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PRODUCTION AND CHARACTERISATION OF EXTRUDED AFRICAN YAM BEAN BASED READY-TO-EAT BREAKFAST PRODUCT

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ABSTRACT

This study was designed for the preparation of composite flour, production and characterization of extruded ready-to-eat breakfast snack at varying levels of (80:10:10; 70:20:10; 60:30:10 and 50:40:10 from African yam bean, millet and tigernut flours respectively). The design of the experiment was carried out using completely randomized design. Proximate composition of composite blends and extruded ready-to-eat breakfast snack as well as characterization and sensory evaluation were determined. Sensory analysis was done using students of the Department of food Technology, University of Ibadan. Result revealed that moisture, protein, fat and total energy contents were highest in composite blends relative to ready-to-eat breakfast snack. Characterization of the extruded breakfast snack showed expansion ratio ranging from 2.11-2.35, lightness (L*) (42.95-45.89), redness (a*) (2.22-3.84) and yellowness (b*) (12.98-14.37); pH values ranged from 6.00- 6.15, loose and tapped bulk density (0.41- 0.59 g/mL), water absorption capacity (1.90- 2.43 g/mL), oil absorption capacity (1.73-2.12 g/mL), swelling power (0.99-1.17 g/mL), milk absorption capacity (0.17-0.18) and moisture retention (79.15-87.97). The sensory results revealed that composite blend 50:40:10 showed the highest value for the entire sensory attribute. The outcome of the study displayed that African yam bean, millet and tigernut complement each other when blended in the right proportions to make composite flour producing nutrient-dense breakfast snack rich in physicochemical properties; better functionality of blends and not devaluing the chromaticity as well as sensory evaluation.

Keywords: African yam bean, Millet, Tigernut, Composite blends, Extruded breakfast snack

INTRODUCTION

Breakfast cereals could be described as food products which are acquired by swelling, milling, rolling or flaking of different types of cereals combined with other food materials such as legume, tuber, fruits and vegetables (Sharma and Caralli, 2004). Breakfast being the first meal of the day, varies widely from region to region among different cultures in the world and it often include sources of carbohydrate, low protein, fruit and vegetables, dairies and beverages. The most widely consumed breakfast among adult and children in the developing countries Nigeria inclusive, can be obtained from the locally available staple foods earlier mentioned. According to Tribelhorn (1991), breakfast cereals could be classified into traditional (hot) cereals that require further cooking or heating before consumption and ready-to-eat (cold) cereals that can be consumed directly with or without the addition of milk. The term ready-to-eat (RTE) breakfast cereals are classified as food which may be eaten directly without further treatment, reconstituted, pre-heated or allow defrosting if frozen prior to consumption. According to Haines *et al*. (1996), ready-to-eat breakfast cereal are now replacing the traditional dishes taken as breakfast and gradually gaining importance in developing countries especially among the urban people due to convenience, nutritional values, improved income, status symbol and job demands. Due to increased interest in the consumption of high quality food combating protein-calorie malnutrition, pellagra, as well as various health challenges being faced by the vulnerable people such as diabetes and cardiovascular diseases; food processor are now sourcing for an alternative means of producing breakfast cereals with high nutritional quality. Incorporation of legumes into cereals formulation for production of breakfast cereals has been shown to yield product of high nutritional value with good amount of essential amino acids (Okaka, 2005). Grain legumes constitute the main source of protein in the diets of the average Nigerian home. The most important ones are cowpea (*Vigna unguiculata*), soybean (*Glycine max*), pigeon pea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*). However, there are other pulses that could meet dietary needs but are cultivated only in localized areas and are underutilized. These under-exploited legumes include African yam bean (AYB) (*Sphenostylis stenocarpa*) and Bambara groundnut (*Vigna subterranea*). The seeds form a valuable and prominent source of plant proteins in the diet of Nigerians cultivated as a pulse for human consumption. According to Eromosele *et al.* (2008), AYB was said to contain about 21-29 % protein with 50 % carbohydrates mainly as starch. Oshodi *et al*. (1995) also reported AYB to contain calcium and amino acids: lysine, cysteine, methionine, phenylalanine and pyrone. AYB, non-conventional pulse has been brought into focus by some previous researchers as it is known to have a nutritive and culinary value (Agunbiade and Ojezele, 2010). Adebanjo *et al.* (2020) reported reduced moisture (4.5 to 3.5 %) and increased fibre (2.84 to 4.53 %) content in the extrusion cooking of carrot and pearl millet.

Pearl millet (*Pennisetum glaucum*) is one of the important cereals cultivated in the tropics and Nigeria being the third largest producer with 59,994 tons of seed and India topping the list with 334,500 tons of seeds (FAO 2010). Devi *et al.* (2011) reported millet as a good source of calcium, dietary fibre, polyphenols and protein. Millet in general has significant amount of essential amino acid most especially the sulphur containing amino acids (methionine and cysteine). Obilana and Manyasa (2002) also report higher fat content with various nutritional and medicinal benefits in pearl millet compare to maize, rice, and sorghum. Awolu *et al*. (2017) reported nutritional composition of cookies produced from pearl millet, rice, soybean and tigernut blends. Tigernut is a tuber but its chemical composition shares similar characteristics with tubers and nuts (Elena *et al.*, 2012). The moisture content is lower than the moisture contents reported for true tubers such as cocoyam (Daramola *et al.*, 2010) and cassava (Hashimoto *et al.*, 2003). Coulibaly *et al.* (2012) have reported that tigernut loses a considerable amount of water during drying and storage. The ash content is within the usual range for tubers and nuts (Temple *et al.*, 1989). It is a good source of dietary fibre which is required by the body and has been found to help in diabetes, colon cancer gastrointestinal issues and managing weight (Anderson *et al.*, 2009). The objective of this study is geared towards mixing of pearl millet, African yam bean and tigernut in preparation of ready-to-eat breakfast snacks with the aid of an extruder.

