

ORIGINAL ARTICLE

Quality Assessment of Formulated Ready-to-eat Breakfast Cereals from Blends of Sorghum (*Sorghum bicolor* L.), African yam bean (*Sphenostylis stenocarpa*) and Unripe Plantain (*Musa paradisiaca*)

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Funding source

None

Abstract

The quality assessment of formulated ready-to-eat breakfast cereals from blends of sorghum, African yam bean and unripe plantain was investigated. Ready-to-eat breakfast products were produced from different flour blends (100:0:0, 65:30:5, 60:30:10, 55:30:15, 50:30:20 and 45:30:25 ratio of sorghum: African yam bean: unripe plantain flour, respectively) by toasting at 150 °C for 5 min. flour blends used to formulate ready-to-eat breakfast product ranged from 18.33 to 40.53 sec for reconstitution time, and 16.50 to 28.50 sec for wettability, respectively. The proximate composition of the formulated breakfast product ranged from 3.03 to 6.06 % for moisture, 1.67 to 3.86 % for ash, 0.79 to 1.48 % for fat, 0.46 to 0.58 % for crude fibre, 1.27 to 5.40 % for dietary fibre, 8.87 to 19.74 % for protein and 68.68 to 85.17 % for carbohydrate content. In-vitro protein digestibility of the product ranged from 69.58 to 85.18%. products ranged from 13.00 to 19.00 mg/100g for magnesium, 10.00 to 22.00 mg/100g for potassium, 0.95 to 3.51 mg/100g for Iron and 22.00 to 72.00 mg/100g for phosphorus. the formulated breakfast product ranged from 5.7×10^4 to 1.4×10^5 Cfu/g for bacteria count and 0.00 to 2.0×10 cfu/g for mould count. There were significant ($p < 0.05$) differences in the sensory scores of the products with sample SAUP₂ (60:30:10) showing the highest score of 6.85 and 6.95 for colour and taste, respectively, while the product showed no significant ($p > 0.05$) difference in texture.

Practical application

African yam bean is rich in protein and high in dietary fibre and these components are required for effective management of diabetes, hypertension and cardiovascular diseases due to its low glycemic index. Unripe plantain though low in protein and fat, is rich in dietary fibre (8.82%) and resistant starch (16.2 %) which helps to reduce blood sugar level. Considering the health benefits of unripe plantain and African yam bean composite blend in the preparation of breakfast product might not only impact nutritional benefits but also improve the health status of consumers of such product and consequently, increase their utilization.

Keywords: African yam beans, Ready-to-eat breakfast cereal, Sorghum, Unripe plantain.

1. Introduction

Breakfast cereals are produced by swelling, grinding, rolling or flaking of any cereal. There are two main classes of breakfast cereal, those requiring cooking, common in China, Japan and many African countries and the pre-cooked

ready-to-eat cereals, common in Europe and North America (Matz, 1970). Ready-to-eat breakfast cereals are gradually gaining acceptance in developing countries and replacing those that require cooking due to convenience, nutritional values, improved income and job demand among urban dwellers. Different

processes used in the preparation of ready-to-eat cereal include flaking, puffing, shredding and granulation.

In developing countries particularly in sub-Saharan Africa, breakfast meals for both adults and infants are made from local staples such as cereals, legumes, roots and tubers (cassava and potatoes) which are energy dense foods. Cereals are known to be deficient in lysine and tryptophan which are essentials for the maintenance of the health of both infants and adults (Enwere, 1998). Consequently, combining cereals with lysine and tryptophan rich legumes like African yam beans, pigeon pea among others in product formulation would complement the amino acid profile of the product. This has been found to be effective in reducing the incidence of malnutrition especially amongst children (Ene-obong & Obizoba, 1996).

