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Full Length Research Paper

Effect of extrusion variables on physical properties and acceptability of *Dakuwa* produced from blends of sorghum (*Sorghum bicolour l*) graundnut (*arachis hypogea l*) and tigernut (*Cyperus esculentus*)

M. Yusuf[1], K. B. Filli[2], I. Umar[2], M. Halilu[3]

[1 2 3]Department of Food Science and Technology Modibbo Adama University of Technology
Yola, PMB 2076 Yola, Nigeria.
Corresponding Auto E-mail: yusufmoh2015@yahoo.com (08031122974)

ABSTRACT

The study was conducted with the aim of producing Dakuwa extrudate from the combination of sorghum (*Sorghum bicolour L*) groundnut (*Arachis hypogeal L*) and tiger nut (*Cyperus esculentus L*) and to ascertain the effect of extrusion on physical properties and acceptability of the extrudate. Three Factor Three Levels Full Factorial Experimental Design (TFTLFFED) was adopted to determine the effect of extrusion on the physical and sensory characteristics of Dakuwa extrudate. With feed moisture content (18, 22 and 26 %) barrel temperature (90, 100, and 110 ^{0}C), feed composition 50:20:30, 50:25:25 50:30:20 using twin screw food extrusion cooker (SLG 65-III Model China). Extrusion increased Expansion ratio from 1.59 at 90 ^{0}C to 1.70 at 110 ^{0}C it increased Specific length from 2.81 cm/g at 90 ^{0}C to 3.46 cm/g at 110 ^{0}C, bulk density increased from 0.20 at 90^{0}C to 0.28 g/cm^3 at 110^{0}C.the result of sensory evaluation indicate that Product extruded at 90 ^{0}C, 50 % 20 % 30 %, 18 %, was perceived as the most accepted product, as compared to other extrudate.

Key words: sorghum, groundnut, tigernut, extrusion, expansion ratio, specific length, bulk density, sensory evaluation

INTRODUCTION

Dakuwa is a cereal and legume 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, 2003). Sorghum is the fifth most widely grown crop in the world. Sorghum gained significance as a result of development of high yielding varieties (Hybrids). However, sorghum production is less than 5 % of the total world cereal grain production International Crop Research Institute for Semi-Arid Tropics and Food and Agricultural Organization [ICRISAT and FAO] (1996). Sorghum is an important source of B-group vitamins except for vitamin B_{12} (Gazzaz *et al*., 1989). Dried matured caryopses do not contain vitamin C. Both vitamins and minerals in sorghum kernel are concentrated in the aleurone and germ and therefore the removal of these tissues by decortications will result in to getting a refined sorghum product that has lost a major part of these important nutrients. Sorghum is the only cereal that contains a significant levels of β-carotene, the provitamin of vitamin A, which is an important vitamin for human physiology, and a good source of lipid soluble vitamins A, D, E and K (Hoseney *et al*., 1981).

Groundnut (*Arachis hypogaea L*.) is the 6th most important oil seed crop in the world. It contains 48-50% oil, 26-28% protein and 11-27 % carbohydrate, minerals and vitamin (Mukhtar, 2009). Groundnut is grown on 26.4 million hectare worldwide, with a total production of 37.1 million metric tons and an average productivity of 1.4 metric tons /ha. Developing countries constitute 97% of the global area and 94% of the global production of this crop (FAO, 2011). In the Northern part of Nigeria, apart from being consumed whole, edible groundnuts are processed into or included as an ingredient in a wide range of other products which includes groundnut paste which is fried to obtain groundnut cake (kuli kuli), salted groundnut (gyada mai gishiri), a gruel or porridge made with millet and groundnut (kunun gyada), groundnut candy (kantun gyada) and groundnut soup (miyar gyada).The shells are used for fuel by some local oil factories or they are sometimes spread on the field as a soil amendment. They could also be used as bulk in livestock rations or in making chipboard for use in joinery (Mukhtar, 2009).

Cyperus esculentus (Tiger nut in English, Habelaziz in Arabic and Chufa in Spanish) has long been recognized for its health benefits as they are rich in fiber, protein, natural sugars, minerals such as phosphorous and potassium and in vitamins such as E and C. They have a high content of soluble glucose and oleic acid, along with high energy content (starch, fats, sugars and proteins (Mason, 2008). Tiger nut (*Cyperus esculentus*) belongs to the family *Cyperaceae* and the order, Commelinalis. It is found worldwide in warm and temperate zones, occurring in Southern Europe and Africa. Tiger nut can be taken by diabetics for its low content of sucrose and starch and its high content of arginine which stimulates the production of insulin (Belewu and Belewu, 2007). It can also be cooked, dried and powdered and may be used in confectionary to make biscuits with a delicious nut-like flavour. Mixing the ground tubers with cinnamon, sugar, vanilla and the cream, makes it a refreshing beverage. The roasted tubers are a substitute for coffee (Okafor *et al*., 2003). Extrusion is one of the contemporary technology used in food processing. 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*., 2000). Generally speaking, extrusion-cooking of cereals and legumes raw materials deals with extrusion of ground material at baro-thermal conditions. With the help of shear energy, exerted by the rotating screw, and additional heating of the barrel, the food material is heated to its melting point or plasticating point.

