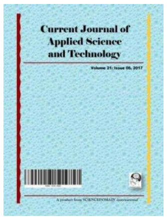

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Influence of Extrusion Variables on Proximate Composition Some Nutrient and Antinutrient Contents of *Dakuwa* Extrudates Produced from Blends of Sorghum (*Sorghum bicolour* L) Groundnut (*Arachis hypogea* L) and Tigernut (*Cyperus esculentus*)

M. Yusuf[1*], M. Halilu[1] and K. B. Filli[1,2]

[1]Department of Food Science and Technology Modibbo Adama University of Technology Yola, PMB 2076 Yola, Nigeria.
[2]Swedish Institute for Food and Biotechnology Gothenburg, Sweden.

Authors' contributions

This work was carried out in collaboration between all authors. Author MY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MY managed the analyses of the study. Authors MH and KBF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Extrusion process was used in the development of *Dakuwa* extrudates from blends of (*Sorghum bicolour* L) groundnut (*Arachis hypogeal* L) and tigernut (*Cyperus esculentus* L). The influence of extrusion variables on proximate composition, some nutrient and antinutrient content of dakuwa extrudate were ascertained using the Three Factor Three Levels Full Factorial Experimental Design (TFTLFFED). The variables used includes feed moisture content (18, 22 and 26%) barrel temperature (90, 100, and 110ºC), feed composition 50:20:30, 50:25:25 50:30:20). The extrusion

**Corresponding author: E-mail: yusufmoh2015@yahoo.com;*

was carried out using twin screw food extrusion cooker (SLG 65-III Model China). The results showed that extrusion significantly ($p<0.05$) affect the proximate nutrient and antinutrient content of the extrudate. Extrusion decreased the moisture and the crude fibre from 22 to 6.25% and 2.65 to 2.44% respectively. It increased the protein, the ash content and the carbohydrate content from 14.73 to 16.89%, 1.50 to 2.06% and 49.74 to 64.64 % respectively. Extrusion decreased the phytic acid and tannins from (5.56 and 3.25 mg/100g) un-extruded to (3.36 and 2.45 mg/100 g) extrudate. Extrusion increased the calcium, iron, magnesium and zinc from (0.47, 1.05, 3.25 and 0.60 g/100 g) un-extruded to (2.33, 1.79, 3.49 and 1.53 g/100 g) extrudate.

Keywords: Sorghum; groundnut; tigernut; extrusion; proximate composition nutrient and antinutrient content.

1. INTRODUCTION

Sorghum is the fifth most widely grown crop in the world. The primary countries that produce sorghum in large quantities are the United States of America, China, India, Argentina, Nigeria and Mexico. These countries produce greater than 5% of world total production. More than 50% of the whole world production of sorghum is for human consumptions except in the United States of America where sorghum is grown entirely as a feed grain for local use or export. Sorghum is grown over a wide range of climatic conditions. It withstands limited moisture and adapts to high temperatures Hui and Willey [1]. Sorghum (*Sorghum bicolor)* (*L.*) *Moench*) is a critically important food crop in Sub-Saharan Africa on account of its drought tolerance. The increased use of sorghum as food in this region could alleviate the problem of chronic undernourishment, as sorghum is much better suited to cultivation in the semi-arid tropics than non-indigenous cereals such as wheat or maize. According to Ryden et al. [2], grain sorghum is cultivated by farmers on the subsistence level in the semi-arid tropics worldwide and consumed as staple food by humans. The continent of Africa is one of the largest producers of sorghum and produces approximately 18.5 million metric tons of sorghum annually. Sorghum contains high protein content its protein content is far better than that of corn however sorghum were underutilized particularly in sub-Saharan Africa despite its abundance what limits its utilization is the presence of anti-nutritional factors which impair digestion. The anti-nutritional factors include phytic acid and tannins. The compound phytic acid is found in the outer layer of the kernel. Sorghum grain is comparable to some other cereal grains in terms of nutrient content. However, it contains some anti-nutrient factors that affect the nutrient absorption by human body system. Reductions of these antinutrient factors such as phytic acid and tannin have been documented. Tannins are plant secondary metabolites (not in a metabolic pathway) that are characteristically rich in phenolic hydroxyl groups Larry et al. [3].

Groundnut has contributed immensely to the development of the Nigerian economy. From 1956 to 1967, groundnut products including cake and oil accounted for about 70% of total Nigeria export earnings, making it the country's most valuable single export crop ahead of other cash crops like cotton, oil palm, cocoa and rubber Harkness et al. [4]. Presently, it provides significant sources of cash through the sales of seeds, cakes, oil and haulms Olorunju et al. [5]. Groundnut plays an important role in the diets of rural populations, particularly children, because of its high contents of protein and carbohydrate. It is also rich in calcium, potassium, phosphorus, magnesium and vitamin E.

Tigernuts (*Cyperus esculentus*) have long been recognized for their health benefits as they are rich in fiber, protein and natural sugars, minerals (phosphorus, potassium) and vitamins E and C Belewu and Belewu [6]. *Cyperus esculentus* is a popular plant seed in Nigeria and known by different names by different ethnic groups. In Hausa, it is known as "aya", in Yoruba "ofio" and in Ibo "aki-Hausa". It grows well in the middle belt of Nigeria Okafor et al. [7] where three varieties are cultivated. These varieties include; the black, brown and yellow that has two varieties, the large and small. The yellow is larger in size, more attractive in colour and has flesher body Belewu and Belewu [8]; Umerie et al. [9]; Belewu and Abodurin [10].

Dakuwa is a cereal and groundnut based snack. It is mainly consumed in the northern parts of Nigeria. *Dakuwa* is prepared from mixtures of cereals, groundnut, ground pepper, ginger, sugar and salt. The ingredients are thoroughly mixed, pounded and molded into balls that can be eaten without further processing Abdulrahman and Kolawole [11]. Nkama and Gbenyi [12] reported that *dakuwa* are also produced from cereals (maize, millet and sorghum), tigernuts and groundnuts. These authors also reported that in the traditional method of *dakuwa* processing, the grains are cleaned, toasted and ground together to give a paste.

Extrusion technology, well-known in the plastics industry, has now become a widely used technology in the agro-food processing industry, where it is referred to as extrusion-cooking. It has been employed for the production of so-called engineered food and special feed. Extrusion cooking is a thermodynamically efficient industrial method of cooking and drying a wide range of foods based on cereals or vegetable proteins or mixtures of both Carl et al. [13]. Extrusion cooking process has become a highly trendy process in the cereal, snack, and pet food industries that use starch and protein as raw materials to produce highly valuable food product Lin et al. [14]. The adoption of extrusion technology in the production of dakuwa is paramount considering the significance of extrusion technology in the development of novel food that is highly nutritious. This observed effect is in line with report by Yusuf et al. [15] in ascertaining the effect of barrel temperature, feed composition and feed moisture content on functional properties of *Dakuwa* extrudate. The result revealed that extrusion played a significant role in increasing the water absorption index, water solubility index, water hydration capacity and a decrease in viscosity. These findings suggest that extrusion has a significant role in improving the nutrient density of the extrudates.

The proximate content considered includes moisture, protein, fat, ash carbohydrates and minerals elements which include zinc iron calcium and magnesium, the antinutrient content considered includes phytic acids and tannins. The objectives of this research are to determine the influence of extrusion variables on the proximate some nutrient and antinutrient content of d*akuwa* extrudates using three factor three level full factorial experimental design.

2. MATERIALS AND METHODS

2.1 Sources of Raw Materials

Sorghum (*Sorghum bicolour L*) red variety, Groundnut (*Arachis hypogeal L*) red skin, Tigernut (*Cyperus esculentus L*) brown variety and granulated red pepper (*Capsicum annum*) was obtained in Jimeta modern market, Yola north local government area of Adamawa State.

2.2 Preparation of Raw Materials

Sorghum, groundnut and tigernut were sorted manually, cleaned and washed with clean water and allowed to dry in the conventional oven at 50ºC for 1hr, the sorghum groundnut and tigernut were roasted at 150ºC for 30 minutes in baking oven. The sorghum and tigernut was size-reduced to flour and sieved to obtain the particle size of 0.05 mm, while the groundnut was grinded to paste using grinding machine (7 hp India). The sorghum, groundnut and tigernut grits were mixed together in a ratio of 50:20:30, 50:25:25 and 50:30:20 respectively. To 1.5 kg of this mixture 2.5% of granulated red pepper (*Capsicum annum*) was added. The mixture were then packaged and ready for extrusion. The raw material preparation, the experiment and the analysis was conducted in the Department of Food Science and Technology, Modibbo Adama University of Technology Yola, Adamawa state Nigeria.