Nigeria accounted for 35 % of African production of sorghum (*Sorghum bicolor* L.) in 2007 (UN/FAO, 2012). In 2013, the production statistic was 6,700.00 Metric tons and yield was 12.182 (hectogram/hectare) (FAOSTAT, 2012). Sorghum is rich in some essential amino acids but low in lysine, but complimenting it with legumes like African yam bean, Bambara nut, groundnut, African yam bean, African breadfruit or pigeon pea will enhance its nutritional value. Such supplementation has been widely used in production of weaning food from sorghum/pigeon-pea blends (Maghoub, 1999), biscuits from blends of millet/pigeon-pea (Eneche, 1999) and breakfast products from sorghum/pigeon pea (Mbaeyi & Onweluzo, 2010).

African yam bean (*Sphenostylis stenocarpa*) is an important legume in Africa, a lesser – known legume of the tropical and sub-tropical areas of

the world which has attracted research interest in recent times (Azeke *et al.*, 2005). It produces nutritious pods, highly proteinous seeds and capable of growth in marginal areas where other pulses would not thrive. Enwere (1998) reported that African yam bean grains contain 21 to 29 % protein, is a good source of fibre, carbohydrates and is also rich in minerals. It has also been reported to be of importance in the management of metabolic disorders like diabetes and hypertension because of its high dietary fibre content. It is eaten, roasted like groundnut or boiled and seasoned with ingredients such as oil, pepper, onions and salt. African yam beans though deficient in Sulphur-containing amino acid (methionine and cysteine), is high in lysine and so can be utilized as a complementary protein in foods to improve its nutritional quality and have been used in foods such as “Apula” to improve the micronutrient level (Yusufu *et al.*, 2014).

Green plantain (*Musa paradisiaca*) is a potent source of vitamins A and C, potassium and fibre. FAO (2014) reported that over 2.3 million metric tons of plantains are produced in Nigeria annually. Plantain has high carbohydrate content (31g/100g) and low fat content (0.4 g/100 g). Plantain provides a better source of vitamin A than most other staples and contains low sodium in dietary terms and hence recommended for low sodium diets (USDA, 2009). Oh *et al.*, (1985) noted that the high starch content (35% on wet basis) of green plantain makes it ideal for plantain flour production. However, due to lack of storage facilities and inappropriate technologies for processing, about 35 to 60 % post-harvest losses have been reported (Abioye *et al.*, 2011). The major aim of this study was to produce and evaluate the qualities of ready-to-eat breakfast product for diabetics from African yam

bean (*Sphenostylis sternocarpa*), sorghum (*Sorghum bicolor L.*) and unripe plantain (*Musa paradisiaca L.*) flour blends.

2. Materials and Methods

2.1 Materials

White sorghum grains, white African yam beans and unripe plantain were purchased from Ogige main market, Nsukka Local Government area, Enugu State.

2.2 Methods

2.2.1. Sample preparation

White variety of sorghum seeds, white variety of African yam bean and unripe plantain were cleaned and sorted to remove stones, dirt, chaff, and other extraneous matters before being used for further processing.

2.1.1.1 Processing of sorghum into flour

Five kilogram (5 kg) of the sorghum grains was prepared by the method described by [Mbaeyi & Onweluzo \(2010\)](#). The grains were sorted, washed and dried to a constant weight and milled in a hammer mill (Bentall superb model 200 L 090), to obtained flour. The flour was sieved by passing through a 0.5 mm pore-sized sieve, stored in a high density polyethylene bags until used for analysis as shown in the Figure 1.

2.1.1.2 Processing of African yam bean flour

The procedure described by [Enwere \(1998\)](#) was used to process the African yam bean flour. Five kilograms (5 kg) of cleaned white African yam beans was washed thoroughly with clean tap water and thereafter soaked for 12 hours and dehulled. The beans were dried in a hot air oven (60 ± 2 °C for 10 h), and milled using an attrition mill. The flour obtained was sieved using 0.5 mm mesh sieve, packaged in high density

polyethylene bags and stored until used. The flow diagram for the production of African yam bean flour is shown in Figure 2.