The physical properties considered include expansion ratio specific length and bulk density. Expansion ratio is one of the main characteristics of extruded products which is necessary to obtain the desired crispy texture. The final expansion of the product can be measured as a combination of longitudinal or radial expansion. The parameter is calculated from the longitudinal or sectional diameter of the product.

Crispness, hardness and brittleness are parameters use to determine the textural properties of the extruded products. Sensory evaluation can be used to determine the texture of the product including hardness. Hardness is manipulated by variation in raw material ingredients and the extrusion process. Bulk density is an important physical attribute from a commercial point of view as product with lower true density values are more acceptable to consumers (Brennan *et al*., 2008). Sensory analysis is a multidisciplinary science that uses human panelists and their senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of food products, as well as many other materials. The sensory attribute considered include colour taste texture and overall acceptability. The objective of this paper was to determine the effect of extrusion on the physical properties and acceptability of extruded snack

MATERIALS AND METHODS

Sources of raw material

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

Preparation of raw materials

Sorghum, groundnut and tiger nut were sorted manually, cleaned and washed with clean water and allowed to dry in conventional oven at 50^oC for 1hour, the sorghum groundnut and tigernut were roasted at 150 ^0C for 30 minutes in baking oven. The sorghum groundnut and tiger nut was milled to flour and sieved to obtained the particle size of 0.05mm, while the groundnut was ground to paste using a disc attrition mill (7 hp India). The sorghum, groundnut and tiger nut grits were mixed together in a ratio of 50:20:30 50:25:25 50:30:20 respectively. To 1.5 kg of this mixture 2.5 % of granulated red pepper (*Capsicum annum*) was added. The mixture was then packaged and ready for extrusion.

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, 1997). A *factorial* experiment is an experimental strategy in which design variables are varied together, instead of one at a time. The lower and

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

	Symbol	Factor Levels		
Factors	**X**	**1**	**2**	**3**
Blends ratio (Sorghum, groundnut, tiger nut)	X_1	50:20:30	50:25:25	50:30:20
Barrel temperature (^{0}C)	X_2	90	100	110
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 & 110 ^{0}C, (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 tiger nut respectively. (Fm) = Feed moisture with levels 1, 2 and 3 which represent 18 %, 22 % and 26 % respectively.

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

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

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.

Experimental Design

A Three factor Three level Experimental Design (3x3x3) was use to determine the effect of extrusion on the

Table 3.Combined Effect of Extrusion Variables on Physical Properties of *Dakuwa* Extrudate

SN Level	Bt 1 2 3	Fc 1 2 3	Fm 1 2 3	Expansion ratio	Specific length (cm/g)	Bulk density (g/cm^3)
1	1	3	2	1.687^b	3.084^b	0.170^a
2	1	3	1	1.580^b	3.360^b	0.178^a
3	1	3	3	1.611^b	1.173^d	0.262^a
4	1	2	2	1.607^b	3.134^b	0.184^a
5	1	2	1	1.577^b	3.143^b	0.187^a
6	1	2	3	1.507^b	2.350^c	0.272^a
7	1	1	2	1.493^b	3.177^b	0.202^a
8	1	1	1	1.577^b	2.967^{bc}	0.213^a
9	1	1	3	1.735^b	2.947^{bc}	0.175^a
10	2	2	3	1.513^b	2.834^{bc}	0.234^a
11	2	2	2	1.831^a	2.973^{bc}	0.144^a
12	2	2	1	1.506^b	3.049^b	0.204^a
13	2	3	1	1.583^b	3.577^b	0.164^a
14	2	3	2	1.620^b	2.540^c	0.240^a
15	2	3	3	1.707^b	2.501^c	0.213^a
16	2	1	1	1.721^b	3.000^b	0.166^a
17	2	1	3	1.507^b	2.501^c	0.213^a
18	2	1	2	1.656^b	3.000^b	0.189^a
19	3	2	3	1.613^b	2.773^c	0.216^a
20	3	2	3	1.707^b	4.456^a	0.351^a
21	3	2	1	1.803^a	3.443^b	0.251^a
22	3	1	1	1.610^b	3.988^{ab}	0.386^a
23	3	1	3	1.707^b	3.925^b	0.250^a
24	3	1	2	1.807^a	2.134^c	0.215^a
25	3	3	3	1.710^b	3.643^b	0.408^a
26	3	3	2	1.713^b	2.934^{bc}	0.232^a
27	3	3	1	1.710^b	3.901^{ab}	0.299^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 % 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.

physico-chemical and sensory characteristics of Nigerian indigenous cereals and legume based snack product (*Dakuwa*).The extrusion variables that were considered includes: Feed moisture content (Fm), Barrel temperature (Bt) and Feed composition (Fc), each were varied at 3, 3 and 3 levels respectively as shown in Figure 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, 2013).