2.3 Full Factorial Design

To construct an approximation model that can capture interactions between *N* design variables, a full factorial approach may be necessary to investigate all possible combinations Montgomery, [16]. A factorial experiment is an experimental strategy in which design variables are varied together, instead of one at a time. The lower and upper bounds of each of *N* design variables in the optimization problem needs to be defined. The allowable range is then discretized at different levels. If each of the variables is defined at only the lower and upper bounds (two levels), the experimental design is called 2^N full factorial. Similarly, if the midpoints are included, the design is called 3^N full factorial. Factorial designs can be used for fitting second-order models. A second-order model can significantly improve the optimization process when a first-order model suffers lack of fit due to interaction between variables and surface curvature. A general second-order model is defined as

$$y = a_o + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n} a_{ii} x_i^2 + \sum_{i=1}^{n} \sum_{i=1, i<j}^{n} a_{ij} x_i x_j \quad (1)$$

Where x_i and x_j are the design variables and a are the tuning parameters. The construction of a quadratic response surface model in *N* variables requires the study at three levels so that the tuning parameters can be estimated. Therefore, at least (*N*+1) (*N*+2) /2 function evaluations are necessary. Generally, for a large number of variables, the number of experiments grows exponentially (3^N for a full factorial) and becomes impractical. A full factorial design typically is used for five or fewer variables. However, in this experiment three factor three levels full factorial design were used for the design as shown in Table 1 and 2 Yusuf et al. [17].

2.3 Experimental Design

A Three factor Three level Experimental Design (3x3x3) was used to determine the effect of extrusion on some nutrient and antinutrient content of Nigerian indigenous cereals and legume based snack product (*Dakuwa*).The extrusion variables that were considered include: Feed moisture content (Fm), Barrel temperature (Bt) and Feed composition (Fc), each was varied at 3, 3 and 3 levels respectively as shown in Fig. 2, Table 1 and 2. Thus, this is a 3 (feed moisture) x 3 (barrel temperature) x 3 (feed composition) full factorial design treatment for a mixture of flour. The analysis of variance was carried out to investigate the effect of operating conditions on the final extruded product quality using version 16 of Gen stat software Genstat [18].

2.4 Extrusion Processing

The extrusion cooking process was performed using a pilot scale co-rotating twin screw food extrusion cooker (SLG65-III Model China) the extruder has a feeder at the top with constant feed rate, it also has a control panel board where the barrel temperature was set. The machine has constant screw speed of 150 rpm and a die diameter of 3mm. The twin screws within the barrel are surrounded with heaters controlled by the control panel board. The grits were alternatively fed into the extruder inlet by the volumetric feeder. The temperature of the three zones of the extruder was controlled by Eurotherm controller and was read on separate control panel board. Extruded samples were collected when the extrusion process parameters reach steady states. Steady state was reached when there was no visible drift in torque and die pressure. Necessary calibration and adjustment of the barrel temperature of the extruder were performed prior to the main extrusion cooking process. Feed rate and screw speed were constant. The feed composition was varied at 50:20:30, 50:25:25 and 50:30:20 ratios of sorghum, groundnut and tigernut respectively. The barrel temperature of zone three, which was located just before the die was allowed to operate at different temperatures ranging from 90°C to 110°C. By looking at the characteristic of the products from the extrusion, the barrel temperature was selected for the experiment. The moisture content of the material was adjusted to give moisture contents of 18%, 22% and 26 % by using hydration equation (2).

$$W_a = S_W \text{ x} \left(\frac{M - Mo}{100 - M}\right) \quad (2)$$

Where:

Wa = Weight of water added (g)
S_w = Sample flour weight (g)
M_o = Original flour moisture content (% weight base)
M = Required dough moisture level (% weight base)

The extrusion experiment was conducted using 3 factor 3 level experiment design (3^3), with 1 factor representing extruder barrel temperature, with levels (90°C 100°C 110°C). 2nd Factor representing feed composition with levels (50:20:30, 50:25:25, 50:30:20) for sorghum groundnut and tigernut respectively, the 3rd factor representing feed moisture, with levels 18% 22% 26% as shown in Table 1 and 2. The extruder barrel temperature was set at 90°C and 9 samples were run, and at 100°C another 9 samples were run. Finally, at 110°C the remaining 9 samples were then run. As shown in

Table 1. Factors and levels of the 3x3x3 full factorial experimental design

Factors	Symbol	Factor levels		
		1	2	3
Barrel temperature (ºC)	X_1	90	100	110
Feed compositon (Sorghum, groundnut, tigernut)	X_2	50:20:30	50:25:25	50:30:20
Feed moisture (%)	X_3	18	22	26

Table 2. Experimental design of extrusion experiment in their coded form independent variables in coded form

Runs	Bt (X_1) Levels 1 2 3	Fc (X_2) Levels 1 2 3	Fm (X_3) Levels 1 2 3
1	1	3	2
2	1	3	1
3	1	3	3
4	1	2	2
5	1	2	1
6	1	2	3
7	1	1	2
8	1	1	1
9	1	1	3
10	2	2	3
11	2	2	2
12	2	2	1
13	2	3	1
14	2	3	2
15	2	3	3
16	2	1	1
17	2	1	3
18	2	1	2
19	3	2	3
20	3	2	3
21	3	2	1
22	3	1	1
23	3	1	3
24	3	1	2
25	3	3	3
26	3	3	2
27	3	3	1

The experiment was carried out in randomized order. (Bt) = Barrel temperature with levels 1 2 and 3 represents 90 100 & 110ºC, (Fc) = Feed composition with levels 1, 2 and 3 representing 50:20:30, 50:25:25 and 50:30:20 for ratios of sorghum groundnut and tigernut respectively. (Fm) = Feed moisture with levels 1, 2 and 3 which represent 18%, 22% and 26% respectively

Tables 1 and 2 for experimental design in coded and natural forms. In each case, the screw speed remains constant at 150 rpm and the die diameter remain 3 mm. At each experimental run, the mean value of length, diameter and weight of the extruded were measured.

3.4 Analytical Methods

3.4.1 Chemical composition

The proximate composition of the ingredients and the extruded was analyzed by standard methods of Association of Official Analytical Chemist AOAC [19].

3.4.1.1 Moisture content

A clean crucible was dried in an oven at 105°C for an hour and placed in desiccators to cool, and the weight of crucible (W_1) was determined. 5g of samples was weighed in dry crucible (W_2) and was dried at 102°C for 5 h in oven after cooling to room temperature, and was weighed (W_3) again.

At the end the moisture content was determined from the equation (3.2):

Moisture content in percent (%) =

$$\left(\frac{W_2 - W_3}{W_2 - W_1}\right) \text{x } 100 \quad (3)$$

Where:

- W_1 = Weight of the drying crucible,
- W_2 = Mass of the drying crucible and the sample before drying,
- W_3 = Mass of the drying crucible and the sample after drying.

3.4.1.2 Crude protein

Protein content was determined according to AOAC [20] using the official method 979.09. A digestion flask containing sample, to which some amount of acid mixture (concentrated sulphuric acid and concentrated orthophosphoric acid) and catalyst mixture (K_2SO_4 and selenium) was added and was exposed to a temperature in a Kjeldahl digestor (Tecator instruments AB, Sweden). Next, the sample was cooled and 40 % NaOH was added to it as indicator. Then the sample was distilled and the distillate was titrated with standardized 0.1N sulphuric acid to a reddish colour.

$$\text{Nitrogen (\%)} = \frac{([(V2-V1)]-B)\text{ X N X }14.007}{Wo} \text{ x } 100 \quad (4)$$

Where:

- V_2 = Volume of the standard sulphuric acid solution used in the titration of the sample
- V_1 = Volume of the standard sulphuric acid solution used in the titration of the blank
- B = Volume of sulphuric acid consumed blank
- N = Normality of standard sulphuric acid
- W_o = Weight of the sample, g

Protein content (%, w/w) = % Nitrogen x Factor specific for different product

3.4.1.3 Crude fat

To measure the fat content of the samples, AOAC [21] method was followed. Empty extraction flasks were cleaned and dried at 92 ^{o}C for at least an hour in an oven and were kept in the desiccators to cool for at least half an hour. The mass of cooled flasks was weighed (W_1). 5 g of the sample was weighed (W_2) into each of the thimbles lined with fat-free cotton at their upper and bottom. The thimbles with their sample content were placed into the soxhlet extraction chamber. A 40 ml of petroleum ether was added into each flask used for the extraction. The extraction process was done for 4 hr. Then the flasks with their contents were removed from the soxhlet and placed in drying oven at 92^{0}C for 1 hr. The flasks were then placed in desiccators for 30 min. The masses of each flask together with its fat contents were weighed immediately after it is taken out of the desiccators (W_3).