MATERIALS AND METHODS

African yam bean were purchased from a local market in Enugu, Enugu state; pearl millet, tigernut and sorghum from Bodija Market in Ibadan Oyo state, Nigeria. They were taken to the laboratory of Food Technology, University of Ibadan for further processing and analysis.

Processing of African Yam Bean Flour

African yam bean was processed according to the method described by Enwere (1998). African yam bean were sorted manually to remove foreign materials. The seeds were soaked for 24 hours at room temperature, drained, rinsed, dehulled using cleaned mortar and pestle and oven dried at 55 ^{o}C for 15 hours. The dried beans were milled into flour using disc attrition mill. The flour obtained was sieved to pass through a 250 µm British standard sieve to obtain flour of uniform size. The flour samples was put in zip-lock bags and kept in covered plastic at 25 ^{o}C until further used.

Processing of Pearl Millet Flour

The pearl millet was processed according to the method (Odunfa and Adeyele, 1985). The grains were cleaned by sorting to remove stones and debris, washed with cleaned water and oven dried at 55 ^{o}C for 6 hours. The dried grains was milled into flour using attrition mill, sieved to pass through a 250 µm British standard sieve to obtain flour of uniform size. The flour samples was put in zip-lock bags and kept in covered plastic at 25 ^{o}C till further used.

Processing of Tigernut Flour

Tigernut was processed according to the method described by Oladele and Aina (2007). The nuts were sorted and washed to remove stones and dirt, oven-dried at 55 ^{o}C for 6 hours. The dried nut was milled into flour using attrition mill, sieved to pass through a 250 µm British standard sieve to obtain flour of uniform size. The flour samples was put in zip-lock bags and kept in covered plastic at 25 ^{o}C until further analysis.

Formulation of Composite Flours

The flour samples of African yam bean, pearl millet and Tigernut (%) were prepared by blending at varying ratios 80:10:10, 70:20:10, 60:30:10 and 50:40:10, respectively. The four different flour blends were prepared in the desired proportions using a laboratory scale mixer for 10 minutes at 10000 rpm. After blending, the flour samples were labeled and put in zip-lock bags at 25 °C until further analysis.

Production of sorghum malt extract

The modification of the procedure described by Okafor and Aniche (1980) was used. **Malting:** About 5 kg of white sorghum grains was steeped in tap water for 18 hour and germinated for 3 days at 25 ^{o}C. The green malt was first kilned at 55 ^{o} C for 8 hours and further at 65 ^{o}C for 16 hours until the shoots and roots are friable and separated from the grains. **Mashing:** Three step decoction methods was used to mash the sorghum malt during which 70 % of the mash was maintained at 55 ^{o}C for 30 minutes and at 65 ^{o}C for 1 hour and lastly at 70 ^{o}C for 1 hour in a hot water bath. The conditioned mash was strained through a clean muslin cloth and the filtrate (malt extract) was stored for further use.

Preparation of ready-to-eat breakfast snack

The ready-to-eat breakfast snack was produced from the composite flour blends and other ingredients such as sugar 5 g, salt 1 g, malt extract 10 g and water to improve the flavor and texture.

Sample preparation for extrusion

The composite flour was mixed on dry basis using a laboratory scale blender for 10 minutes at 10000 rpm. The individual moisture contents of the composite flour was determined (on dry weight basis) using a Sartorius moisture analyzer MA-30000V3 (Göttingen, Germany). Each portion of blends (100 g), malt extracts (10 g), sugar (5 g), salt (1 g) and water were mixed together using mixer and water was gradually added until fluffiness was achieved.

Extrusion Cooking

The prepared samples were extruded at selected constant extrusion condition: screw speed of 100 rpm and barrel temperature of 110 ^{o} C in a fabricated laboratory single-screw extruder fitted with 2mm die nozzle. The extruder was set at the desired barrel temperature and allowed to run till stabilization at a screw speed of 40 rpm using African yam bean flour before the experimental runs commenced. Temperature of the barrel was measured by a thermocouple inserted along the length of the extruder. The raw material was fed into the extruder barrel and the screw conveys the flour blend. Further down the barrel, smaller flight-depths resist the volume and increase the resistance to movement of the flour. As a result, it fills the barrel spaces between the screw flights and becomes compressed. As it moves further along the barrel, the screw kneads the material into a semi-solid and plasticized mass during extrusion. Finally, it was forced through one restricted openings (dies) at the discharge end of the barrel as the extrudates. Samples were extruded as straight rope and extruded samples were collected when the extrusion process parameters reach steady state. Steady state is reached when there is no visible drift in torque and dies pressure (Coulibaly *et al.*, 2012).