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 at the control panel board. The grits were alternatively fed into the extruder inlet by 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 was 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 tiger nut respectively. The barrel temperature of zone three, which was located just before the die was allowed to operate at different temperatures ranging from 90 ^{o}C to 110 ^{o}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

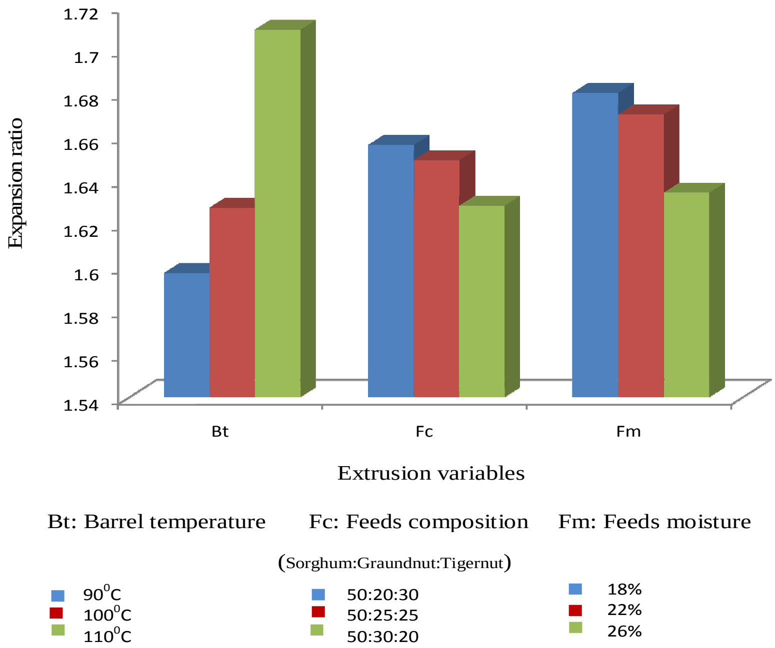

Figure 1. Effect of Extrusion Variables on the Expansion Ratio of the Extrudate

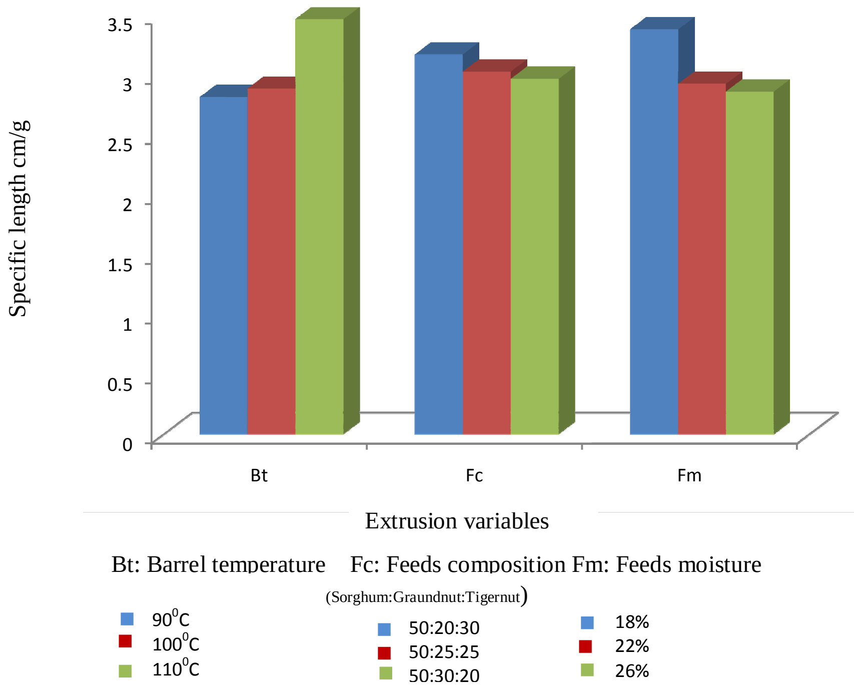

Figure 2. Effect of Extrusion Variables on the Specific length of the Extrudate

moisture contents of 18 %, 22 % and 26 % by using hydration equation (1).

$W_a = S_W \times \left(\frac{M - Mo}{100 - M}\right)$ Eq. (2)

Where:

Wa= Weight of water added (g)

S_w = Sample flour weight (g)

M_o=Original flour moisture content (% wet basis)

M= Required dough moisture level (% wet basis).