The crude fat content was calculated from the equation (3.4):

Weight of fat W= W_3-W_1

$$\text{Fat } \frac{\text{g}}{100\text{g}} \text{ fresh sample} = \frac{\text{W1}}{\text{W2}} \times 100 \qquad (5)$$

Where:

- W = weight of fat
- W_3 = weight of fat + flask after extraction and drying
- W_1 = weight of empty extraction flask
- W_2 = weight of the sample

3.4.1.4 Dietary fiber

To measure the dietary fiber content of the samples, AOAC [22] method was followed. 2.0 g of the sample was weighed in each of 600 ml beaker. A 200 ml of 1.25%.

Sulphuric acid solution was added to each beaker and it was allowed to boil on hot plate for 30 min by rotating and stirring periodically. During boiling the level was kept constant by addition of hot distilled water. After 30 min, 20 ml of 28% potassium hydroxide solution was added to each beaker and again allow to boil for another 30 min. The level was kept constant by addition of hot distilled water. The solution in each beaker was then filtered through crucibles containing sand by placing each of them on Buchner funnel fitted with rubber stopper. During filtration, the sample was washed with hot distilled water. The final residue was washed with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution and finally with acetone. Each of the crucibles with their contents was dried for 2 hr at 130°C in an oven and cooled in desiccators and weighed (W_1). Then again they were ashed for 30 min at 550°C in furnace and were cooled in desiccators. Finally, the mass of each crucible was weighed (W_2).

The crude fiber was calculated from the equation (3.5):

$$\text{Total Crude fiber} = \left(\frac{W_1 - W_2}{W_3}\right) \times 100 \qquad (6)$$

Where:

- W_1 = Crucible weight after drying
- W_2 = Crucible weight after ashing
- W_3 = Sample dry weigh

3.4.1.5 Total ash

Ash was determined by the method of the Association of Official Analytical Chemists" AOAC [23] using the official method 923.03. Clean porcelain crucible, was dried at 120^{o}C in an oven, it was ignited at 550°C in a muffle furnace for 3 hours. And was cooled in desiccators and weighed (m_1). Then 2.0 g samples were weighed into a previously dried and weighed (m_2) porcelain crucible. These samples were dried at 120°C for 1 hour and carbonized in an oven until the contents turn black. The crucible with the contents was placed in a Muffle furnace and be set at 550˚C for 1h to ignite until ashing was completed. After this period the crucible with its content was removed and cool in desiccators. The crucible with the residue was weighed (m_3). The weights of the ash were express as a percentage of the initial weight of the samples. The total ash was expressed as percentages on dry matter basis as follows

$$\text{Total Ash (\%)} = \left(\frac{M_3 - M_1}{M_2 - M_1}\right) \times 100 \qquad (7)$$

Where:

(M_2-M_1) is sample mass in g on dry base and (M_3-M_1) mass of ash in gm

3.4.1.6 Total carbohydrates

Total carbohydrates (CHO) including fiber was determined by the difference that is by subtracting the sum of the percentages of moisture (M), crude protein (P), lipid (F) and ash content (A) from100.

Total% CHO= 100- [% M +% P+% F+%A] (8)

3.4.4.3 Determination of mineral content of dakuwa extrudate

The AOAC [24] method was used for the total mineral determination. 2 g of raw and extruded samples were weighed and placed in a crucible and heated at 600°C for 3hrs in muffle furnace. After cooling in a desiccator, the ashes were transferred into individual beaker and 20ml of concentrated trioxonitrate (v) acid was added in each case and followed by 10ml of H_2O_2. The mixture was heated to a temperature of 90°C for 1h in a muffle furnance. It was then transferred to a 500 ml volumetric flask and made up to mark with distilled water. From this stock solution, 2 ml was further pippeted into 500ml volumetric flask and made up to mark with distilled water. From this stock solution, 2 ml was further pippeted into 50 ml volumetric flask and made to mark with distilled water. The solution was analysed using atomic absorption spectro-photometer (AAS model PERKIN- ELMER 2380). Standard was prepared from 1000ppm stock solutions supplied along with the equipment. 10ml of each solution was pippeted into a 100 ml volumetric flask and the volume made up to mark with distilled water to give 100 ppm of each element. From this solution, 0.2, 0.5, 1.0, 2.0, 3.0 and 10 ml respectively were taken and made up to mark with distilled water in 100ml volumetric flask. Concentrations of samples were obtained from the calibration curve and the results were verified using the equation below.

$$\text{Concentration (mg)} = \frac{\textit{Sample absorbance X Concentration of standard}}{\text{Absorbance of standard}} \quad 9)$$

3.4.3 Analytical method of anti-nutritients

3.4.3.1 Phytic acid

Phytic acid analysis was determined by using Latta and Eskin method as modified by Vaintraub and Lapteva [25]. 5 mg of the sample was extracted with 100 ml 2.4% HCl for 1h at an ambient temperature and centrifuged (3000 rpm/30min). The supernatant was used for phytate estimation. 1 ml of Wade reagent was added to 3 ml of the sample solution and centrifuged. The absorbance at 500 nm was read using UV-VIS spectrophotometer (Beckman DU-64-spectrometer, USA). A series of standard solutions were prepared containing 0, 5, 10, 20, and 40 µg/ml of phytic acid (analytical grade sodium phytate) in 00.2N HCl. A 3ml of standard was added into 15ml of centrifuge tubes with 3 ml of water which was used as a blank. A 1 ml of the Wade reagent was added to each test tube and the solution was mixed on a Vortex mixer for 5 seconds. The mixture was centrifuged for 10 min and the absorbance of solutions (both the sample and the standard) was measured at 500 nm by using de-ionized water as a blank. A standard curve was plotted from absorbance versus concentration and the slope and intercept were determined and used in the calculation of phytic acid. Phytate: mineral molar ratios were calculated using the molecular weight of IP6 =660.

PA (mg/100g) = (absorbance-intercept)3/ (slope x density x weight of sample x 10) (10)

Where:

PA=Phytic acid

3.4.3.2 Tannins

Tannins were determined by the modified vanillin assay Butter et al. [26]. 200 mg of the flour samples were weighed and then extracted with 10 ml absolute methanol for 20 min rotating screw cap culture tubes (130 x100 mm). The mixture was centrifuged for 10 min at 3000 x G and the supernatant was used in the analysis. 1.0 ml aliquot of catechin standard was dispended into two sets of culture tubes and each sample was brought to 1.0 ml by the addition of absolute methanol. The tubes were incubated in water bath. 5 ml of the working vanillin reagent was added at 1 min interval to one set of standards, and 5 ml of the 4% HCl solution was added at 1 min interval to the second set of standards. After 20 min, the absorbance of sample solution and the standard solution were measured at 500 nm by using spectrophotometer. The absorbance of the blank was subtracted from the absorbance of the corresponding vanillin- contain sample. A standard curve was plotted (Absorbance vs Catechin) and the linear portion of the curve was extrapolated to produce the standard curve.

Tannins in mg/100g = (absorbance density x weight of sample x10) (11)

4. RESULTS AND DISCUSSION

4.1 Proximate Composition of Extruded and Un-extruded Product

The results of proximate composition of extruded are shown in Table 3. The least moisture content of 5.40 % was recorded at design point 11 representing 100°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut respectively and 22% feed moisture content, which was not significant with design points 3, 4, 8, 11, 15, 16. On the other hand, the highest moisture content of 7.40% was observed at design point 20 representing 110°C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut which is not significant with design point 24. The least moisture content recorded at design point 11 was as a result of 25% groundnut content in the blend that is characterized with high fat content that hindered moisture absorption during extrusion. On the other hand the highest moisture content recorded at design point 20 could be as a result of low percentage of groundnut content 20% in the blend and high tiger nut content of 30% which is characterised of having high carbohydrate that influences moisture retention. The analysis of variance reveal that both linear quadratic and interaction significantly ($p<0.05$) affect the moisture content of the extrudates.

