Effect of Extrusion process on the quality attributes of extruded snacks from Malted Sorghum at optimized condition using response surface methodology

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ABSTRACT

Background: *The absence of gluten in our indigenous cereals makes them unsuitable as replacement for wheat flour in confectioneries and this has led to increasing use of different processing methods that will produce nutritious and acceptable products.*

Objective: *To determine the effect of extrusion process on the quality attributes of extruded snacks from malted sorghum at optimized condition using response surface methodology.*

Methods: *Experimental design was done with the aid of Central Composite Design (CCD) with two independent variables which generates thirteen runs and the independent variables were barrel temperature (BT) and screw speed (SS). Production of extruded snacks was done by using a single screw extruder and the extruded snacks were analyzed for proximate, anti-nutritional and physical properties and data generated were analyzed using analysis of variance (ANOVA) and regression model.*

Results: *The moisture, crude protein, crude fat, crude fibre, total ash and carbohydrate content ranged from 3.54 – 4.96%, 10.30 – 12.86%, 8.80 – 16.97%, 0.28 – 0.89%, 0.31 – 1.34% and 64.85 – 74.09%, respectively. Lightness, yellowness, chewiness, tannin and phytic acid contents of the extruded snacks decreased as the BT and SS increased. Increase in barrel temperature increased the redness of the extruded snacks. BT and SS had a decreasing significant ($p < 0.05$) effect on the tannin and phytic acid of extruded snacks. The quadratic effect of increasing BT had a significant ($p < 0.05$) effect on the lightness of the extruded snacks.*

Conclusion: *Extruded snacks produced from BT of 95°C and SS of 101.4 rpm had the highest desirability.*

Keywords: Extrusion, snacks, malted sorghum, screw speed, barrel temperature

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INTRODUCTION

Snack is food smaller than a conventional meal and mostly eaten between meals (1). Wheat flour is a major raw material in the production of snacks and its major utilization compare to other cereals lies in the presence of gluten which has a major impact on the quality of its final products. The absence of gluten in other cereals makes them unsuitable as replacement for wheat flour in baking (1). In addition, tropical climate does not favour wheat production therefore, utilization of indigenous crop such as sorghum in developing countries such as Nigeria would help in conservation of foreign exchange and better production of high yielding indigenous crops.

Sorghum (Sorghun bicolor L. Moench) is a food and cash crop in Africa with well over ninety million people depending on it directly in the east and central Africa region. United States Grains Council specified sorghum to be the fifth most important cereal in the world and in Africa (2). More than 50% of the area allotted to grow cereal crops in Nigeria is used for the cultivation of sorghum (3) resulting in Nigeria being the number one producer in Africa (2). It is rich in carbohydrates, proteins, minerals and vitamins (4). Earlier researches conducted on sorghum provided both challenges and successes and most of these researches were on sorghum composites (5, 6, 7). Sorghum has great potential in gluten free food market. Diet free of gluten is recommended for individuals with coeliac disease. Literatures have recorded that phytochemicals can be decreased substantially by food processing operations such as dehulling, heat treatment, malting, and fermentation (8). Malting of sorghum is the control germination of grains in a moist environment (9). Malted sorghum has the potential to be used as soft dough in snacks production (10). Malting generally involves steeping in water, germination and finally kilning to terminate sprouting (11). It is beneficial to the activities of hydrolytic enzymes and brings about changes to the component and structure of the grain and also improves the digestibility of protein and availability of minerals by reducing the anti-nutritional factors in grains (1). Germination of grain enhances the development of alpha-amylase, endo - beta - 1, 3 - glucanase, carboxypeptidase, pentosanase, limit dextrinase and endoprotease in the grain (10).

Extrusion of food is becoming popular in food industries; it is a processing method that involves high temperature for short time. It has been used in the processing of so many food products such breakfast cereals, flat bread, pasta, snacks, cookies, confectionery and some beverages (12). Extrusion cooking would provide more opportunities for production and consumption of value-added sorghum food products (4). Many works have been done on extrusion cooking using composite flours for process and product development. However, information is still limited on extrusion process using malting process. The overall objective is to determine the effect of extrusion process on the quality attributes of malted sorghum extruded snacks at optimized condition using response surface methodology.