Handling of extrudates

The emerging extrudates at the die nozzle was collected and cut manually to a uniform length. The extruded products was placed on a table and allowed to cool for 30min at room temperature. The extrudates were later dried in an air convection oven (Gallenkamp, England) at 60 ^{o}C for 10 hours. The resulting dried extrudates was allowed to cool and then packaged in zip lock bags and stored at room temperature till further analysis Plate 1.

Plate 1. Extruded ready-to-eat breakfast snack

Chemical Analysis

Proximate composition of the composite flour and extrudates ready-to-eat breakfast snack

The moisture content, crude protein, crude fat, ash, crude fibre and Total energy for composite flour blends and extrudates ready-to-eat breakfast snack was determined according to the standard method (AOAC, 2010). Carbohydrate was calculated by difference.

Determination of Moisture Content

A Sartorius moisture analyzer MA-30000V3 (Göttingen, Germany) was used to determine the moisture content (Equation 1). The moisture analyzer was warmed up for at least 30 minutes; approximately 1 g of sample was evenly spread on the tarred aluminum pan. Analysis was performed in the fully automated mode at 110 °C. The principle behind this analyzer is that, it determines the weight loss of the sample simultaneously as heat dries the sample using infrared dark radiator tubes.

Calculation: $Moisture\ content\ (\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times \frac{100}{1} \ldots\ldots (1)$

Determination of total energy
The total energy was determined by the method described by Kanu *et al.* (2009). The total energy or the caloric values was estimated by calculation using the water quantification factors of 4, 9 and 4 kcal/100g respectively for protein, fat and carbohydrate.

Characterization of extruded ready-to-eat breakfast snack

Milk absorption capacity (MAC)
Four grams of extrudate sample was placed in 30 mL of milk at 8 °C for 3 minutes and the milk was drained from the extrudate using a stainless steel mesh screen (2.8 microns) for 10 seconds (Luckett *et al.,* 2012). The milk absorption capacity was calculated using the following formula:

$$MAC\ (\%) = \frac{Drained\ extrudate\ weight\ (g) - initial\ extrudate\ weight\ (g)}{Initial\ extrudate\ weight}\ x\ 100$$
……. (2)

Moisture Retention (MR)
The feed and extrudate moisture content was determined by AOAC official method (2010).

$MR\ (\%) = \frac{Product\ moisture}{Feed\ moisture}\ x\ 100$….. (3)

Expansion ratio (ER):
The method developed by Fan and colleagues was used to determine the expansion ratio. The mean of 10 random measurements of the extrudate diameter was determined using a vernier caliper. Expansion ratio was calculated using the equation:

$ER = \frac{D\ (mm)}{d\ (mm)}$ ……… (4) Where D = mean diameter of the extrudate and d = diameter of the die

Colour
The color of the flour samples and extruded ready-to-eat breakfast snack was determined using a Chroma-meter equipped with D65 illuminant on the basis of CIE L*, a* and b* system as described by (Kaur and Singh, 2005). L* represented lightness (with 0= darkness/ blackness to 100= perfect/brightness); a*corresponds to the extent of green colour (in the range from negative= green to positive = redness); b* represents blue in the range from negative=blue to positive=yellow. The colorimeter was calibrated against a standard white reference tile. The L*, a* and b* readings were obtained directly from the instrument and provided measures of lightness, redness and yellowness, respectively. All measurements were performed in triplicate and mean value recorded.

Sensory Evaluation
Sensory evaluation was carried out using 30 untrained panelists to assess the sensory attribute of trial extruded ready-to-eat breakfast snack. Selected panelists were student of the Department of Food Technology, University of Ibadan, Nigeria. They were provided with potable water and, instructed to rinse and swallow between samples. Prior to the sensory analysis, they were screened with respect to their interest and ability to differentiate food sensory properties. They were asked to evaluate the samples for appearance, consistency, aroma, taste, mouthfeel, and overall acceptability based on a 9- point hedonic scale ranging from 9-liked extremely to 1-disliked extremely.

Statistical Analysis of Data
Experiments were replicated five times and the collected data were subjected to the analysis of variance using a completely randomized design. The difference between the means was separated using Duncan Multiple range test and significance difference was taken at 5% confidence limit.

RESULTS

The Proximate Composition of African yam bean, Pearl millet and Tigernut Flour Blends
The proximate composition of flour blends obtained is presented (Table 1). The moisture content of the flour blends ranged between 10.56

to 12.18 %. Samples 60AYB:30M:10T was found to be highest in moisture content and 70AYB:20M:10T appeared lowest. There were significant ($p<0.05$) differences within 80AYB:10M:10T and 70AYB:20M:10T but no noticeable ($P>0.05$) differences between 60AYB:30M:10T and 50AYB:40M:10T. The protein content of the flour blends decreased from 16.12 to 14.67 % with increasing substitution levels of pearl millet flour. The protein content was highest in sample 80AYB:10M:10T while lowest was observed in sample 50AYB:40M:10T. Significant ($p<0.05$) differences were observed among the samples.