The influence of independent variables (Barrel temperature, Feed composition and feed moisture) on the moisture content of the extrudate was also studied. Barrel temperature significantly ($p<0.05$) affect the moisture content of the extrudate. As the temperature increased from 90°C to 110°C the moisture content decreased from 6.09 to 5.84%. A significant difference ($p>0.05$) was not observed on feed composition and feed moisture on the moisture content of the extrudate. However, as the feed moisture increases the extrudate moisture content was found to increase as shown in Table 4. The moisture content of raw and extruded product are 22% and 6.25% with extrudate having the lower moisture content. The decrease in moisture could be attributed due to the extrusion barrel temperature and the loss of moisture in to vapour as the product coming out from the extruder die with the flash off of vapour. The moisture content of the product is important as far as keeping the quality of the product is concerned. High moisture content encourages microbial growth and allows an increase in metabolic rate which depletes extract content.

The least protein content was recorded at design point 23 representing 110°C barrel temperature, 50:20:30 feed composition for sorghum groundnut and tiger nut and 26% feed moisture content, which is not significant ($p<0.05$) with design point 12. On the other hand, the highest protein content of 25.07% was recorded at design point 2 representing 90°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 18% feed moisture content. The least protein content recorded at design point 23 was as a result of high barrel temperature of 110°C, and the least groundnut content in the blend 50:20:30 and the reason being that groundnut contains high protein content. The highest moisture content in the blend also contributed to lesser protein content in the product. And this observed effect is in line with reported literature by Filli & Nkama [27] that moisture content plays the significant role in reducing the protein content of millet-soybean extrudate.

On the other hand, the highest protein content recorded at design point 2 could be because of low barrel temperature of 90 ^{0}C high groundnut content of 30% in the mix and low moisture content. All these contributed to the increase in the protein content of the extruded. Analysis of variance showed that both linear quadratic and interaction significantly ($p<0.05$) affect the protein content of the extrudates. Therefore as the barrel temperature increased from 90°C to 100°C protein content increased from 16.7% to 17.9%, but further increase in temperature resulted in decrease in protein content of the extrudates, at 110°C barrel temperature protein decreased to 16%. The decrease in protein content of the extrudate with increase in barrel temperature could be because during extrusion cooking, the chemical constituent of the feed material is exposed to high temperature, high shear and high pressure and these improve or damage the nutritional quality of the protein in the extrudate material by various mechanisms Leszek [28].

Feed composition significantly ($p<0.05$) affect the protein content of the extrudate, with 50: 20:30 recorded the high protein content of 17.74% while 50:30:20 recorded the lowest protein content of 16.37%. feed moisture content significantly ($p<0.05$) affect the protein content of the extrudate as the moisture increased from 18 to 22% the protein content of the extrudate increased from 16.9% to 17.45% but at 26% moisture content protein decreased to 16.32% Table 4.

Table 3. Combine effect of extrusion variables on proximate composition (%) of extrudate

SN levels	Bt 1 2 3	Fc 1 2 3	Fm 1 2 3	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
1	1	3	2	6.13^{b}	12.18^{h}	6.60^{d}	2.33^{a}	1.50^{b}	71.24^{a}
2	1	3	1	6.33^{b}	25.07^{a}	7.20^{c}	2.60^{a}	1.51^{b}	57.28^{c}
3	1	3	3	5.73^{c}	14.13^{f}	8.94^{ab}	2.67^{a}	2.24^{a}	66.29^{b}
4	1	2	2	5.73^{c}	24.97^{b}	9.13^{a}	2.73^{a}	1.84^{ab}	55.60^{c}
5	1	2	1	6.13^{b}	14.00^{f}	7.77^{c}	2.67^{a}	2.34^{a}	67.15^{b}
6	1	2	3	6.67^{b}	13.20^{g}	6.54^{d}	2.67^{a}	2.27^{a}	68.66^{b}
7	1	1	2	6.13^{b}	14.12^{f}	9.20^{a}	2.80^{a}	1.90^{ab}	65.84^{b}
8	1	1	1	5.53^{c}	17.77^{d}	7.64^{c}	2.80^{a}	2.04^{a}	64.23^{b}
9	1	1	3	6.40^{b}	15.01^{e}	7.27^{c}	2.13^{a}	2.20^{a}	66.98^{b}
10	2	2	3	6.20^{b}	15.97^{de}	7.60^{c}	2.67^{a}	2.34^{a}	62.45^{b}
11	2	2	2	5.40^{c}	20.06^{d}	7.00^{c}	1.87^{ab}	2.44^{a}	62.34^{b}
12	2	2	1	5.80^{bc}	11.67^{i}	6.14^{d}	1.87^{ab}	1.84^{ab}	70.63^{a}
13	2	3	1	5.80^{bc}	18.16^{d}	6.90^{d}	2.33^{a}	1.51^{b}	66.20^{b}
14	2	3	2	6.00^{b}	15.17^{e}	8.00^{b}	2.47^{a}	2.00^{a}	67.53^{b}
15	2	3	3	5.60^{c}	15.97^{e}	8.47^{b}	2.46^{a}	1.51^{b}	57.71^{c}
16	2	1	1	5.73^{c}	14.20^{f}	5.87^{e}	2.13^{a}	1.77^{b}	66.93^{b}
17	2	1	3	6.20^{b}	24.13^{b}	8.14^{b}	2.68^{a}	2.43^{a}	59.79^{c}
18	2	1	2	5.87^{bc}	24.16^{b}	6.54^{d}	1.88^{ab}	2.34^{a}	61.92^{b}
19	3	2	3	6.87^{b}	18.11^{d}	8.57^{b}	2.47^{a}	1.60^{b}	63.71^{b}
20	3	2	3	7.40^{a}	13.20^{g}	8.00^{b}	2.40^{a}	2.57^{a}	64.98^{b}
21	3	2	1	6.40^{b}	14.02^{f}	7.70^{c}	2.47^{a}	1.97^{ab}	64.10^{b}
22	3	1	1	6.87^{ab}	24.00^{b}	5.74^{e}	2.46^{a}	2.07^{a}	58.82^{c}
23	3	1	3	6.73^{b}	11.03^{i}	6.63^{d}	2.53^{a}	2.40^{a}	70.67^{a}
24	3	1	2	7.27^{a}	15.23^{e}	8.60^{b}	2.40^{a}	1.77^{b}	64.73^{b}
25	3	3	3	6.93^{ab}	22.15^{c}	8.00^{b}	2.60^{a}	2.61^{a}	57.71^{c}
26	3	3	2	6.33^{b}	13.64^{g}	8.93^{ab}	2.50^{a}	2.80^{a}	66.39^{b}
27	3	3	1	6.73^{b}	13.15^{g}	7.81^{bc}	2.53^{a}	1.97^{ab}	67.81^{b}
Extruded				6.25^{b}	16.89^{ce}	7.58^{c}	2.06^{a}	2.44^{a}	64.64^{b}
Un-extruded				22^{f}	14.73^{f}	9.80^{a}	1.50^{c}	2.65^{a}	49.74^{d}

Bt= barrel temperature, 1 represent 90 ^{0}C barrel temperature, 2 represent 100 ^{0}C barrel temperature, 3 represent 110 ^{o}C barrel temperature. Fc= feed composition, 1 represent 50 % 25 %25 %, 2 represent 50 % 30 % 20 %, 3 represent 50 % 20 % 30 %. Fm= feed moisture, 1 represent 18%, 2 represent 22%, 3, represent 26 %. Mean with the same superscript within a column are not significantly different (p>0.05) values are triplicate of means. All compositions are represented as Sorghum %: Groundnut % and Tigernut % respectively

Table 4. Influence of independent extrusion variables on proximate composition (%) of extrudate

Extrusion parameters	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
Bt (^{0}C)						
1	6.09^{ab}	16.72^{b}	7.81^{a}	2.59^{a}	1.98^{a}	64.81^{a}
2	5.84^{a}	17.95^{c}	7.18^{a}	2.26^{a}	2.02^{ab}	64.79^{a}
3	6.83^{b}	16.00^{c}	7.74^{a}	2.49^{a}	2.19^{b}	64.32^{a}
Fc (%)						
1	6.30^{a}	17.74^{c}	7.29^{a}	2.42^{a}	2.10^{a}	64.43^{a}
2	6.29^{a}	16.37^{a}	7.57^{a}	2.42^{a}	2.13^{a}	64.40^{a}
3	6.18^{a}	16.56^{c}	7.87^{a}	2.50^{a}	1.96^{a}	65.09^{a}
Fm (%)						
1	6.15^{a}	16.90^{b}	6.97^{a}	2.42^{a}	1.89^{a}	64.80^{a}
2	6.19^{a}	17.45^{c}	8.07^{a}	2.38^{a}	2.02^{a}	64.37^{a}
3	6.43^{a}	16.32^{a}	7.69^{ab}	2.53^{a}	2.29^{a}	64.76^{a}