MATERIALS AND METHODS

Materials

White sorghum grains, margarine, sugar and egg were obtained from Eleweran market in Abeokuta, Nigeria.

Methods

Processing of malted sorghum flour

The processing of sorghum to malted sorghum flour as described by Ojha et al (13) was employed. The grains were sorted to remove the extraneous materials, washed twice in a large amount of water, and steeped in water at ratio (1:4) for 12 hours. The grains were drained and spread for 3 days on jute bag at (25±2°C) and sprayed with water at 6 hours intervals to allow sprouting. It was then kilned with the aid of a cabinet dryer (LEEC Limited, Serial No 3114, United Kingdom) set at 50°C for 24 h, cooled, winnowed (to remove rootlets), dry milled with a laboratory hammer mill (Fritsch, D-55743 Idaroberstein-Germany), sieved (pass passed through a 600 μm sieve) and stored (25±2°C) in a polyethylene bag before usage.

Experimental design

Response Surface Methodology using CCD was used for the experimental design with two independent variables and variations. The independent variables were BT (80-100°C) and SS (110-130 rpm) at constant feed moisture of 20%.

Preparation of extruded snacks from malted sorghum flour

The method described by Azeez et al (14) was employed in the production of snacks. Laboratory single screw extruder having screw length (16.43 mm), diameter (18.5 mm), length (304 mm) and a power of 0.25 hp of the Department of Food Science and Technology was used for this work. The extruder comprises of two sections which are the die and the transmission zone, with the band heater heating the band as described by Sobukola et al (15). Malted sorghum flour (600 g), margarine (100 g), sugar (50 g), egg (130 g) and water (120 g) were mixed together in a stainless container and the mixture was extruded following the specification of the design. After the extrusion process, the extruded snacks were dried (50 °C for 24 h) to the desire moisture content in a convective oven (Model OV-160 Gallenkamp) and were cooled at ambient temperature and were packaged in polyethylene bags prior to analyses.

Proximate composition of extruded snacks from malted sorghum flour

Proximate content which includes moisture, crude fat, crude protein, total ash and crude fibre content of extruded snacks were analyzed in triplicates using standard methods (16) and total carbohydrate were determined by difference method.

Anti-nutritional composition of extruded snacks from malted sorghum flour

Tannin content was determined using the method of Makkar et al (17) while Phytic acid content was determined using the method of Talamond et al (18).

PHYSICAL PROPERTIES OF EXTRUDED SNACKS

Colour properties of extruded snacks

Extruded snacks colour measurement was done using the method of Feili et al (19). Minolta chroma meter was used in the scale of L*, a*, b*. After calibration, the image of the extruded snacks was captured by placing the extruded snacks on the petri dish. The colour parameters such as lightness (L) ranges from 0 to 100 (black to white), redness (a*) which ranges from negative values (green) to positive values (red) and yellowness (b*) ranges from negative values (blue) to positive values (yellow) were recorded.

Textural properties of extruded snacks

The textural properties of extruded snacks samples which includes chewiness, fracturability and hardness were determined using the TA-XT Plus texture analyzer (Stable Micro Systems Serial No. 5014 England) in accordance to the method described by Ahmad et al (20).

Data analysis and process optimization

A central composite design (CCD) was used for the data analysis with two independent variables including barrel temperature (A) and screw speed (B) using a statistical package, Design Expert Version 6.0.2 (Stat Ease Inc, Minneapolis, MN, USA). The levels of the variables were coded as -1, 0, 1 resulting to thirteen experimental runs to evaluate the effect of BT and SS on the responses (proximate and anti-nutritional composition, colour and textural properties) at $p < 0.05$ level of significance. The optimization of the extrusion parameter was done using Design Expert version 12.0, desirability concept was used to identify extruded snacks of acceptable properties. Moisture, tannin and phytic acid were minimized while protein, lightness and fracturability were maximized.