Table 1: The Proximate Composition of Varied Ratio of African Yam Bean, Pearl Millet and Tigernut Flour Blends

Sample	Moisture	Protein	Fat	Ash	Fibre	CHO	Total energy
AYB	12.37±1.0.80[a]	20.82±1.92[a]	2.27±0.93[b]	3.32±0.33[a]	3.46±0.56[b]	57.76±1.46[b]	-
Millet	10.74±0.22[b]	10.93±1.03[b]	3.71±1.17[b]	2.25±0.05[a]	2.36±0.05[b]	70.00±1.78[a]	-
Tigernut	12.63±0.33[a]	6.17±0.01[c]	29.31±1.54[a]	3.03±0.15[a]	9.87±1.26[a]	46.41±1.59[c]	-
80AYB: 10M:10T	11.44±0.60[b]	16.12±0.11[a]	10.50±0.50[a]	3.03±0.15[a]	2.71±0.19[b]	56.19±0.26[c]	383.74±3.27[a]
70AYB: 20M:10T	10.56±0.38[c]	15.57±0.08[b]	9.53±0.93[ab]	2.70±0.44[ab]	3.19±0.21[a]	57.45±0.96[ab]	381.88±5.47[a]
60AYB: 30M:10T	12.18±0.20[a]	15.17±0.23[c]	10.10±0.26[a]	2.37±0.15[b]	2.87±0.16[ab]	58.52±0.45[ab]	381.65±1.26[a]
50AYB: 40M:10T	11.63±0.76[a]	14.67±0.06[d]	8.47±1.00[b]	2.03±0.25[ab]	2.43±0.25[a]	59.61±1.13[a]	373.35±5.04[b]

*Values are means ±S.D of duplicate determinations. * SD= Standard deviation. Values in the same row with different superscripts were significantly different at 5% probability level (p< 0.05).*
Remark: AYB- 100 % African yam bean; M- Pearl millet flour; T- Tigernut flour

The fat content ranged between 8.47 to 10.50 %. The optimum value was recorded in sample 80AYB:10M:10T while minimum content was found in sample 50AYB:40M:10T. The ash content (%) of the composite flour significantly ($p<0.05$) decreased from 3.03 to 2.03 with increasing inclusion of pearl millet flour. The fibre content of the flour blends ranged from 2.27 to 3.19 %. Significant ($p<0.05$) differences were observed among the samples. The fibre content was highest in sample 70AYB:20M:10T while lowest value was observed in sample 50AYB:40M:10T. Carbohydrate content of the composite flour varied significantly ($p<0.05$) and increased from 56.19 to 59.61 % with increasing substitution of pearl millet. Sample 50AYB:40M:10T had highest carbohydrate while lowest was found in 80AYB:10M:10T. The energy value of the flour blend decreased from 383.74 to 373.35 kcal/100g.

The Proximate Composition Extruded African Yam Bean based Ready-to eat Breakfast Snack

Table 2 shows the proximate composition of African yam bean with millet and tigernut extruded breakfast snack. There was a significant ($p<0.05$) difference in the selected extrusion variables. The moisture content varied from 8.36 to 10.06 %. The breakfast snack at varying level 50AYB:40M:10T had highest moisture (10.06 %) while 70AYB:20M:10T had lowest values (8.36 %).

Table 2: The Proximate Composition Extruded African Yam Bean Based Ready-to eat Breakfast Snack

Parameters	80AYB:10M:10T	70AYB:20M:10T	60AYB:30M:10T	50AYB:40M:10T
Moisture	10.05±0.05[a]	8.36±0.13[c]	9.78±0.18[b]	10.06±0.06[a]
Protein	14.88±0.26[a]	13.31±0.02[b]	12.96±0.03[c]	12.74±0.18[d]
Fat	5.18±0.28[b]	5.62±0.36[ab]	5.99±0.50[a]	5.52±0.29[ab]
Ash	3.03±0.15[a]	2.70±0.44[ab]	2.17±0.15[b]	2.63±0.25[ab]
Fibre	3.67±0.22[a]	3.38±0.35[a]	2.84±0.06[b]	1.94±0.05[c]
Carbohydrate	63.65±0.40[c]	64.09±0.73[b]	65.55±0.28[ab]	66.16±0.28[a]
Total energy	360.69±0.98[d]	372.15±1.42[c]	380.15±3.94[b]	391.88±0.99[a]

*Values are means ±S.D of duplicate determinations. * SD= Standard deviation. Values in the same row with different superscripts were significantly different at 5% probability level (p< 0.05).*
Key: *AYB- African yam bean flour; M- Millet; T- Tigernut flour*

The protein content of the breakfast snack decreased significantly (p<0.05) from 14.88 to 12.47 % with increasing substitution of millet flour. There is a noticeable difference (p<0.05) among the products. The breakfast snack containing 80AYB:10M:10T was highest and lowest value was observed at varying ratio 50AYB:40M:10T. The selected extrusion variables significantly (p<0.05) affect the fat content of the flour blends. However, highest fat content was observed in the varying ratio 60AYB:30M:10T while lowest occurred in 80AYB:10M:10T. The ash content showed significant (p<0.05) difference in variations. The highest ash content in breakfast snack occurred in varying ratios 80AYB:10M:10T and lowest value was obtained in 60AYB:30M:10T. Fibre content decreased from 3.67 to 1.94 % in extruded breakfast snack as substitution of millet flour increases in the blends. The carbohydrate content of the breakfast snack was significantly (p<0.05) different from each other with increasing substitution of millet flour. The values of carbohydrate increased from 63.65 to 66.16 %. The carbohydrate contents of the samples with 50AYB:40M:10T was highest (66.16 %) while sample 80AYB:10M:10T was significantly (p<0.05) lowest within the samples. The values obtained for the total energy content of the formulated samples increased from 360.69 to 391.88 kcal.