Bt= barrel temperature, 1 represent 90 ^{o}C barrel temperature, 2 represent 100 ^{o}C barrel temperature, 3 represent 110 ^{o}C barrel temperature. Fc= feed composition, 1 represent 50% 20% 30%, 2 represent 50% 25% 25%, 3 represent 50% 30% 20%. Fm= feed moisture, 1 represent 18%, 2 represent 22%, 3, represent 26%. All compositions are represented as Sorghum %: Groundnut % and Tigernut % respectively

Extrusion increased the protein content of the extrudate by 12.7% from 14.73% to 16.89% as shown in Table 3. And that could be because of in activation of anti-nutrient, the result obtained is in line with reported literature by Cindio et al. [29] who revealed that protein undergoes crosslinking reactions due to the applied heat and shear that causes denaturation of protein during extrusion. Cross-linking causes the formation of a new molecular aggregate structure as a result of that process, the possible cause might be the denaturation of proteins and the in activation of anti-nutritional factors that impair digestion. Onwulata et al. [30] reported incorporation of protein-rich materials into the extruded product will not only increase utilization of that product but also improve the nutritive value of the product by increasing its protein content. The nutritive value of protein depends on the relative amount of essential amino acids and the protein digestibility and bioavailability Mensa-Wilmot et al. [31].

The least fat content was obtained at design point 12 representing 100°C barrel temperature 50:25:25 feed composition and 18% feed moisture content which is not significant with design points 6, 13, 18 and 23. The highest fat content of 9.13 was recorded at design point 4 representing 90°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22% feed moisture content which is not significant with design point 7. The least fat content recorded at design point 12 could be attributed to barrel temperature of 100°C and the least moisture content of 18% since temperature and moisture play significant role in reducing the fat content of the extrudate. Meanwhile, the highest fat content recorded at design point 12 could be as a result of low barrel temperature of 100°C and high moisture content of 22%. The low barrel temperature and feed moisture content deplete the oil extraction in the extrudate, thereby making the extruded to posses high fat content as obtained. The analysis of variance showed that on linear only feed moisture was significant however barrel temperature and feed composition was not significant on quadratic significant difference were not observed. The interaction was significant ($p<0.05$) on the fat content of the extrudates. Feed moisture content showed significant effect at ($p<0.05$) level with 26% feed moisture recording a low-fat content value of 7.69%. Extrusion decreased the fat content of the extrudate from 9.80% raw to 7.58 extrudate, with extrudate having a low fat content. Extrusion cooking has been reported to aid oil extraction since oil is freed during cooking and shearing operations which break fat globules Nelson et al. [32]. Leszek [33] revealed that, lost of lipids during extrusion was first used to explain a mass balance dilemma. The loss of lipid can also be attributed to starch-lipid and protein-lipid complex formations which confer resistant to some lipid extraction techniques. However, in certain extruded foods high in bran than starch tend to contain high free lipid due to non interaction of lipids with starch Guzman et al. [34]. The chance for lipid oxidation that significantly affects product sensory attributes and nutritional quality is reduced during extrusion. This could be attributed to high temperature that inactivates lipolytic enzymes; low residence time of the feed material in the barrel and the formation of starch-lipid complex. However, air cells in expanded products and the release of pro-oxidants by screw wear favour lipid oxidation Leszek [35].

The least ash content of 1.87% was recorded at design points 11 and 12 representing 100°C barrel temperature 50:25:25 feed composition and 22% and 18% feed moisture content respectively, which is not significant with design point 18. The highest ash content of 2.80 % was recorded at design point 7 & 8 representing 90°C barrel temperature 50:20:30 feed composition and 22% feed moisture content respectively.

The least ash content recorded at design point 11 could be because of 100°C barrel temperature and 50:25:25 feed composition for sorghum groundnut and tigernut. This indicates that at high temperature the low ash content was recorded in the extruded and that could be because of the effect of barrel temperature on the ash content of the extruded. The highest ash content recorded at design point 7 could be because of low barrel temperature of 100°C and the highest tigernut content of 30% in the blend which could be attributed to high ash content in tigernut. The analysis of variance revealed that both linear quadratic and interaction were significant ($p<0.05$) on the ash content of the extrudates. Barrel temperature, feed composition and feed moisture were not significant ($p<0.05$) on the ash content of the extrudate, however, the effect of extrusion on the ash content of extrudate has also being studied, with extrudate having the high ash content of 2.06% and the non extruded having 1.50%. The high ash content of the extrudate could be attributed to high barrel temperature and high shear rate involve during the extrusion cooking process.

The least crude fiber content of 1.50% was recorded at design point 1 representing 90°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 22% feed moisture content which is not significant ($p<0.05$) with design points 2 15 16 and 24. On the other hand the highest fiber content of 2.80% were recorded at design point 26 representing 110°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content which is not significant with design points 3, 5, 8, 9, 10, 11, 14, 17, 18, 20, 22, 23, 25, 26.

The least fiber content recorded at design point 1 could be because of low barrel temperature of 90°C. On the other hand the highest fiber content of 2.80% recorded at design point 26 could be because of high barrel temperature since barrel temperature plays significant role in increasing the crude fiber content of the product. The analysis of variance showed that both linear quadratic and interaction were significant ($p<0.05$) on the crude fiber content of the extrudates. Barrel temperature significantly ($p<0.05$) affect the crude fibre content of the extrudate, as the barrel temperature increased from 90 to 110°C, crude fiber increased from 1.98 to 2.19% (Table 4). However, feed composition and feed moisture content were not significant ($p>0.05$) on the crude fiber content of the extrudate. The effect of extrusion condition on the crude fiber content of the extrudate has also being studied. Extrusion reduces the crude fiber content of the extrudate from 2.65 % to 2.44 % as shown in Table 4. This could be because, larger fragments of fibre molecules may be sheared off during extrusion Leszek [36]. The author further reveals that fragments could unite to form large insoluble complexes or Maillard compounds generally termed as lignin. This physicochemical rearrangement may influence profoundly the health benefits of the extruded foods. This phenomenon is utilized in the production of resistant starch (RS) for specific group of people such as the diabetics. Insoluble dietary fibre offers lubrication to anal linings which tremendously helps in minimizing inter luminal pressure, reduced food transient time in the stomach, cut rise in blood glycemic index among others.

The least carbohydrate was recorded at design point 4 representing 90°C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut and 22% feed moisture content, which was not significant with design points 2, 15, 17, 22 and 25. On the other hand, the highest carbohydrate content was recorded at design point 1 representing 90°C barrel temperature 50:30:20 feed composition and 22% feed moisture content, which was not significant ($p<0.05$) with design point 12, 23. The analysis of variance showed that both linear quadratic and interaction were significant ($p<0.05$) on carbohydrate content of the extrudates. However, extrusion increased the carbohydrate content of the extrudate from 49.74% to 64.64% with extrudate having the highest value of 64.64% as shown in Table 4. Increasing temperature, share and pressure conditions during extrusion tends to increase the rate of gelatinization. The possible cause of the high carbohydrate content of the extruded might be due to starch degradation into dextrin and simple sugars like free glucose, this is easily observed in increasing the water solubility index (WSI) value of the extruded which may cause an increase in the proportion of carbohydrates. Complete gelatinization may not occur but, digestibility is improved nonetheless Wang et al. [37]. In essence extrusion may predigest starch depending on the composition of the feed material and operating conditions.

4.2 Effect of Extrusion on the Mineral Content of the Extrudate

4.2.1 Effect of extrusion on the calcium (Ca) content of the extruded

Calcium, the least calcium content of 1.34 g/100g was recorded at design point 12 representing 100°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 22% feed moisture content which is not significant with design points 11, 12 and 23. On the other hand, the highest calcium content of 3.013 g/100 g was recorded at design point 15 & 16 representing 100°C barrel temperature 50:20:30 feed composition for sorghum groundnut and tigernut and 18 & 26 % feed moisture contents respectively.

The least calcium content recorded could be as a result of low calcium content in groundnut which is 30% in the blend formulation. On the other hand, the highest calcium content obtained at design point 15 & 16 could be as a result of high calcium content in tigernut which is 30% in the formulation. A significant difference ($p>0.05$) was not observed on linear and quadratic but the interaction was significant for barrel temperature, feed compositon and feed moisture content on the calcium content of the extrudates.