RESULTS

Proximate composition of the extruded snacks from malted sorghum flour

Table 1 shows the proximate composition of extruded snacks from malted sorghum flour per 100 g. The moisture content of extruded snacks ranged from 3.54 to 4.96%, the lowest was found in BT of 100°C and SS of 110 rpm and the highest was found in BT of 90°C and SS of 120°C. The main, quadratic and the interaction effect of BT and SS had a significant ($p < 0.05$) effect on the moisture content with coefficient of regression (R^2) of 0.63.

The crude protein content of extruded snacks ranged

Table 1: Proximate composition of extruded snacks from malted sorghum flour per 100g

Experimental Runs	Barrel Temperature (°C)	Screw Speed (rpm)	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	Total Ash (%)	Carbohydrate Content (%)
1	80.00	110.00	3.92	10.95	15.69	0.45	1.34	67.98
2	100.00	130.00	3.96	10.65	12.54	0.28	1.17	71.14
3	90.00	134.14	4.90	10.88	14.71	0.44	1.20	67.95
4	100.00	110.00	3.54	10.64	16.97	0.86	1.43	64.85
5	90.00	120.00	4.93	10.86	13.88	0.69	1.18	66.27
6	90.00	120.00	4.81	11.86	13.76	0.67	1.26	68.24
7	90.00	105.86	5.37	11.78	12.11	0.51	1.21	69.92
8	90.00	120.00	4.95	12.86	13.98	0.71	1.27	67.00
9	80.00	130.00	4.93	10.61	8.80	0.61	0.31	73.09
10	90.00	120.00	4.96	10.75	14.88	0.59	1.28	67.25
11	75.86	120.00	4.76	10.30	12.34	0.43	0.43	70.89
12	90.00	120.00	4.73	10.76	13.98	0.89	1.27	67.97
13	104.14	120.00	4.93	10.60	8.80	0.61	0.66	74.09

from 10.30 to 12.86%, the lowest was found in BT of 75.86°C and SS of 120 rpm and the highest was found in BT of 90°C and SS of 120°C. The main effect of SS had a significant ($p < 0.05$) effect on the protein content of the extruded snacks, the interaction effect of BT and SS had significant ($p < 0.05$) effect on extruded snacks with coefficient of determination of 0.76 as shown in Table 2. The crude fat content of the extruded snacks ranged from 8.80 to 16.97%, the lowest was found in BT of 80°C and SS of 130 rpm and the highest was found in BT of 100°C and SS of 110°C. The main effect of BT and SS had a significant ($p < 0.05$) effect on the crude fat content of the extruded snacks while the quadratic effect of BT and SS, the interaction effect of BT and SS speed also had a significant ($p < 0.05$) effect on the crude fat content of the extruded snacks with the coefficients of regression of 0.83.

The crude fibre content of the extruded snacks ranged from 0.28 to 0.89%, the lowest was found in BT of 100°C and SS of 130 rpm and the highest was found in BT of 90°C and SS of 120°C. The main effect of BT and SS had a significant effect on the crude fibre content with coefficient of determination of 0.81. The total ash of the extruded snacks ranged between 0.31 and 1.34%, the lowest was found in BT of 80°C and SS of 130 rpm and the highest was found in BT of 80°C and SS of 110°C and the carbohydrate content ranged from 64.85 to 74.09%, the lowest was found in BT of 100°C and SS of 110 rpm and the highest was found in BT of 104.14°C and SS of 120°C. The main effect of BT and SS had a significant ($p < 0.05$) effect on the carbohydrate content of the extruded snack with coefficients of determination of 0.86 as shown in Table 2.

Anti-nutritional factors of the extruded snacks from malted sorghum flour

Figure 1 shows the anti-nutritional composition of extruded snacks from malted sorghum flour per 100 g. The tannin content of the extruded snacks ranged from 3.50 to 4.41 mg the lowest was found in BT of 100°C and SS of 130 rpm and the highest was found in BT of 90°C and SS of 134.14°C. Phytic acid content of the extruded snacks ranged from 1.29 to 2.95 mg, the lowest was found in BT of 100°C and SS of 110 rpm and the highest was found in BT of 100°C and SS of 130°C. The quadratic effect of SS had a significant ($p < 0.05$) effect on phytic acid. Similarly, the interaction effect of BT and SS had a significant ($p < 0.05$) effect on the phytic acid.