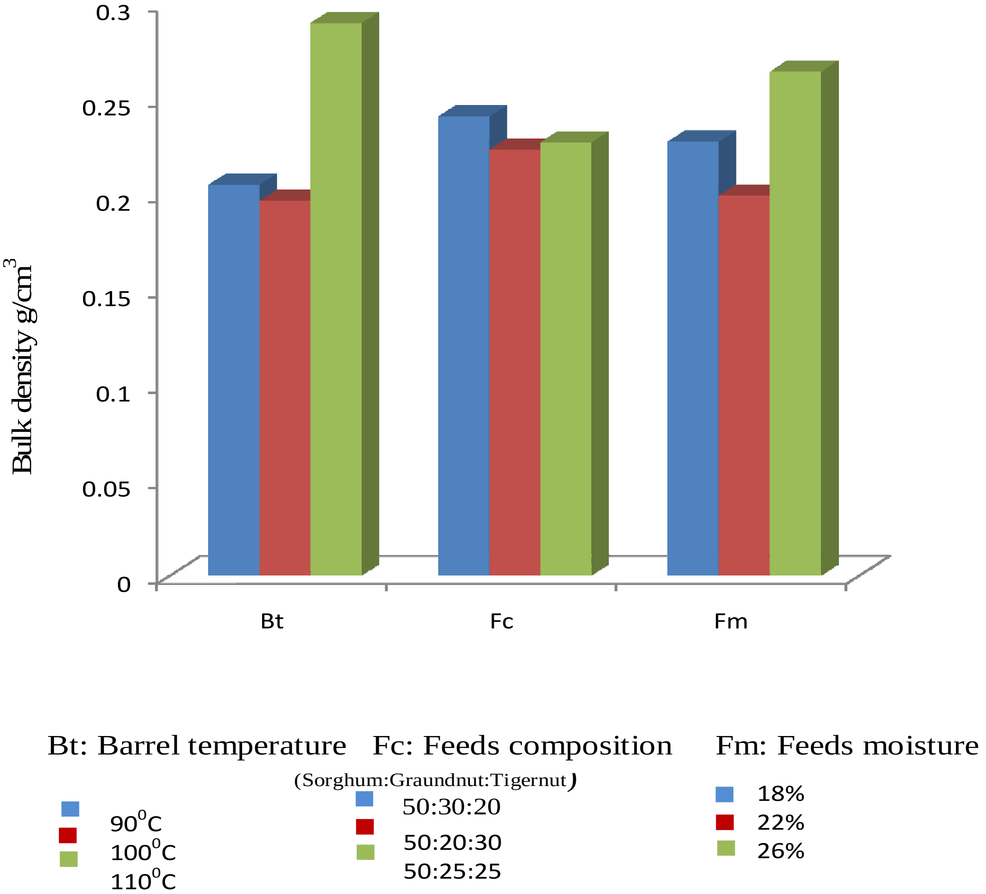

Figure 3. Effect of Extrusion Variables on the Expansion Ratio of the Extrudate

The extrusion experiment was conducted using 3 factor 3 level experiment design (3^3), with 1 factor representing extruder barrel temperature, with levels (90 ^{0}C 100 ^{0}C 110 ^{0}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 ^{0}C and 9 samples were run, and at 100 ^{0}C another 9 samples were run. Finally at 110 ^{0}C the remaining 9 samples were then run. As shown in Table 1 and 2 for experimental design in coded and natural forms. At 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 and the result was used in calculating the physical properties of the extrudate using the appropriate equations.

Physical properties

Specific length and degree of expansion

Sample products were extruded as straight ropes for a time interval of ten seconds. Length was measured by a pocket size steel tape of 1mm accuracy. The diameter of the extrudates was measured by a Vernier calliper having 0.05 mm accuracy. A mean value of length, weight and diameter was recorded for each experimental run. The expansion ratio (diameter) is defined as the ratio of the diameter of the extrudate to the diameter of the die hole. The specific length of the extrudate is defined as the length (cm) of the extrudate per unit mass (g).

$$\mathrm{ER} = \frac{\text{Diameter of the extrudate}}{\text{Diameter of the die hole}}$$

Eq. (3)

Where: ER- Expansion ratio

$$\mathrm{SL} = \frac{\text{Length of the extrudate}}{\text{Mass of the extrudate}}$$

Eq. (4)
Where:
SL- Specific length

Bulk density

From the measurements of weight, length and diameter

Table 4. Combine Effect of Extrusion Variables on Sensory Characteristics of *Dakuwa* Extrudate

