinization. Álvarez et al. (2001) earlier reported that gelatinization of starch has a negative effect on microstructure and texture of potato tuber during cooking.

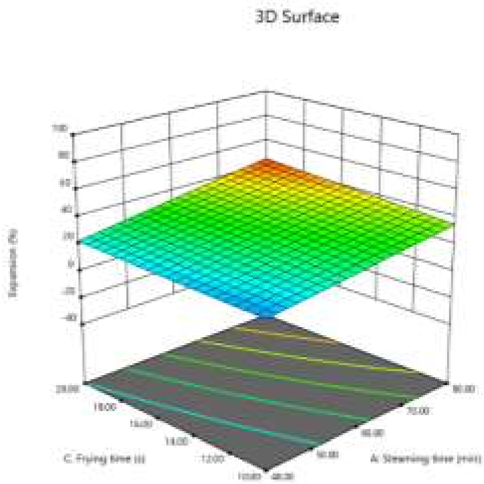

Fig. 3. Response surface plot of expansion (%) of fried cassava-defatted peanut cracker showing the effect of frying time (s) and steaming time (min) at constant dough slice thickness (mm)

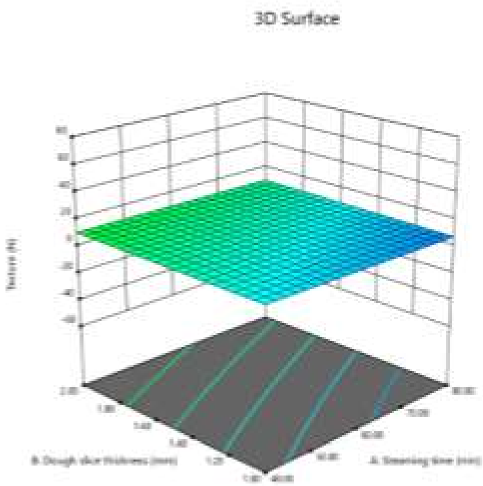

Fig.4. Response surface plot of Texture (Breaking force-N) showing the effect of frying time (s) and steaming time (min) at constant dough slice thickness

Table 4. Mean sensory scores of cassava-defatted peanut crackers

Sample code	Colour	Aroma	Taste	Crispiness	OA
$S_{40}D_1F_{10}$	6.70 ± 1.51[a]	6.03 ± 0.97[ab]	6.37 ± 1.07[a]	7.20 ± 1.32[b]	7.10 ± 1.32[b]
$S_{80}D_2F_{20}$	6.50 ± 1.07[a]	6.73 ± 1.17[ab]	7.27 ± 1.41[b]	7.21 ± 1.34[b]	7.17 ± 1.02[bc]
$S_{40}D_2F_{10}$	5.93 ± 1.68[a]	6.07 ± 1.70[a]	6.30 ± 1.44[a]	6.07 ± 1.72[a]	6.57 ± 1.43[ab]
$S_{40}D_2F_{20}$	6.70 ± 1.24[a]	6.63 ± 1.50[ab]	6.50 ± 1.59[a]	6.20 ± 1.94[a]	6.50 ± 1.20[ab]
$S_{80}D_1F_{10}$	6.95 ± 1.46[a]	6.03 ± 1.25[a]	6.98 ± 1.27[a]	7.35 ± 1.88[a]	7.67 ± 1.48[c]
$S_{80}D_1F_{20}$	6.57 ± 1.74[a]	6.10 ± 1.16[a]	6.27 ± 1.26[a]	6.10 ± 1.52[a]	6.23 ± 1.01[a]
$S_{80}D_2F_{10}$	6.67 ± 1.35[a]	7.03 ± 1.19[b]	6.37 ± 1.77[a]	6.63 ± 2.31[ab]	6.93 ± 1.53[ab]

Where OA is overall acceptability. Mean values in the same column with same alphabet are not significantly different at 5% level.