Physical properties of the extruded snacks from malted sorghum flour

Table 3 shows the physical properties of extruded snacks from malted sorghum flour. The lightness (L*) of the extruded snacks ranged from 35.89 to 56.83, the lowest was found in BT of 104.14°C and SS of 120 rpm and the highest was found in BT of 75.86°C and SS of 120°C. The main effect of BT had a negative significant ($p < 0.05$) effect on the lightness of the extruded snacks. The redness (a*) of the extruded snacks ranged from 7.17 to 9.08 the lowest was found in BT of 80°C and SS of 110 rpm and the highest was found in BT of 104.14°C and SS of 120°C. The quadratic effect of BT and SS had a significant ($p < 0.05$) effect on the redness of the extruded snacks. The quadratic model for redness, had a coefficient of determination (R^2) of 0.92 for extruded snacks. Also, the interaction effect of BT and SS had a significant ($p < 0.05$) effect on the redness of the extruded snacks. The yellowness of the extruded snacks ranges from 16.76 to 23.25 the lowest was found in BT of 104.14°C and SS of 120 rpm and the highest was found in BT of 75.86°C and SS of 120°C. The main effect of BT had a significant ($p < 0.05$) effect on the yellowness of the extruded snacks. The quadratic effect of screw speed had a significant ($p < 0.05$) effect on the yellowness of extruded snacks with the model developed having a coefficient of regression (R^2) of 0.90 as shown in

Table 2: Regression coefficient of proximate composition of extruded snacks from malted sorghum flour

Parameters	Moisture Content	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Carbohydrate
β_0	4.88	11.16	14.1	0.71	1.25	67.91
A	-0.14*	0.094	0.0017*	0.042*	0.071	-0.069*
B	0.096*	-0.048*	-0.96*	-0.065*	-0.1	1.08*
A^2	-0.24*	-0.036	-1.39*	-0.082	-0.18	1.93
B^2	-0.096*	0.089	0.035*	-0.1*	-0.073	0.15
AB	-0.15*	-0.61*	0.62*	-0.18	0.03	0.30
R^2	0.63	0.76	0.83	0.81	0.64	0.86

Where βo = Intercept, A = Main effect of barrel temperature, B = Main effect of screw speed, A^2 = Quadratic effect of barrel temperature, B^2 = Quadratic effect of screw speed, AB = Interaction between of barrel temperature and screw speed, R^2 = Coefficient of determination, * = Significant effect ($p < 0.05$)

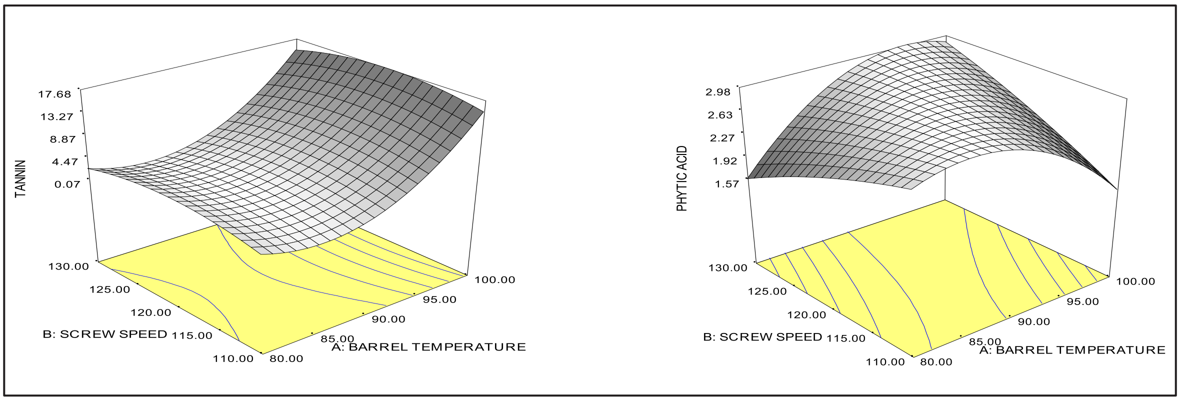

Figure 1: Response surface plots for tannin and phytic acid content of extruded snacks from malted sorghum flour per 100 g