Characterization of Extruded African Yam Bean Based Ready-to-eat Breakfast Snack

The degree of lightness (L*) value for sample 60AYB:30M:10T was the least (42.95) and sample 80AYB:10M:10T had highest (45.89).

Table 3 The Colour Properties of Extruded African Yam Bean Based Ready-to-eat Breakfast Snack

SAMPLES	L*	a*	b*
80AYB:10M:10T	45.89±0.22[d]	3.84±0.12[a]	14.37±0.10[c]
70AYB:20M:10T	43.66±0.12[c]	2.41±0.21[b]	13.99±0.07[ab]
60AYB:30M:10T	42.95±0.19[b]	3.53±0.01[c]	12.98±0.25[a]
50AYB:40M:10T	43.55±0.18[a]	2.22±0.02[d]	13.79±0.07[c]

*Values are means ±S.D of triplicate determinations. * SD= Standard deviation. Values in the same column with different superscripts were significantly different at 5% probability level (p< 0.05).*
Key: AYB- African yam bean flour; M- Millet; T- Tigernut flour

With respect to a* (red-green) assessment, results showed a considerable variation in extruded breakfast product with values ranging from 2.22 to 3.84. Extruded breakfast snack at varying level 80:10:10 had the highest value (3.84) while sample 50AYB:40M:10T had lowest (2.22). The degree of yellowness (b*) had lowest value in samples 60AYB:30M:10T and highest obtained in 80AYB:10M:10T. The results showed great significant differences (P<0.05) among the samples.

The Physical and Functional Properties of Extruded African Yam Bean Based ready-to-eat Breakfast Snack

The pH values of the extrudates which ranged from 6.00 to 6.15 showed that there were no significant differences (p<0.05) between the extruded ready-to-eat breakfast snack (Table 4).

Table 4: The physical and Functional Properties of Extruded African Yam Bean Based ready-to-eat Breakfast Snack

Parameters	80AYB: 10M:10T	70AYB: 20M:10T	60AYB: 30M:10T	50AYB: 40M:10T
pH	6.00 ± 0.20^{a}	6.13 ± 0.15^{a}	6.15 ± 0.06^{a}	6.06 ± 0.58^{a}
Expansion Ratio	2.11 ± 0.02^{c}	2.20 ± 0.02^{b}	2.18 ± 0.02^{b}	2.35 ± 0.02^{a}
Loosed Bulk Density (g/mL)	0.47 ± 0.01^{a}	0.45 ± 0.01^{b}	0.43 ± 0.01^{c}	0.41 ± 0.01^{d}
Tapped Bulk Density (g/mL)	0.49 ± 0.01^{c}	0.59 ± 0.02^{a}	0.57 ± 0.02^{a}	0.54 ± 0.01^{b}
Water Absorption Capacity (g/g)	1.90 ± 0.10^{b}	2.00 ± 0.10^{b}	2.17 ± 0.21^{ab}	2.43 ± 0.25^{a}
Oil Absorption Capacity (g/g)	1.73 ± 0.15^{b}	1.90 ± 0.10^{ab}	1.76 ± 0.14^{b}	2.12 ± 0.13^{a}
Milk Absorption Capacity (%)	0.17 ± 0.01^{a}	0.18 ± 0.03^{a}	0.18 ± 0.10^{a}	0.17 ± 0.00^{a}
Swelling Capacity	0.99 ± 0.11^{b}	1.07 ± 0.00^{ab}	1.13 ± 0.02^{a}	1.17 ± 0.02^{a}
Moisture Retention	87.97 ± 0.08^{a}	79.15 ± 0.02^{a}	80.27 ± 0.25^{b}	80.12 ± 0.01^{c}

*Values are means ±S.D of duplicate determinations. * SD= Standard deviation. Values in the same row with different superscripts were significantly different at 5% probability level (p< 0.05).*

Expansion Ratio (ER) and Bulk Density

Extrusion results in high expanded products and significantly lower bulk densities showed a significant differences (p<0.05) in the expansion ratio (Table 4). The values ranged from 2.11 to 2.35 with lowest value in sample 80AYB:10M:10T and highest in sample 50AYB:40M:10T. The highest loose bulk density was observed in sample 80AYB:10M:10T and lowest value was observed in sample 50AYB:40M:10T. The highest tapped bulk density was observed in sample 80AYB:10M:10T and lowest value was observed in sample 60AYB:30M:10T.

Swelling Capacity

The swelling capacity of extruded breakfast snack increased from 0.99 to 1.17 g/mL. There was no significant differences (p<0.05) among the extruded breakfast snack. The extruded breakfast snack of sample 80AYB:10M:10T was lowest while sample 50AYB:40M:10T had optimum values.