Colour parameters of fried cassava-defatted peanut cracker

Non-enzymatic browning reactions such as maillard reaction, caramelization and chemical oxidation of phenolic compounds has been reported to be responsible for the formation of brown pigments associated with characteristic colour of fried products. These reactions are usually governed by frying oil temperature, frying time among others thus affecting the basic colour parameters namely, redness, yellowness and lightness (Manzocco et al., 2001). Lightness, redness, yellowness and change in colour of fried cassava-defatted peanut crackers were reported as L*, a*, b*, and ΔE. L* value decreased with increase in frying time. The coefficient of performance of colour parameters varied between 0.87 and 0.99. This indicated that the regression models developed for colour parameters can predict substantially a large percentage of the experimental data obtained. The models were used to generate the response surface plots (not presented) revealing the variation of the colour parameters as the processing conditions varies. However, the values of L* increased with increase in slice thickness and steaming time as shown in figure 5. From Table 2, the b* value of crackers fried at 20 sec, were significantly ($p<0.05$) higher than crackers fried at 10 sec. The trend observed agrees with the findings of Sobukola et al. (2013) who reported that the yellowness of yam slices increased with frying time. According to Moyano et al. (2002), modification of physical, chemical and sensory characteristics of food materials are modified during frying process of which frying time and temperature are major contributors to these changes. As frying time increases, lightness decreased with increase in frying time and frying temperature, while a* and b* values increased (Esan et al., 2015). These observations were consistent with what was obtained in this study. This may be due to the fact that as frying time increases, more moisture is evaporated from the fried crackers and the maillard reaction becomes more intense resulting in decrease in lightness and higher redness and yellowness values. Increase in lightness, redness, yellowness and change in colour with increase in steaming time and dough thickness may be due to higher expansion degree of crackers due to complete gelatinization of starch granule. Pedreschi et al. (2005) reported that the changes in the lightness of fried products may be associated with moisture loss and browning that occur during frying.

Optimization of processing conditions

Design Expert version 12.0 was used for the numerical optimization procedure to obtain fried cassava-defatted peanut crackers of acceptable quality attributes. The main quality attributes such as oil content, moisture content, texture (breaking force), redness, yellowness and change in colour were minimized while expansion and lightness were maximized. However, the independent variables were kept within the range used for the experiments. A total of seven results were obtained with the first result selected as the most desirable for retaining high quality parameters of deep-fried cassava–defatted peanut crackers. The selected optimized processing conditions were steaming time, dough slice thick and frying time of 80 min, 1.00 mm and 10.02 s, respectively with a desirability value of 0.708.

Sensory Analysis of fried cassava-defatted peanut cracker

Table 4 shows the mean sensory scores of fried cassava-defatted peanut crackers. From the sensory result obtained, there were significant differences at 5% level in the quality parameters of the fried cassava-defatted peanut crackers except for colour. The final quality of most fried foods is usually related with sensory perception of the colour, flavour and texture (during mastication). On a general view, the panelist accepted the colour, taste, aroma and crispiness of deep-fried cassava-defatted peanut crackers at different processing condition. This could be due to the characteristic peanut flavour and crispiness, as it has been reported to be one of the important factors that determines consumers acceptance of fried products. From the table, the mean scores of colour attributes were not significantly different (p>0.05) among the samples. For most of the sensory attribute scores as well as overall acceptability, sample $S_{80}D_1F_{10}$ had the highest scores. The implication of this was that the result obtained by numerical optimization is comparable with the sensory scores obtained.

Conclusion

The steaming time, dough slice thickness and frying time significantly (p<0.05) affected oil content and texture of fried cassava-defatted peanut crackers. Developed models can predict between 87 to 99% of the experimental data. The optimized processing conditions to obtain high nutritious and healthier fried cassava – defatted peanut crackers were 80 min, 1.00 mm and 10.02 s for steaming time, dough slice thickness and frying time, respectively. Sensory analysis also revealed same sample as the most acceptable.

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