Table 3: Physical properties composition of extruded snacks from malted sorghum flour

Runs	Barrel Temperature (°C)	Screw Speed (rpm)	Lightness (L*)	Redness (a*)	Yellowness (b*)	Chewiness (N)	Fracturability (N)	Hardness (N)
1	80.00	110.00	53.66	7.17	22.70	26.56	23.71	668.32
2	100.00	130.00	41.16	7.78	18.25	22.93	62.12	405.45
3	90.00	134.14	44.05	8.15	19.40	18.69	29.39	446.4
4	100.00	110.00	40.74	8.84	19.97	20.29	59.70	411.37
5	90.00	120.00	47.22	8.90	22.11	17.63	30.65	473.70
6	90.00	120.00	4 8.12	8.72	22.31	16.62	30.55	474.70
7	90.00	105.86	42.10	8.19	18.62	18.93	37.26	471.61
8	90.00	120.00	47.42	8.60	22.31	17.63	30.65	473.70
9	80.00	130.00	51.77	7.85	23.39	24.98	25.13	674.66
10	90.00	120.00	47.32	8.72	22.21	18.53	28.55	475.70
11	75.86	120.00	56.83	7.64	23.25	28.12	13.24	767.65
12	90.00	120.00	47.32	8.90	22.30	18.63	27.65	473.70
13	104.14	120.00	35.89	9.08	16.76	15.78	72.29	405.65

Table 4. The chewiness of the extruded snacks ranged from 15.78 to 28.12N. The main effect of BT and SS, the interaction effect of BT and SS had a significant ($p < 0.05$) effect on the chewiness of the extruded snacks with the coefficient of regression of 0.90. The fracturability of the white and red extruded snacks ranged from 13.24 to 72.29N. The main effect of BT, quadratic effect of BT and interactive effect of BT and SS had a significant ($p < 0.05$) effect on the fracturability of the extruded snacks with the coefficient of determination of 093. The hardness of the extruded snacks ranged from 405.45 to 767.65N. The main effect of BT had a significant ($p < 0.05$) effect on the hardness of extruded snacks. Also, the main effect of screw speed had a significant ($p < 0.05$) effect on the hardness of extruded snacks. Also, quadratic effect of BT and SS had a significant ($p < 0.05$) effect on the hardness of extruded snacks.

DISCUSSION

The decrease in moisture content as the BT and SS increased could be as a result of increased thermal energy of the material thereby enhancing moisture removal. With the low moisture content observed in this study, quality of the extruded snacks will discourage microbial attack because moisture content is a major factor, it is the amount of moisture present in food and it goes a long way in determining the shelf life of food products (21). It was reported that high moisture product higher than 12% mostly have short shelf life in comparison with low moisture product of less than 12% (22). Similarly, low moisture content of 1.86 to 5.20% was reported Oke et al (23) in extruded noodles. The low moisture content in the

Table 4: Regression coefficient of physical properties composition of extruded snacks from sorghum flour

Parameters	Lightness (L*)	Redness (a*)	Yellowness (b*)	Chewiness	Fracturability	Hardness
β_0	47.48	8.77	22.25	13.61	10.61	674.3
A	-6.64*	0.45*	-2.13*	7.84*	10.29*	286.92*
B	0.16	-0.055	9.14E-03	7.85*	2.62	148.11*
A^2	-0.031*	-0.29*	-0.73	-2.17	17.86*	-58.85
B^2	-1.67*	-0.39*	-1.23*	-0.74	5.64	-25.85
AB	0.58	-0.43*	-0.60	6.73*	25.25*	225.19*
R^2	0.96	0.92	0.90	0.90	0.93	0.92