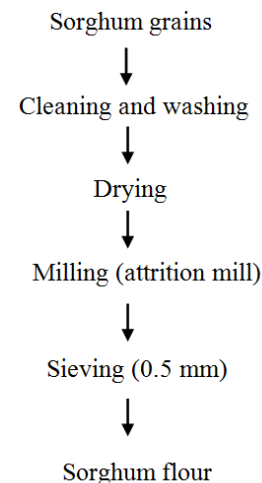


Figure 1: Flow diagram of the processing of sorghum flour. Source: [Mbaeyi & Onweluzo \(2010\)](#)

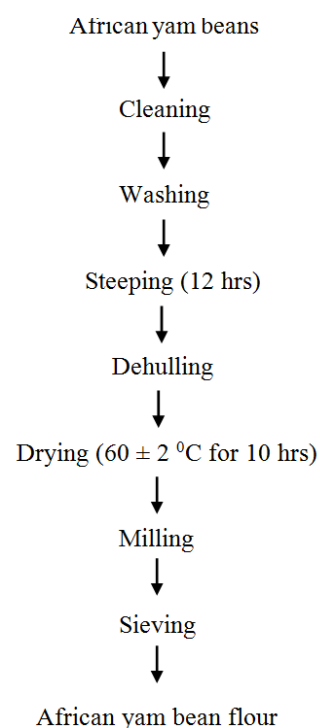


Figure 2: Flow diagram of the processing of African yam bean flour. Source: [Enwere \(1998\)](#)

2.1.1.3 Preparation of plantain flour

The method described by Enwere (1998) was used to prepare the plantain flour. Mature unripe plantain fruits were washed to remove adhering soil particles, peeled, sliced into thin slices of about 2 mm thickness, steam blanched (10 seconds at 80 °C) and dried (Gallenkamp S/No 90/20/190, U.K) at 50 ± 5 °C for 24 h. The dried plantain slices were milled into flour using a hammer mill (Bentall Superb, Model 200 L 09) and sieved through 500 μ m sieve. The flour was then packaged in high density polyethylene bag for further use and analysis (Figure 3).

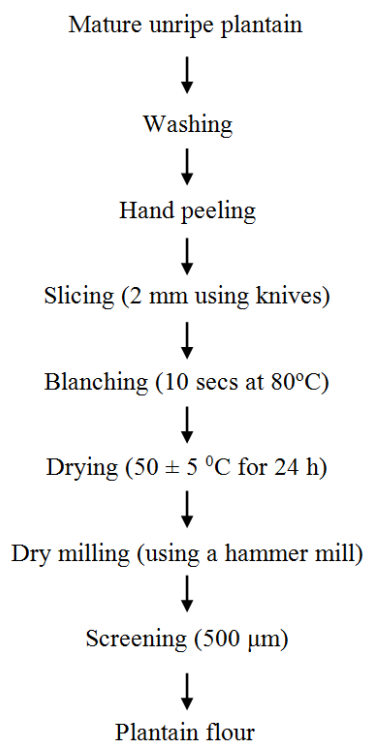


Figure 3: Flow diagram of the processing of plantain flour. Source: Enwere (1998)

2.2.2 Product Formulation

Composite flour was produced by blending sorghum, African yam bean flour and unripe plantain flour in different ratios as shown below

in Table 1. The blends were mixed, conditioned and steamed for 10 minutes.

Table 1: Composition of flour blends

Sample	Sorghum (%)	AYB (%)	Unripe plantain (%)
S ₀	100	0	0
SAUP ₁	65	30	5
SAUP ₂	60	30	10
SAUP ₃	55	30	15
SAUP ₄	50	30	20
SAUP ₅	45	30	25

S = Sorghum; A= African yam bean; UP= unripe Plantain flour blend.

The steamed product was allowed to age at 4 °C for 24 hours, sliced by using knife to a flat thin size, and toasted in an oven at 150 ± 2 °C for 5 minutes, cooled and packaged in high density polythene bag to maintain crispiness and designated as product breakfast cereals (Mbaeyi & Onweluzo, 2010) as shown in Figure 4.