SN	Bt	Fc	Fm	Colour	Texture	Taste	Overall acceptability
Levels	1 2 3	1 2 3	1 2 3				
1	1	3	2	5.83^{a}	6.23^{a}	6.03^{a}	6.03^{a}
2	1	3	1	5.47^{a}	6.03^{a}	6.00^{a}	5.87^{ab}
3	1	3	3	5.87^{a}	5.93^{b}	5.73^{b}	5.93^{ab}
4	1	2	2	5.10^{a}	5.83^{ab}	5.60^{b}	5.67^{b}
5	1	2	1	5.33^{a}	5.80^{ab}	5.47^{b}	5.90^{ab}
6	1	2	3	5.57^{a}	5.70^{b}	5.60^{b}	6.07^{a}
7	1	1	2	4.87^{ab}	5.57^{b}	5.03^{b}	5.93^{ab}
8	1	1	1	5.67^{a}	5.50^{b}	5.73^{b}	6.18^{a}
9	1	1	3	5.57^{a}	6.00^{a}	6.00^{a}	6.13^{a}
10	2	2	3	5.33^{a}	5.63^{b}	5.86^{ab}	5.60^{b}
11	2	2	2	5.40^{a}	6.10^{a}	5.80^{ab}	5.50^{b}
12	2	2	1	5.60^{a}	5.47^{b}	5.87^{ab}	5.87^{ab}
13	2	3	1	5.73^{a}	5.57^{b}	5.87^{ab}	5.77^{b}
14	2	3	2	5.17^{a}	5.70^{b}	5.73^{b}	5.67^{b}
15	2	3	3	5.17^{a}	5.70^{b}	5.73^{b}	5.76^{b}
16	2	1	1	5.40^{a}	5.87^{ab}	5.77^{b}	5.80^{ab}
17	2	1	3	4.90^{ab}	5.63^{b}	5.77^{b}	5.87^{ab}
18	2	1	2	5.17^{a}	5.60^{b}	5.80^{ab}	5.53^{b}
19	3	2	2	4.97^{ab}	5.80^{ab}	5.30^{b}	6.17^{a}
20	3	2	3	5.67^{a}	5.90^{ab}	6.03^{a}	6.03^{a}
21	3	2	1	5.10^{a}	5.60^{b}	5.83^{ab}	5.93^{ab}
22	3	1	1	5.33^{a}	5.63^{b}	5.53^{b}	6.03^{a}
23	3	1	3	5.00^{a}	5.60^{b}	5.47^{b}	5.77^{b}
24	3	1	2	5.13^{a}	5.50^{b}	5.23^{b}	6.17^{a}
25	3	3	3	5.93^{a}	5.90^{ab}	6.20^{a}	6.17^{a}
26	3	3	2	5.20^{a}	6.10^{a}	5.40^{b}	5.90^{ab}
27	3	3	1	5.43^{a}	5.97^{ab}	5.93^{ab}	5.41^{b}

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 % 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.

as stated above in section 2.5.1, immediately after extrusion, the bulk density of the extrudates was calculated as in Eq. (3.9) (Mason and Hoseney, 1986).

$$\rho = \frac{4W}{\pi d^2 x L}$$

Eq. (5)

Where:

ρ - Bulk density (g/cm^3)

d - Diameter of extrudate (cm)

L - Length of extrudate (cm)

W - Weight of extrudate (g)

Sensory Evaluation

Sensory evaluation of *Dakuwa* extruded was carried out using the method of Iwe (2003). The panellists consist of 10 persons from Modibbo Adama University of Technology, Yola. A 7-point hedonic scale (7-like extremely, 1-dislike extremely) was use to rate the sensory attributes of colour, taste, texture, and overall acceptability of the products. Each attribute was evaluated separately. At each session, each panellist assessed (9 sample per day for 3 days) samples which were presented randomly, with fresh tap water that was use for mouth rinsing in between evaluations (Ihekoronye and Ngoddy, 1985).

Statistical Analyses

Values obtained were subjected to Analysis of variance (ANOVA) using Genstat software (Genstat, 2013). Significance was accepted at 0.05 level of probability. Mean separation was performed by Least Significant Difference (LSD) for multiple comparisons of means. All the graphical presentations were carried out using Microsoft of excel.

RESULT AND DISCUSSION

Effect of Extrusion Operating Variables on Physical Properties of the Extruded

Expansion ratio

The least expansion ratio value of 1.49 was recorded at design point 7 representing 90 ^{0}C barrel temperature, 50:20:30 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content, while the highest value of 1.07 was recorded at design point 24 representing 110 ^{0}C barrel temperature 50:20:30 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. The least expansion ratio

Table 5. Effect of independent extrusion variables on Sensory characteristics of *Dakuwa* extrudate

Extrusion Parameters	Colour	Texture	Taste	Overall acceptability
Bt (^{0}C)				
1	5.47^a	5.84^a	5.69^a	5.97^b
2	5.31^a	5.78^a	5.66^a	5.95^b
3	5.31^a	5.70^a	5.79^c	5.67^a
Fc (%)				
1	5.41^a	5.79^a	5.73^a	5.98^a
2	5.34^a	5.76^a	5.71^a	5.81^a
3	5.34^a	5.78^a	5.70^a	5.80^a
Fm (%)				
1	5.48^a	5.68^a	5.81^a	5.86^a
2	5.25^a	5.79^a	5.72^a	5.80^a
3	5.64^a	5.86^a	5.62^a	5.93^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

recorded at design point 7 was as a result of low barrel temperature of 90 ^{0}C. On the other hand the highest expansion ratio recorded at design point 12 could be as a result of high barrel temperature of 110 ^{0}C, this is because the higher the temperature the higher would be the gelatinisation and the higher the expansion ratio. Significant difference at p>0.05 was not observed for barrel temperature, feed composition and feed moisture content on the expansion ratio of the extrudate. However as a barrel temperature increased from 90 ^{0}C to 110 ^{0}C expansion ratio increased from 1.59 to 1.70 Table 5. As temperature increase, starch gelatinization would be more and that bring about an increase in the expansion ratio (ER). Aynadis Molla (2010) revealed that barrel temperature has significant effect on the expansion ratio ER. Expansion ratio increase with barrel temperature. As temperature increased from 120 to 180 expansion ratio increased from 0.1-1.2. The maximum gelatinization occurs at high moisture and barrel temperatures or vice versa. (Yu *et al*., 2009).