However calcium content increased with increase in feed composition from 2.103 g/100 g at 50:20:30 to 2.51 g/100 g at 50:30:20 on the other hand calcium content decreased with increase in barrel temperature from 2.72 g/100g at 90°C to 2.15 g/100 g at 110°C The decrease in calcium with barrel temperature could be as a result of sensitivity of calcium to heat, hence high calcium content was recorded at 90°C. The feed moisture content (fmc) decreased the calcium content of the extruded, as the feed moisture increased from 18% to 26% the calcium content was found to decrease from 2.32 g/100 g to 2.30 g/100 g (Table 6).

The effect of extrusion on calcium content of the extruded was studied, with extruded recorded the highest calcium content of 2.33 g/100 g and the un-extruded recorded a low calcium of 0.47 g/100 g. A 79% increase in calcium content was recorded as a result of extrusion. This clearly attested to the fact that extrusion has significant role in increasing the nutrient density of the extruded by in activating anti-nutrient content and enzymes. Calcium is an essential mineral element due to its nutritional significance. Calcium help in bone development and its deficiency could lead to improper development of bone in growing children leading to various deformities of the skeletal system Gahlawat and Sehgel [38]. Calcium contributes towards bone and teeth formation, muscle concentration and blood clothing Beal et al. [39]. The deficiency of calcium may lead to bone disorder known as osteoporosis which is a major public health problem, as it may cause serious complication and requiring costly medical care Badau et al. [40].

4.2.2 Effect of extrusion on the Iron (Fe) content of the extruded

Iron (Fe), the least iron content of 0.67 g/100 g was recorded at design point 20 representing 110°C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut and 26% feed moisture content. And the highest iron content of 2.56 mg/100 g was recorded at design point 1&2 representing 90°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 22 and 18% feed moisture content respectively which is not significant ($p>0.05$) with design points 3, 4 5 6. Barrel temperature plays significant role in reducing the iron content of the extrudate as shown in Table 5. Significant difference ($p>0.05$) was not observed on linear and quadratic but interaction was significant on barrel temperature, feed composition and feed moisture content. Iron content increased with increase in feed composition from 1.56 g/100 g at 50:20:30 to 2.12 g/100 g at 50:30:20. And these could be as a result of inactivation of anti-nutrient content that impairs iron like phytate. The mean iron Fe content decreased with increase in barrel temperature from 2 g/100 g to 1.6 g/100 g and that could be as a result of the effect of heat on Iron (Fe). Feed moisture content decreases the Iron (Fe) content of the extruded from 1.80 g/100 g at 18% to 1.75 g/100 g at 22% and further increase in moisture resulted in an increase in the iron content of the extrudates to 1.81 g/100 g at 26% feed moisture content respectively (Table 6).

Effect of extrusion on the Iron content of the extruded has also being studied, the iron content of the extruded was found to be higher than the non extruded product with extruded having 1.79 g/100 g while un extruded value is 1.05 g/100 g as shown in Table 5 above. Anti-nutrient content like phytate are known to form complexes with element like iron and make it unavailable for digestion, traditional artisanal technologies were found to reduce the anti-nutrient content to the greatest level, however, extrusion was found to reduce anti-nutrient content and improved the nutrient density of the extruded. This is because the phytates binding these minerals are broken down by the extrusion process. Iron is an important element that is necessary for the haemoglobin of red blood cells for the conveyance of oxygen during respiration in the red blood cells hence its prevent anaemia Beal et al. [41].

4.2.3 Effect of extrusion on the magnesium (Mg) content of the extruded

The least magnesium (Mg) content of 3.4 g/100 g was recorded at design point 14 representing 100°C barrel temperature 50:20:30 feed composition for sorghum groundnut and tiger nut and 22% feed moisture content. And the highest magnesium content of 3.59 g/100 g was recorded at design point 16, 17 and 18 representing 100°C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 18% 26% and 22% feed moisture contents respectively.

The least magnesium content recorded at design point 14 could be as a result of high groundnut content of 30% in the blend. On the other hand the highest magnesium content obtained at design point 16 17 and 18 could be attributed to high percentage of tiger nut in the blend (30%). Significant difference at p>0.05 level was not observed for barrel temperature, feed composition and feed moisture content on the magnesium content of the extrudate for both linear and quadratic however it was observed on interaction. Magnesium (Mg) content increased with increase in moisture from 3.48 g/100 g at 18% to 3.49 g/100 g at 26% feed moisture content. And that slight increase could be as a result of inactivation of phytic acid that impaired minerals like (Mg). On other hand magnesium (Mg) content increased with increase in feed composition from 3.49 mg/100g at 50:20:30 to 3.49 g/100 g at 50:25:25 and the highest of 3.53 g/100 g is at 50:30:20 for percentages of sorghum, groundnut and tiger nut respectively.

On the other hand extrudates, magnesium (Mg) content was observed to be decreasing with increase in barrel temperature with 3.50 g/100 g at 90°C and 3.48 g/100 g at 110°C as shown in Table 6. These could be as a result of the effect of barrel temperature on the phytic acid but at high temperature of about 110°C magnesium (Mg) content was found to decrease, and these could be as a result of the effect of heat on the mineral content of the extruded.

The effect of extrusion on the magnesium (Mg) content of the extruded was also studied, with extruded recording the highest number of 3.49 g/100 g magnesium while the un-extruded recorded the lowest content of 3.25 mg/100 g. The percentage increase in magnesium (Mg) content was found to be 6.9% and these could be attributed to the effect of extrusion on the anti-nutrient content of the extruded, extrusion was found to decrease the anti nutrient content, increased the nutrient density of the extruded product.

4.3.4 Effect of extrusion on the Zinc (Zn) content of the extruded

The least zinc content of 0.65 g/100 g was recorded at design point 12 representing 100°C barrel temperature, 50:30:20 feed composition for sorghum groundnut and tigernut which is not significant (p>0.05) with design points 13 &14. The highest zinc content of 2.34 g/100 g was recorded at design point 2&3 representing 90°C barrel temperature, 50:30:20 feed composition for sorghum groundnut and tigernut and 18 & 26% feed moisture contents respectively which are not significant with design point 6.

The least zinc content recorded at design point 12 could be as a result of barrel temperature of 100°C and that could be attributed to the effect of barrel temperature on the zinc content of the extrudate. Then the highest zinc content recorded at design points 2 &3 could be because of low barrel temperature of 90°C. Significant difference was not observed at p>0.05 level for barrel temperature (Bt) feed composition (Fc) and feed moisture content (Fm) on quadratic but it was observed on linear and interaction. Feed moisture content showed positive effect on the zinc content of the extrudate as the feed moisture increased from 18% to 26% the zinc content increased from 1.53 g/100 g to 1.54 g/100 g as shown in Table 6.

Feed composition also showed positive effect on the zinc (Zn) content of the extruded. As the feed composition increased from 50:20:30 to 50:30:20, zinc content increased from 1.23 g/100 g to 1.87 g/100 g. However barrel temperature showed negative effect on the zinc content of the extruded as the barrel temperature increased from 90°C to 110°C zinc was found to decrease from 1.91 mg/100 g to 12.5 g/100 g, and that could be because of high temperature which resulted in decreasing the mineral content of the extruded like Zinc (Zn). The effect of extrusion on Zinc (Zn) content of the extruded has also being studied with the extruded having the high zinc (Zn) content of 1.53 g/100 g while the un extruded showed low level of zinc (Zn) of 0.60 g/100 g. Therefore a 60% increase in Zinc content was recorded as a result of extrusion. This affirmed to the fact that extrusion improves the nutrient density of the extruded by increasing its value. Zinc on the other hand functions in nucleic acid metabolism, protein synthesis and cell growth Beal et al. [42]. In line with the result obtained above extrusion had significant effect on the mineral content of the extrudate. The mineral content includes calcium (Ca) magnesium (Mg) Ion (Fe) and Zinc (Zn) in all case, the extrudates had higher values for mineral composition than individual raw samples which show that extrusion had improved the nutritional value of extrudates. This increase has been attributed to screw wear in the extruder Artz et al. [43].