Where βo = Intercept, A = Main effect of barrel temperature, B = Main effect of screw speed, A^2 = Quadratic effect of barrel temperature, B^2 = Quadratic effect of screw speed, AB = Interaction between of barrel temperature and screw speed, R^2 = Coefficient of determination, * = Significant effect ($p < 0.05$)

extruded snacks from malted sorghum flour will enhance its shelf stability. The crude protein content decreased with increase in BT and SS which could be as a result of protein denaturation. In the process of extrusion cooking, the components of the feed materials come in contact with pressure and high temperature and this damages or improves the protein quality in the extruded materials (24). Proteins are compound that have amino acids as building blocks. During the process of extrusion cooking, disulfide bonds are broken down and may also reform which may harm the protein quality of the extruded snacks (14). Fat gives a lubricating effect as well as enhances the eating quality of foods (15). The crude fat content of the extruded snacks decreased with increase in BT and SS. During extrusion, there is formation of amylose-lipid complex and the rate depends on the type of lipid and starch present (25). Barrel temperature of between 80 to 100°C and relatively low feed moisture (20%) that was used in this work was reported to cause higher amount of starch and lipid complex formation (26). Therefore, high viscosity of the feed used may have resulted into formation of lipid complex thereby causing the reduced fat content in the extruded snacks. Fibre is responsible for the movement of food during digestion in the body. The fibre content of extruded snacks increased with increase in BT and SS. This may possibly be due to increase in fibre (soluble) and the enzyme resistance starch fraction. This is in line with the report of Sobukola et al (15) in the production of extruded yam-based pasta. Total ash content present in food can be used as a measure of mineral elements present in food. Ash is the remains left after organic matter and moisture have been removed as a result of heating (27). The total ash content of the extruded snacks decreased with increase in BT and SS, in accordance with the report of Ainsworth et al (28) in extruded snacks. The carbohydrate content of the extruded snacks increased with increase in BT and SS. This is expected because increasing pressure, temperature and shear conditions during the process of extrusion cooking increase the rate at which gelatinization takes place and this result into simple sugars like free glucose and starch degradation into dextrin (29). From the response surface plot in Figure 1, tannin content reduced as the BT and SS increase which may be due to high temperature the materials were exposed to during extrusion cooking. A similar trend was reported by Anton et al (30) extruded snacks from cereal and legume blend. Phytic acid reduced as the BT and SS increases, this reduction may be attributed to phytate degradation to simpler molecular weight substances (30). The decrease in the anti-nutritional compounds could be as a result of its breakdown due to thermal treatment and this would help the bioavailability of minerals in the extruded snacks; as the presence of phytic acid may be responsible for non-availability of such minerals as revealed by Anuoye et al (31). Colour plays a very important quality role in snacks. It shows the extent to which cooking and chemical reactions have occurred (32). The reduced lightness could be as a result of mallard reaction between amino groups and carbonyl group and also as a result of degree of cooking Murphy et al (32). As the BT and SS increased, the redness also increases. This may be due to starch dextrinization and caramelization reaction (33). Increase in BT and SS increases the yellowness of extruded snacks and this result agrees with the findings of Samaila et al (24). As the BT and SS increased, chewiness decreased in extruded snacks. This reduction agrees with the findings of Liu et al (34) which linked decrease in chewiness to the increase in screw speed. Hardness is the amount of force needed by molar teeth to crush the extruded snacks. It was observed from the study that hardness decreased as the BT and SS increased, in accordance with the findings of Dehghan et al (35) which stated that increased BT and SS resulted in the production of softer snacks.

CONCLUSION

Results obtained from this study showed that proximate compositions of the extruded snacks from malted sorghum flour were significantly affected by BT and SS. Tannin and phytic acid were significantly affected by BT and SS. Lightness, fracturability and hardness significantly reduced with increase in BT and chewiness is significantly affected by SS. However, from the optimization result, extruded snacks with BT of 95°C and SS of 115.5 rpm had the highest desirability of 0.87. Based on the outcome of the optimization process, the optimum extrusion condition for the extruded snacks were BT of 95°C and SS of 115.5 rpm.

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