Water, Oil and Milk absorption capacity (WAC, OAC and MAC) and Moisture Retention of Extruded Ready-to-eat Breakfast Snack

It was observed that WAC increases with the level of millet substitution. Extruded ready-to-eat breakfast snack at varying level 80AYB:10M:10T had lowest value (1.90 g/g) while 50AYB:40M:10T was highest (2.43 g/g). The oil absorption capacity (OAC) of the extrudate was highest (2.12 g/g) in sample 50AYB:40M:10T. There were noticeable differences (p<0.05) among all the samples. The milk absorption capacity value ranged between 0.17 to 0.18 %. There was no significant differences (p>0.05) among the extrudates. The moisture retention ranged from 79.15-87.97 % with highest in sample 80AYB:10M:10T and lowest in sample 70AYB:20M:10T. There was a significant differences ($p<0.05$) among moisture retention recorded. Extrusion temperature has a great effect on the feed moisture. However, it was observed that little moisture was reduced from the product as result of the extruder temperature used in this study. The result obtained was higher than the result reported for chemical and sensory properties of protein-fortified extruded breakfast cereals which ranged between 17.9 and 33.3 % (Navam *et al.,* 2014). It was also reported that at high barrel temperature (275 ^oC), the heat is intense enough to reduce more water from the initial feed moisture content of the blended flour.

Sensory Evaluation of Extruded Ready-to-eat Breakfast Snack

The sensory properties of the extruded ready-to-eat breakfast snack are presented in Table 5. The results of colour in the extrudate snack ranged from 6.23 to 7.17 with highest score in 50AYB:40M:10T. There was a significant difference ($p<0.05$). The aroma ranged from 5.95 to 6.63 with no significant ($p>0.05$) differences between the extrudates. The lowest was observed in sample 80AYB:10M:10T while 50AYB:40M:10T had the highest score. There is no significant ($p>0.05$) differences among the extruded ready-to-eat breakfast snack except with 50AYB:40M:10T having maximum score of 7.10. Extruded ready-to-eat breakfast snack varied at 80AYB:10M:10T had the lowest score of 5.77. The mouthfeel of the extruded breakfast snack ranged from 5.83 to 6.90 as sample 50AYB:40M:10T embraced highest rating. Sample 50AYB:40M:10T formulation was most preferred by the panelist rated 7.27.

Table 5 Sensory Evaluation of Extruded African Yam Bean Based Ready-to-eat Breakfast Snack

Samples	Colour	Aroma	Taste	Mouthfeel	Texture	Overall acceptability
80AYB:10M:10T	6.40 ± 1.10^b	5.93 ± 0.69^b	5.77 ± 1.00^b	6.03 ± 1.13^b	5.63 ± 0.72^a	6.37 ± 0.93^b
70AYB:30M:10T	6.67 ± 0.99^a	6.37 ± 0.85^{ab}	6.33 ± 1.24^b	6.40 ± 0.97^{ab}	5.66 ± 0.61^a	6.63 ± 0.99^b
60AYB:30M:10T	6.23 ± 1.14^b	5.97 ± 1.22^b	6.10 ± 1.45^b	5.83 ± 1.17^b	5.33 ± 0.76^a	6.20 ± 1.27^b
50AYB:40M:10T	7.17 ± 1.05^a	6.63 ± 1.13^a	7.10 ± 1.09^a	6.90 ± 1.51^a	5.67 ± 0.66^a	7.27 ± 1.17^a

*Values are means ±S.D of triplicate determinations. * SD= Standard deviation. Values in the same column with different superscripts were significantly different at 5% probability level (p< 0.05).*
Key: AYB- African yam bean flour; M- Millet flour; T- Tigernut flour

DISCUSSION

The Proximate Composition of African yam bean, Pearl millet and Tigernut Flour Blends

Moisture is a crucial aspect in flour which appreciably alters the life span of food product. The moisture content of the composite blends obtained was below 14 % water content for shelf-stable storage and viability of flour blends thus, useful for a shelf stable product (Chakraverty, 2004). Otherwise, there will be mold and bacterial growth if above 14 %. Protein is an important component that determines the rheological properties of composite flours. The highest protein content recorded was probably due to high amount of protein associated with legume which form basic amount of the flour. The result obtained in this study is similar to value reported by Adelekan *et al*. (2012) for use of African yam beans and shrimps in the production of maize-based cereal blends. The fat content of the flour blends varied significantly and were relatively high in all the flour samples. The high fat might be due to fat content in tigernut which reflected in the flour and the statement was justified by Basman and Koksel (2003) reported 24 to 30 %. Result achieved in this study agreed with ranged values 1.3 to 11.0 % reported by Adebayo-Oyetoro *et al.* (2017) for production and acceptability of *chinchin* snack made from wheat and tigernut flour. However, de-fatting the tigernut before utilization may yield better result. Ash content is a reflection of mineral status in a sample. The decrease in ash content with increasing substitution of pearl millet flour may be attributed to low ash content of pearl millet. Nevertheless, the values were higher than 1.34-2.58 % for banana-wheat composite cake (Eke *et al.*, 2007). More so, trend in results obtained in this work was in agreement with rice-based composite flour (Awolu *et al.*, 2017). Fibre is important in the diet for enhancing bowel movement, preventing overweight, constipation and reducing the risk of colon cancer (Anderson *et al*., 2009; Ayinde *et al*., 2012). Tigernut had substantial highest crude fibre than African yam bean and pearl millet (Table 1), and this justify the high amount of fibre obtained in the blends. In addition, Ibeogu (2020) concur with the statement in production of weaning food from mung bean, pearl millet and tigernut; and Ade-Omowaye *et al.* (2008) observed increased in value as tigernut substitution increases in the formulation of wheat-tigernut based bread. The highest values observed in sample 50AYB:40M:10T was attributed to highest carbohydrate content in pearl millet flour (Table 1). In addition, all the flour blends suggested a very good source of energy. However, Ibeogu (2020) concur with the statement and reported high values in weaning food due to increase in pearl millet inclusion. In contrary, Ade-Omowaye *et al.* (2008) reported decrease in values owing to increase in tigernut substitution in wheat-tigernut based bread. The decreasing substitution level of African yam bean in the blends decreased the total energy. The results obtained are within values reported by Kent (1983) for treated ready-to-eat breakfast cereal foods of energy value between 314.0-420.0 Kcal/100g. The high energy content in sample 80AYB:10M:10T is advantageous for product formulation like breakfast cereals.