4.3 Effect of Extrusion on the Anti-nutrient Content of *Dakuwa* Extrudate

4.3.1 Effect of extrusion on phytic acid content of dakuwa

The result of phytic acid content was presented in Table 7. The least phytic acid value was recorded at design point 23 representing 110°C barrel temperature, 50:20:30 feed composition for sorghum groundnut and tigernut and 26% feed moisture content. And the highest value of 4.33 mg/100 g was recorded at design point 5 representing 90°C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut and 18% feed moisture content. The least phytic acid recorded at design point 23 was as a result of high barrel temperature of 110°C on the other hand the highest phytic acid recorded at design point 5 was as a result of low barrel temperature of 90°C. Significant difference ($p>0.05$) was not observed on barrel temperature, feed composition and feed moisture content for both linear and quadratic but interaction was significant. On the independent variables barrel temperature decreased the phytic acid from 3.50 mg/100 g at 90°C to 3.29 mg/100 g at 110°C. On feed composition the highest phytic acid was recorded at 50:30:20. Feed moisture content decreased the phytic acid from 3.59 mg/100 g at 18% to 3.34 mg/100 g at 26% as shown in Fig. 1.

Table 5. Combine effect of extrusion variables on mineral content (g/100g) of extruded

SN levels	Bt 1 2 3	Fc 1 2 3	Fm 1 2 3	Calcium	Zinc	Iron	Magnesium
1	1	3	2	2.04^{b}	1.89^{ab}	2.56^{a}	3.47^{a}
2	1	3	1	2.91^{ab}	2.34^{a}	2.56^{a}	3.56^{a}
3	1	3	3	2.91^{ab}	2.34^{a}	2.55^{a}	3.56^{a}
4	1	2	2	2.85^{ab}	2.04^{a}	2.15^{a}	3.56^{a}
5	1	2	1	2.90^{ab}	1.97^{ab}	2.15^{a}	3.52^{a}
6	1	2	3	2.84^{ab}	2.04^{a}	2.14^{a}	3.56^{a}
7	1	1	2	2.68^{b}	1.54^{b}	1.51^{b}	3.45^{a}
8	1	1	1	2.67^{b}	1.53^{b}	1.50^{b}	3.44^{a}
9	1	1	3	2.68^{b}	1.54^{b}	1.51^{b}	3.45^{a}
10	2	2	3	2.00^{b}	1.33^{b}	0.88^{bc}	3.48^{a}
11	2	2	2	2.00^{b}	1.31^{b}	2.25^{a}	3.46^{a}
12	2	2	1	1.35^{c}	1.30^{b}	2.35^{a}	3.45^{a}
13	2	3	1	1.35^{c}	0.65^{c}	1.10^{b}	3.39^{a}
14	2	3	2	1.34^{c}	0.66^{c}	1.11^{b}	3.39^{a}
15	2	3	3	1.56^{c}	0.69^{c}	1.69^{b}	3.40^{a}
16	2	1	1	3.01^{a}	1.79^{b}	2.35^{a}	3.59^{a}
17	2	1	3	3.01^{a}	1.78^{b}	2.14^{a}	3.59^{a}
18	2	1	2	3.00^{a}	1.77^{b}	1.31^{b}	3.59^{a}
19	3	2	2	2.21^{b}	1.17^{b}	1.24^{b}	3.48^{a}
20	3	2	3	2.28^{b}	1.09^{b}	0.67^{c}	3.45^{a}
21	3	2	1	2.20^{b}	1.16^{b}	1.24^{b}	3.48^{a}
22	3	1	1	2.47^{b}	1.50^{b}	2.21^{a}	3.46^{a}
23	3	1	3	1.59^{c}	1.93^{b}	1.89^{ab}	3.52^{a}
24	3	1	2	2.21^{b}	1.49^{b}	1.55^{b}	3.46^{a}
25	3	3	3	2.19^{b}	1.53^{b}	1.78^{b}	3.48^{a}
26	3	3	2	2.25^{b}	1.53^{b}	1.57^{b}	3.49^{a}
27	3	3	1	2.11^{b}	1.46^{b}	2.28^{a}	3.46^{a}
Extruded				2.33^{b}	1.79^{b}	3.49^{f}	1.53^{b}
Un-extruded				0.47^{d}	1.05^{b}	3.25^{f}	0.60^{c}
Percentage increase (%)				79	41.3	6.9	60

Bt= barrel temperature, 1 represent 90°C barrel temperature, 2 represent 100°C barrel temperature, 3 represent 110°C barrel temperature. Fc= feed composition, 1 represent 50% 20% 30%, 2 represent 50 % 25 % 25 %, 3 represent 50% 30% 20%. Fm= feed moisture, 1 represent 18%, 2 represent 22%, 3, represent 26%. Mean with the same superscript within a column are not significantly different (p>0.05) values are triplicate of means. All compositions are represented as Sorghum %: Groundnut % and Tigernut % respectively

Table 6. Influence of independent extrusion variables mineral content (g/100g) of extrudate

Extrusion parameters	Calcium (Ca)	Magnesium (Mg)	Iron (Fe)	Zinc (Zn)
Bt (^{0}C)				
1	2.721^a	3.508^a	2.070^a	1.916^b
2	2.115^a	3.474^a	1.605^a	1.430^{ab}
3	2.155^a	3.483^a	1.687^a	1.256^a
Fc (%)				
1	2.103^a	3.439^a	1.563^a	1.238^a
2	2.377^a	3.492^a	1.675^a	1.492^{ab}
3	2.510^a	3.534^a	2.124^a	1.871^b
Fm (%)				
1	2.321^a	3.486^a	1.801^a	1.531^a
2	2.361^a	3.487^a	1.753^a	1.530^a
3	2.309^a	3.492^a	1.808^a	1.540^a

Bt= barrel temperature, 1 represent 90 ^{0}C barrel temperature, 2 represent 100 ^{0}C barrel temperature, 3 represent 110 ^{0}C barrel temperature. Fc= feed composition, 1 represent 50 % 20 % 30 %, 2 represent 50 % 25 % 25 %, 3 represent 50 % 30 % 20 %. Fm= feed moisture, 1 represent 18%, 2 represent 22%, 3, represent 26 %. All compositions are represented as Sorghum %: Groundnut % and Tigernut % respectively

Extrusion showed significant ($p<0.05$) effect on the phytic acid content of the extrudate with extrudate recording the low phytic acid content of 3.36 mg/100 g, and the un extrudate recorded the highest value of 5.56 mg/100 g with percentage reduction of 65.47%. The result of anti-nutrient component (phytic acid and tannin content) of formulated flour and extrudate blend were analysed as shown in Table 7. Extrusion cooking reduced the phytic acid from 5.56 mg/100g to 3.36 mg/100 g. It would be expected that lowering the phytate level should enhance the bioavailability of such minerals as zinc and ion in the extrudate as phytic acid has been implicated in making these minerals un-available as reported Anuonye et al. [44].

Literature by Anuonye et al. [45] on their studies of effect of extrusion cooking on the nutrient and anti-nutrient composition of pigeon pea and unripe, they found that extrusion cooking reduced the phytate level by 68.8% from (0.86% to 0.26%). The phytate reduction in extrusion cooking product is still discussed: a 25% decrease was found by Lefrancois [46] whereas Sandberg et al. [47] observed no change in the phytate content in extrudate products. Extrusion cooking process denature detrimental enzymes; in activate some anti-nutritional component of food (trypsin inhibitors, tannin and phytates) disinfect the final product and maintain normal colours and flavours of food Bhadari et al. [48]. Phytic acid forms insoluble complex with certain trace elements zinc, iron and copper reducing their bioavailability with resultant effects of reduced tune over of haemoglobin production and impaired metabolic process.

4.3.2 Effect of extrusion on the tannin content of the extrudate

The results of the tannin content of *dakuwa* extrudate were presented in Table 7. The least tannin content is at design point 6 representing 90°C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 26% feed moisture content. On the other hand the highest tannin content is 2.47 mg/100g. The influence of independent variables showed that as the barrel temperature increased from 90 to 110 ^{0}C the tannin content was found to decrease from 2.57 to 2.42 mg/100 g on feed composition the highest tannin content was recorded at 50:30:20. The tannin content decreased with increase in moisture from 2.45 mg/100g at 18% to 2.44 mg/100 g at 26% as shown Fig. 2.