Moisture content showed influence on the expansion ratio. Increasing the feed moisture content from 18 % to 26 % resulted in decreased in the expansion ratio from 1.1 to 1.07 figure 5. Therefore feed moisture content negatively affected the expansion ratio of the extrudate by decreasing it. Extruded with higher moisture content shrank after they came out of the die as a result of higher moisture feed material provided low structural integrity in extruded which could not hold their expanded shape very well (Kim and Maga, 1993). The result obtained agree with the reported literature by Hagenimana *et al*. (2006), who found that expansion ratio decreased with increase in feed moisture from 15% to 18% and 22% when rice flour was extruded in a twin screw extruder.

Park (1976) reported that puffing phenomena of extrudates result from the vaporisation of superheated water as the extruded exit the die. The simultaneous flash-off of vapour expands the starch material resulting in a porous and sponge like structure within the extrudate. The degree of expansion of extrudate is closely related to the size number and distribution of air cells surrounded by the cooked material. However, at very high temperature the vaporization occurs in a violent way and may cause breakage of the structure hampering expansion. This observation is in agreement with Kokini *et al*. (1991) who reported that moisture plays a key role in the mechanism responsible for expansion. Harman and Harper (1973) postulated two factors in governing expansion (a) dough viscosity and (b) elastic force die swell in the extrudate. The elastic force would be dominant at low moisture and temperature. The bubble growth, which is driven by the pressure difference between the enterior of the growing bubble and atmosphereric pressure resisted primarily by the viscosity of the bubble wall, would usually dominate the expansion at high moisture content and high temperature (Panmanabhan and Bhattacharyya, 1989). Increased water content in the melt would soften the amylopectin molecular structure and reduced its elastic characteristics to decrease diametral expansion (Alvarenz-Martinez *et al*., 1988). Extrudate can expand in both crossectional (diametral) direction and the longitudinal direction (Launary and Lisch, 1983). A porous, expanded sponge like structure is formed inside extrudates as a result of many tiny steam bubbles created by the rapid release of pressure after exiting the die (Conway, 1971). Increased feed moisture during extrusion would provoke change in the amylopectin molecular structure of the material reducing the melt elasticity thus decreasing the expansion and increasing the density of the extrudate (Qing-Bo *et al*., 2005).

The feed composition with high percentage of groundnut (30 %) recorded low expansion ratio of 1.62 while the one with low percentage of groundnut (20 %)

recorded high expansion ratio of 1.65 as shown in Figure 5. The low expansion attributed to high groundnut content could be as a result of high oil content in groundnut which decreases the expansion. On the other hand high expansion ratio recorded with low groundnut content could be because of low groundnut and high tiger nut content which contain carbohydrate that aid expansion. Ainsworth *et al*. (2007) reported increased expansion of snack produced from mixture of corn and dehulled chickpea flours. Extrusion parameters, especially an increase in temperature of the barrel and decrease in the moisture content, increase the viscosity of the melt thus improve melt extensibility enabling bubble growth and expansion (Lillford, 2008).

Specific length of the extrudate

Table 3 showed the effect of extrusion on the specific length of the extrudate. The least specific length of the extrudate value of 1.173 cm/g was recorded at design point 3 representing 90 ^{0}C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 26 % feed moisture content. However the highest value of 4.456 cm/g was recorded at design point 20 representing 110 ^{0}C barrel temperature, 50:25:25 feed composition for sorghum, groundnut and tigernut and 26 % feed moisture content.

The least specific length recorded at design point 3 could be as a result of barrel temperature of 90 ^{0}C and feed composition that contains 30 % of groundnut that is characterized by having high oil content that decreases the specific length of the extrudate. The highest specific length recorded at design point 20 could be as a result of high barrel temperature of 110 ^{0}C and 25 % ratio of groundnut to tigernut content. An increase in barrel temperature is characterized by high gelatinisation of starch and an increase in specific length of the extrudate. Barrel temperature and feed moisture content significantly ($p<0.05$) affect the specific length of the extrudate, however feed composition showed no significant difference ($p>0.05$) on the specific length of the extrudate. As the barrel temperature increased from 90 to 110 ^{0}C specific length increased from 2.81 to 3.46 cm/g.