The Proximate Composition Extruded African Yam Bean based Ready-to eat Breakfast Snack

The results show that composite flour (Table 1) had high moisture content and extrusion cooking significantly affected the entire composite snack. There was a simultaneous increase in the sample products. The value of moisture content obtained is below the bakery product ranging from 14 – 18 % which could apparently prolong the shelf life of the products (Coutinho et al., 2013). However, Adebanjo *et al.* (2020) reported reduced moisture content from 4.5 to 3.5 % content in the extrusion cooking of carrot and pearl millet. The decreasing order in protein content could be attributed to low content of protein in millet flour substituted in the composite flour. The protein contents detected in this study were lower than the value (15.13 to 6.43%) reported by Semasaka *et al*. (2010) for extruded products from corn, millet and soybean blend. The selected extrusion variable significantly had pronounced effect on the protein content of the flour blends. During extrusion cooking, the chemical constituents of the feed material are exposed to high temperature, high shear and high pressure and these improve or damage the nutritional quality of the protein in the extruded material by various mechanisms (Leszek, 2011). According to earlier scientist, extrusion causes peptides of proteins massively undergo unfolding and/or aggregation and this releases low molecular weight peptides thereby enhancing their digestibility. Extrusion cooking randomly disrupts the disulphide and linear linkages of peptides, hence increasing the cleavage sites of the amino acids in the molecule by proteases Agunbiade and Ojezele (2010). This is highly important in legume based food materials as enhancement of protein demonstrates the effect of supplementing legumes in breakfast cereals called protein complementation. This order of increase in breakfast snack could be attributed to increasing substitution of millet flour. According to Obilana and Manyasa (2002), pearl millet mode of preparation is not well developed owing to short storage because it is oil-rich. Higher values (8.70- 14.20 %) were reported for breakfast cereals made from sorghum and pigeon pea composite flour (Mbaeyi, 2005) and 8.76-9.26 %was reported for extruded adult breakfast based on millet and soybean (Coulibaly *et al.*, 2012). However, the fat can be a transport vehicle for fat soluble vitamins providing essential fatty acids (n-3 and n-6polyunsaturated) which have the ability to reduce blood level of low density lipoprotein (LDL) cholesterol thereby reducing the risk of coronary heart disease (Waniska *et al.*, 2002). Increase in ash content of sample 80AYB:10M:10T could be attributed to highest percentage of African yam bean substitution which was reflected in Table 1. The ash contents of these breakfast snack were higher than the value ranging from 1.50 to 2.50 % for extruded products from corn, millet and soybean blend (Mbaeyi, 2005), but concurred with the value (3.53 %) reported (Anuonye *et al*., 2010). Adebanjo *et al.* (2020) prepared extruded flakes from pearl millet and carrot. The author reported fibre content ranging from 3.71 to 4.53 %. The result obtained in this study fall within the values earlier stated. Extrusion technology has been increasingly used in the production of breakfast snack which is connected to improving dietary profile of cereals (Jisha *et al*., 2010; Porter, 1992). The extruded breakfast snack has a great potential for application in diabetic food, because fibre-rich food formulated in the diet could generate a perfect recipe for diabetic patient. The increase in carbohydrate content implies that the breakfast snack is a good source of energy needed for normal body metabolism. The increase could be attributed to the significantly ($p<0.05$) high levels protein and fat in the sample. The range of carbohydrate detected was in agreement with the value (63.62 to 64.34) reported for extruded adult breakfast based on millet and soybean (Coulibaly *et al*., 2012). Semasaka *et al.* (2010) reported lower values (54.34 to 58.34 %) for extruded products made from corn, millet and soybean blends relative to this study. The total energy values obtained in this work were found to be within the range of values recorded for breakfast cereals made from treated and untreated sorghum and pigeon pea (316.46-420 Kcal) as well as treated ready-to-eat breakfast cereals (314 – 420 Kcal) (Mbaeyi, 2005; Kent, 1983), respectively. These values represent the amount of energy in food that can be supplied to the body for maintenance of basic body functions such as breathing, circulation of blood, physical activities and thermic effect of food (Mbaeyi, 2005).

Characterization of Extruded African Yam Bean Based Ready-to-eat Breakfast Snack

Color is one of the most critical quality attributes of food products (Aly and Seleem, 2015). From Table 3, the trend showed that extrusion increased the color profile of the composite products, all exhibiting noticeable difference ($p<0.05$). Numerous studies have shown that visual acceptance is the first thing consumers rely on when making choices in food (Mares and Campbell, 2001). Food color is so influential, it can even change the way consumers perceive taste and quality in foods and provides some indication of quality in the starting materials (Mares and Campbell, 2001). However, degree of lightness, redness and yellowness of extruded ready-to-eat snack were influenced most extensively by the selected extrusion variables used in this study (Table 3).