Extrusion affects the tannin content of the product by reducing it from 3.25 mg/100g un-extrudate to 2.45 mg/100 g extrudate with a percentage decrease of 32.65%. The tannin content of legumes ranging from a high value of 200 mg/100 g in faba beans to a lower value of 45 mg/100 g in soybeans Kim et al. [49]. But as it is shown in Table 7, the tannin value of the formulated flour and extrudates as well were lower than the value of tannin which legume is expected to have. This is attributed to the raw material preparation process. Reported literature by Kim et al. [50] revealed that condense tannins are located in the seed coat of dark coloured cereals, such as sorghum and millet, and in beans and other legumes. The tannin content in beans varies with colour with darker beans having a higher content. And during the raw material preparation stage, the sorghum which is expected to have high tannin content were soated washed and grinded so also the tigernut and groundnut, these may be the probable reason for a lower tannin content in the product. In addition to that of raw material preparation extrusion also have a significant effect in decreasing the anti-nutrient content of the extrudate. Tannin form insoluble complexes with proteins thereby decreasing the digestibility of proteins Uzoechina [51]. Tannin also decreases palatability, cause damage to the intestinal tract, and enhance carcinogenesis Makkar and Becker [52]. The significant reduction in tannin content of the extrudates indicate the bioavailability of protein.

Table 7. Combine effect of extrusion variables on antinutrient content of the extruded

SN levels	Bt 1 2 3	Fc 1 2 3	Fm 1 2 3	Phytic acid (mg/100 g)	Tannins (mg/100 g)
1	1	**3**	**2**	3.96^{b}	2.43^{ab}
2	1	3	1	2.87^{bc}	2.43^{ab}
3	1	3	3	4.10^{a}	2.42^{a}
4	1	2	2	2.37^{c}	2.43^{ab}
5	1	2	1	4.33^{a}	2.43^{ab}
6	1	2	3	3.23^{b}	2.42^{a}
7	1	1	2	2.98^{bc}	2.43^{ab}
8	1	1	1	2.78^{c}	2.42^{a}
9	1	1	3	2.99^{bc}	2.44^{ab}
10	2	2	3	2.87^{bc}	2.47^{b}
11	2	2	2	3.54^{b}	2.47^{b}
12	2	2	1	4.08^{a}	2.47^{b}
13	2	3	1	3.58^{b}	2.47^{b}
14	2	3	2	3.94^{ab}	2.47^{b}
15	2	3	3	3.94^{ab}	2.47^{b}
16	2	1	1	3.41^{b}	2.47^{b}
17	2	1	3	3.78^{b}	2.47^{b}
18	2	1	2	3.58^{b}	2.47^{b}
19	3	2	2	2.37^{c}	2.43^{ab}
20	3	2	3	3.41^{b}	2.44^{ab}
21	3	2	1	2.99^{c}	2.45^{ab}
22	3	1	1	4.29^{a}	2.44^{ab}
23	3	1	3	2.36^{b}	2.45^{ab}
24	3	1	2	2.83^{bc}	2.44^{ab}
25	3	3	3	3.82^{ab}	2.43^{ab}
26	3	3	2	3.66^{b}	2.44^{ab}
27	3	3	1	3.87^{ab}	2.47^{b}
Extruded				3.36^{b}	2.45^{a}
Un-extruded				5.56^{f}	3.25^{f}
Percentage decrease (%)				65.47	32.65

Bt= barrel temperature, 1 represent 90 °C barrel temperature, 2 represent 100 °C barrel temperature, 3 represent 110 °C barrel temperature. Fc= feed composition, 1 represent 50% 20% 30%, 2 represent 50% 25% 25%, 3 represent 50% 30% 20%. Fm= feed moisture, 1 represent 18%, 2 represent 22%, 3, represent 26%. Mean with the same superscript within a column are not significantly different (p>0.05) values are triplicate of means. All compositions are represented as Sorghum %: Groundnut % and Tigernut % respectively

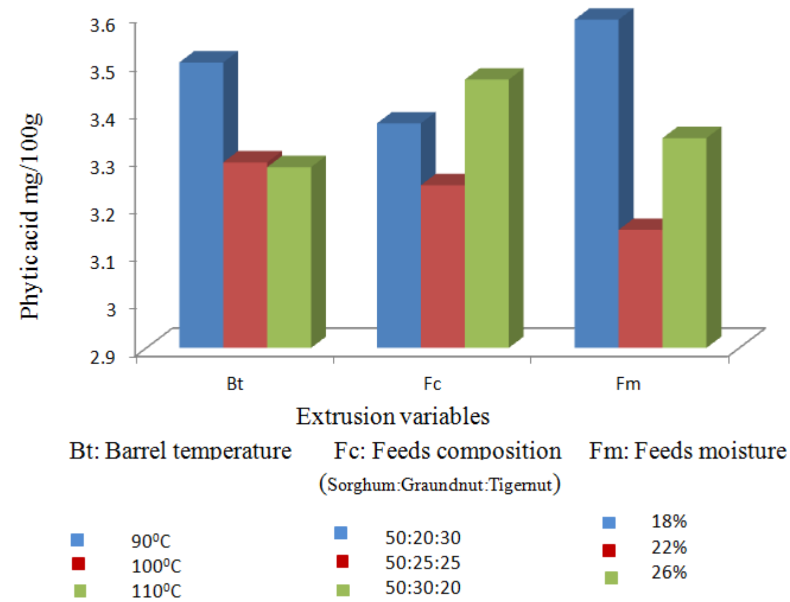

Fig. 1. Influence of independent extrusion variables on the phytic acid of the extrudate

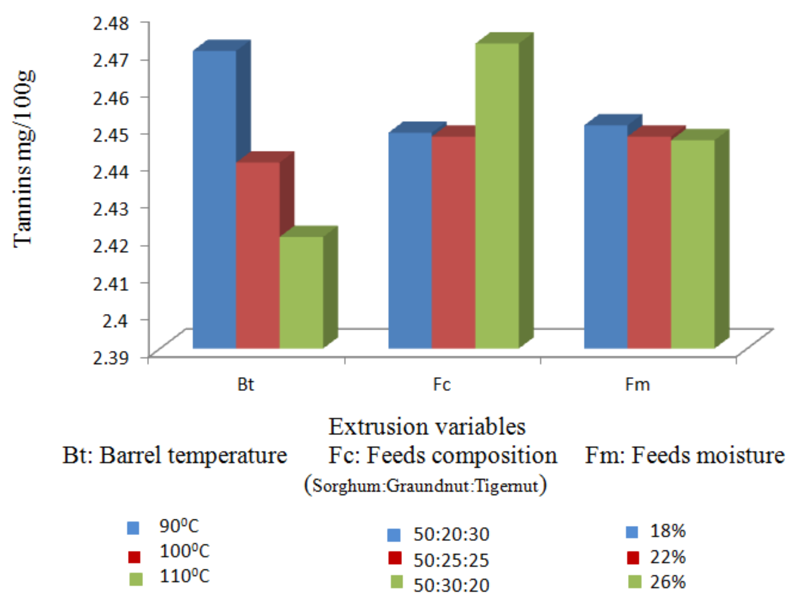

Fig. 2. Influence of independent extrusion variables on the tannin content of the extrudate

5. CONCLUSION

The effect of extrusion on the proximate composition of the extruded shows that extrusion significantly ($p<0.05$) affect the proximate composition of *dakuwa* extrudate. Extrusion decreased the moisture content of *dakuwa* from 22% un extrudate to 6.25% extrudate that gives the product ability to stay longer. However, it increases protein content from 14.73% Un extrudate to 16.89% extrudate that had resulted in increase in nutrient density. It decreases the fat content from 9.80% un extruded to 7.58% extrudate, ash content increased from 1.50% un extrudate to 2.06% extrudate. Extrusion decreased Crude fiber from 2.65% un extruded to 2.44% extruded, and carbohydrate was increased from 49.74% un extruded to 64.64%

extruded. Extrusion significantly increased the mineral content of extrudate, the calcium (Ca) Iron (Fe) magnesium (Mg) and Zinc (Zn) value of extruded (2.33 g/100 g, 1.79 g/100g, 3.49 g/100 g and 1.53 g/100g) were higher than the unextruded value (0.47 g/100 g, 1.05 g/100 g, 3.25 g/100 g,0.60 g/100 g) with percentage increase of (32.65%, 41.3%, 79%, 6.9% and 60%) respectively. Similarly due to the application of heat and moisture during the extrusion process phytic acid and tannin value of the extrudate (3.36 mg/100 g and 2.45 mg/100 g) were lower than the formulated flour (5.56 mg/100 g and 3.25 mg/100g) with percentage decrease of 65.47% and 32.65%, respectively. The result reveals that *Dakuwa* is a very important snack item in terms of consumption pattern, economic importance, inherent quality factors and potential for industrialization. An attempt towards the optimization of the processing techniques through extrusion process yielded very promising result.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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