Feed moisture content decreased the specific length, as feed moisture increased from 18 % to 26% specific length decreased from 3.38 to 2.86 cm/g. Feed compositions also affect the specific length negatively, by decreasing it. The specific length decreased from 3.07 cm/g at 50:20:30 to 2.97 cm/g at 50:30:20 for sorghum groundnut and tiger nut respectively as shown in Table 1. The extrudate longitudinal expansion and melt viscosity were inversely related (Launary and Lisch, 1983). Unlu and Faller (2002) found that product temperature increase with increasing screw speed.

Bulk density of the extruded

The least bulk density value of 0.144 g/cm^3 was recorded at design point 11 representing 100 ^{0}C barrel temperatures 50:25:25 feed composition for sorghum graundnut and tiger nut and 22% feed moisture content. The highest bulk density of 0.408 g/cm^3 was recorded at design point 25 representing 110 ^{0}C barrel temperature 50:30:20 feed composition and 26 % feed moisture content. The lowest bulk density value observed at design point 12 could be as a result of 100 ^{0}C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. Mean while the highest bulk density value observed at design point 25 could be attributed to high barrel temperature of 110 ^{0}C, 30 % groundnut content in the blend and 26 % feed moisture content.

Barrel temperature and feed moisture significantly ($p<0.05$) affect the bulk density of the extrudate, however on feed composition significant difference ($p>0.05$) was not observed on the bulk density of the extrudate. As the barrel temperature increased from 90 to 100 ^{0}C the bulk density decreased from 0.20 g/cm^3 to 0.19 g/cm^3. The decrease in bulk density with barrel temperature could be attributed to starch gelatinisation increase gelatinisation could increase the volume of the product and hence decrease it density. Gomez and Aguilera (1984) reported that puffing was directly related to the temperature, and it was reported that there was decrease in bulk density of the blend snack extrudate as the barrel temperature increased. Gelatinisation of starch is complete at high temperature. This means that the melt has lower viscosity and a higher is available causing increase in expansion and decrease in bulk density (Bhattachary and Hanna, 1978). But at 110 ^{0}C the bulk density increased to 0.28 g/cm^3, that could be attributed to the nature of the raw material of having high fat content that decrease the puffed ratio an increase in bulk density at high temperature. The result obtained from this study agreed with the reported literature by Aynadis Molla (2010) who reported that, increased gelatinisation due to temperature increases volume of products consequently bulk density decreases. Bulk density increased from 0.22 g/cm^3 at 50:20:30 to 0.24 g/cm3 at 50:30:20 feed composition for percentages of sorghum groundnut and tiger nut respectively as shown in Table 3. Filli and Nkama (2010) reported that pearl millet: cowpea fura (80:20) had the highest puffed ratio 4:71 while the pearl millet: groundnut (70:30) fura had the least puffed ratio 2:90. Samples with higher fat content appear to have lower puffed ratio. In another report a puffer extruded resulted by decreasing the lipid content in the feed mix (Bhattachyrya and Hanna, 1988).

Of rice based expanded snacks. Increasing the feed moisture content from 18 to 22 % caused a decrease in expansion ratio for tapioca and corn starch. Increasing of soybean protein from 0 to 25% resulted in decrease expansion of extruded of corn starch also according to the same author lipids also affected the expansion ratio of extrudates.

Literature reported by Mohamed (1990) showed that expansion of corn grits was little affected by addition of oil up to 3 %. Another report by Faubion and Hoseney (1982) showed that flour lipids reduce extrudate expansion. Bulk density is a very important parameter because its impact container fill and thus storage and transport (Mercier *et al.,* 1989). It depends on the size shape and extent of expansion during extrusion (Kurt *et al*., 2009). Radial expansion ratio and bulk density represent the extent of puffing of the extrudate therefore it may be expected that these two properties would be negatively correlated higher radial expansion ratio contributing to lower bulk density. Bulk density is an important physical attribute from a commercial point of view as product with lower true density value are more acceptable to consumers (Brennan *et al*., 2008).

Effect of Extrusion on Sensory Qualities of the Extrudate

Extrudate produced were evaluated using sensory techniques as described in Section 2.6. The sensory attributes considered for the evaluation were colour, texture (hardness or ability to be easily crushed by teeth) taste and overall acceptance.

Colour

The least sensory score of 4.87 for colour were recorded at design point 7 representing 100 ^{0}C barrel temperature 50:20:30 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. Meanwhile the highest value of 5.93 were recorded at design point 25 representing 110 ^{0}C barrel temperature, 50:30:20 feed composition for sorghum groundnut and tigernut and 26 % feed moisture content. The highest barrel temperature of 110 ^{0}C contributed to the acceptability of the extrudate, hence the sensory acceptability for colour is influenced by barrel temperature.