The Physical and Functional Properties of Extruded African Yam Bean Based ready-to-eat Breakfast Snack

pH is the degree of alkalinity and acidity in a sample. The values of pH in this study were higher relative to Agunbiade and Ojezele (2010). Earlier scientist recorded slightly lower values (4.88) for fortified breakfast cereal made from maize, sorghum, African yam bean and soybeans. The pH range observed in this study may be due to partial hydrolysis which might have occurred during soaking of the African yam bean.

Expansion Ratio (ER) and Bulk Density

The loose bulk density of extruded breakfast snack decreased with increasing substitution in millet flour (Table 4). Decrease in bulk density of composite snack would be an added advantage for infant foods. The high value in bulk density could be attributed to its high content of fat and protein in the extrudate. Protein decreases shear within the extruder, and reduces the amount of moisture flashed off, thus expansion is decreased (Hood-Niefer and Tyler, 2010). Fat also provides a lubricant function for extrusion cooking and may reduce the grinding effect within raw materials, thereby lowering expansion. More importantly, due to the ability of amylose to bind lipids, extrusion cooking results in the formation of amylose-lipid complexes, thus increasing bulk density and creating more compact macrostructure (De Pilli *et al.,* 2011). Swelling power is the ability to increase in volume when mixed with water. The increase in swelling of the ready-to-eat extruded snack was observed with increase in substitution level of pearl millet.

Water, Oil and Milk absorption capacity (WAC, OAC and MAC) and Moisture Retention of Extruded Ready-to-eat Breakfast Snack

High temperature and shear extrusion cooking in water absorption capacity of breakfast snack led to the disruption of some hydrogen bonds and starch molecules. The crystalline structure in starch granular is thus destroyed and exposes more hydroxyl groups. Therefore, WAC increases with the degree of starch destruction. This could be explained by the formation of the porous macrostructure in the die outlet facilitating the entry of water and its combination with hydrophilic groups, resulting in higher WAC of extrudates (Chau and Cheung, 1998). The highest value in sample 50AYB:40M:10T may be attributed to hydrophobicity of proteins known to play a major role in fat absorption. This acts to resist physical entrapment of oil by the capillary of non-polar side chains of the amino acids of the protein molecules (Chau and Cheung, 1998). The milk absorption capacity (MAC) values obtained in this work were lower than the reported values for protein-fortified extruded breakfast cereal (0.2-0.6 %) at a screw speed of 60 rpm barrel temperature of 190 °C and at a screw speed of 85 rpm barrel temperature of 275 °C (Navam *et al.,* 2014). It was also reported that extruded product at highest barrel temperature (275 °C) had highest MAC because at high barrel temperature, extruded products were the most dehydrated as a result of excess heat; and therefore expected to have a better MAC (Navam *et al.,*2014). Therefore, the relatively low milk absorption capacity was as a result of extruder variable used. Extrusion temperature has a great effect on the feed moisture. However, it was observed that little moisture was reduced from the product due to extruder temperature used in this study. The result obtained was higher than the result reported for chemical and sensory properties of protein-fortified extruded breakfast cereals which ranged between 17.9 and 33.3 % (Navam *et al.,* 2014). It was also reported that at high barrel temperature (275 ^{o}C), the heat is intense enough to reduce more water from the initial feed moisture content of the blended flour.

Sensory Evaluation of Extruded Ready-to-eat Breakfast Snack

Sensory assessment is a very crucial point in food industry (Table 5). Taste is an important component judged by consumers when buying food as it enhances the likeness for the product. Extrusion processing variables like screw speed, cooking temperature and moisture level have large effect on the taste of extruded breakfast snack. Also, high moisture has negative effect on extrudates quality while screw speed and cooking temperature have a positive effect on extrudates quality. Texture can be attributed to the crispiness or crunchiness of ready-to-eat breakfast snack. This may sometimes signifies freshness and high quality. However, accurate proportion and type of starch present in food material has a greater influence on the extruded final product‘s texture or hardness (Delcour *et al*., 2010). This is because during extrusion, water penetrates the starch granules and separates the amylose and amylopectin chains from each other causing the granule to swell and soften; a process known as gelatinization and on cooling, the amylose and amylopectin chains slowly re-bond and the granule becomes firmer and harder, this process is known as retrogradation (Wrangham and Conklin-Brittain, 2003). It is evident from results that the variation of millet flour, reduction of African yam bean flour and selected extrusion variables as well as the drying time used after extrusion significantly affected the acceptability of the extruded snack. The overall acceptability shows the preferred ready-to-eat breakfast snack.

Conclusion

This study revealed that acceptable ready-to-eat breakfast snack could be developed from African yam bean, millet and tigernut flour because the extruded snack obtained posed a good functional properties and desirable nutritive value. The study had shown that producing breakfast snack with legume could boost the protein level (up to 14%) in the final products without altering the chromaticity and sensory attributes. African yam bean, millet and tigernut is projected by the findings of this work to be promising cheap source of nutrients that are lacking in most expensive ready-to-eat food products, and could also play a key role in the acceptability and nutritional value of monotonous diets in the world at large. Thus, the products would help to alleviate the problem of protein-energy malnutrition in Nigeria.

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