Significant difference ($p>0.05$) was not observed for barrel temperature, feed composition and feed moisture content on the sensory acceptability of colour. But from the result it has been observed that the highest acceptability value of 5.474 for barrel temperature was recorded at 90 ^{0}C. On feed composition the highest acceptability value of 5.407 was recorded at 50:30:20 while the least was recorded at 50:25:25 and 50:30:20 respectively for sorghum groundnut and tiger nut. On the feed moisture content the sensory score for colour was recorded high 5.481 at 18 % feed moisture while the least value of 5.248 was recorded at 22 % feed moisture content. The sensory score for colour fall within the acceptable limit except at design point 7, 17 and 19 which recorded neither like nor dislike Table 4.

Texture

The least sensory score of 5.46 for texture were recorded at design point 12 representing 100 ^{0}C barrel temperature 50:25:25 feed composition for sorghum groundnut and tigernut and 18 % feed moisture content. And the highest value 6.10 were recorded at design point 1 representing 90 ^{0}C barrel temperature, 50:30:20 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. Significant ($p>0.05$) difference was not observed for barrel temperature feed composition and feed moisture content on sensory score of texture of the extrudate. Though not significant, the texture of the extrudate decrease with increase in barrel temperature. On feed composition the highest acceptability of texture was at 50:20:30 while the least value of 5.78 was recorded at 50:25:25. Also observed as the feed moisture increased the acceptability on texture decreased. All the sensory scores for texture fall within the acceptable limit Table 4.

Taste

The least sensory score of 5.03 for taste were recorded at design point 7 representing 90 ^{0}C barrel temperature, 50:20:30 feed composition for sorghum groundnut and tigernut and 22 % feed moisture content. The highest score of 6.20 were recorded at design point 25 representing 110 ^{0}C barrel temperature, 50:30:20 feed composition for sorghum groundnut and tiger nut and 26 % feed moisture content and 6.20 representing 100 ^{0}C barrel temperature, 50:25:25 feed composition for sorghum groundnut and tiger nut and 18 % feed moisture content.

Barrel temperature significantly affect ($p<0.05$) the taste of the extrudate from 5.68 at 90 ^{0}C to 5.65 at 100 ^{0}C. And the highest acceptable score of 5.79 was recorded at 110 ^{0}C, and that could be because of starch modification to simple sugars that increase the sweetness. As the feed composition increased the sensory score for taste decrease. As the feed moisture content increased from 18% to 26% the sensory score for taste decreased from 5.81 to 5.61 as shown in Table 4 and 5. Therefore all the sensory score for taste fall within the acceptable limit.

Overall acceptability

The least sensory score of 5.40 for overall acceptability were recorded at design point 27 representing 110 ^{0}C barrel temperature 50:30:20 feed composition for sorghum groundnut and tigernut and 18% feed moisture content. And the highest value of 6.18 were recorded at design point 8 representing 90 ^{0}C barrel temperature 50:20:30 feed compositions for sorghum groundnut and tigernut and 18 % feed moisture. Barrel temperature significantly ($p<0.05$) affect the overall acceptability of *Dakuwa* extrudate. As the barrel temperature increased from 90 ^{0}C to 110 ^{0}C the overall acceptability decreased from 5.96 to 5.67. Feed composition and feed moisture showed no significant ($p>0.05$) effect on the overall acceptability of the extrudate.

However as the feed composition increased from 50:20:30 to 50:30:20 the overall acceptability decreased from 5.97 to 5.80, on moisture content, as the feed moisture content increased from 18 % to 26 % the sensory score for overall acceptability decreased from 5.85 to 5.80 and increased at 26 % to 5.93 as shown in Table 4 and 5. The sensory score for the overall acceptability revealed that all the extrudate are within the acceptable limit.

The most accepted sample recorded 6.18 overall acceptability and is at design point 8 representing 90 ^{0}C barrel temperature, 50:20:30 feed composition for sorghum groundnut and tiger nut, and 18 % feed moisture content, at 150rpm and 3mm die diameter.

CONCLUSION

The effect of extrusion on physical properties (expansion ratio, bulk density and specific length) of *dakuwa* extrudate has been studied. Barrel temperature feed composition and feed moisture content had influence on the expansion ratio. As the barrel temperature increased from 90 ^{0}C to 110 ^{0}C expansion ratio increased from 1.59 to 1.70. Also as the feed moisture increased from 18% to 26% the expansion ratio decreased from 1.10 to 1.07 and the bulk density increased. Feed composition, sample with high content of groundnut 30 % showed low expansion. While the one with low content of groundnut 20 % revealed high expansion ratio of 1.65. Specific length, barrel temperature had influence on the specific length of extrudate as the barrel temperature increased from 90 ^{0}C to 110 ^{0}C specific length increased from 2.81 cm/g to 3.46 cm/g. Feed moisture had negative influence on the specific length, as the feed moisture content increased from 18% to 26% specific length decreased from 3.38 cm/g to 2.92 cm/g. The result of sensory evaluation indicate that, the product produced with a barrel temperature of 90 ^{0}C, feed composition of 50:20:30 for sorghum groundnut and tiger nut, feed moisture content of 18 %, screw speed of 150rpm, was perceived as the most accepted product, as compared to other extruded.

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