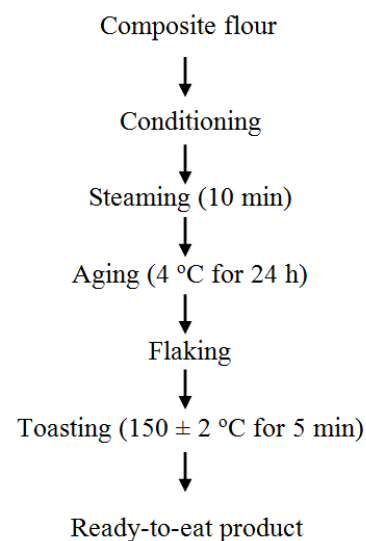


Figure 4: Flow diagram for the processing of breakfast product from blends of sorghum, African yam bean and unripe plantain. Source: Mbaeyi & Onweluzo (2010)



Figure 5: Sample before toasting (A) and after toasting (B).

2.2.3 Determination of selected functional properties of the flours

2.2.3.1 Determination of Bulk density

Bulk density was determined by the method documented by [Onwuka \(2005\)](#). Each of the formulated samples was transferred into separate 100 ml graduated cylinder and the loose volume was determined. The cylinder was tapped for about 10 - 15 minutes until the powder stopped settling and the packed volume was recorded.

2.2.3.2 Reconstitution time

The reconstitution time was determined using the procedure described by [Nwanekezi *et al.* \(2001\)](#). Two grams (2 g) of each sample was dispersed onto the surface of 50 ml of cold distilled water in a 150 ml graduated cylinder. The time taken for each of the sample to completely dissolve without stirring was recorded. The mean value of the time taken (replicates) was obtained as the reconstitution time.

$$\text{Reconstitution time} = \frac{\text{volume of sediment}}{\text{weight of sample}}$$

2.2.3.3 Wettability

Wettability was determined by the method recorded by [Onwuka \(2005\)](#). One gram (1 g) of the sample was put into 25 ml graduated cylinder of 1 cm in diameter. Placing a finger over the open end of the cylinder, it was inverted and clamp at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml distilled, thereafter, the finger was removed to allow the test material to be damped. The wettability is the time required for the sample to become completely wet (measured in secs).

2.2.3.4 Determination of in-vitro protein digestibility

In-vitro protein was determined by the method described by [Sadasivam & Manickam \(1992\)](#). Ten (10 ml) of distilled water was added to the lot and thereafter the sample was allowed to hydrate for at least one hour at 5 °C. The sample and the three enzymes (1.6 mg of trypsin, 3.1 mg chymotrypsin and 1.3 mg peptidase) was equilibrated to a pH of 8.0 at 37 °C, then, 1 ml of the enzyme solution was added to the sample suspension and stirred while held at 37 °C. After 10 minutes from the time of addition of the sample solution, 1 ml of the bacterial protease solution was added and then immediately transferred to 55 °C water bath. After 9 minutes of addition of the bacterial enzymes, the solution was transferred into 37 °C water bath, and the pH of the hydrolysate was measured at exactly ten minutes after addition of the bacterial enzyme, and the protein digestibility was calculated as

$$\text{Protein digestibility (\%)} = 234.84 \times 22.56 X$$

Where; X= pH after 20 min incubation.

2.2.4 Proximate analysis of the ready - to-eat (RTE) breakfast product

The moisture, fat, protein, ash, fibre and carbohydrate contents were determined according to the AOAC standard method (AOAC, 2010).

2.2.5 Mineral analysis of formulated breakfast product

The mineral content of the samples was evaluated using the method described by AOAC (2010). One gram of the dried sample was digested with a mixture of 12 ml of HNO₃ and 4 ml of perchloric acid (HClO₄) was added to the mixture and kept in a fume chamber. The mixture was allowed to cool and the contents transferred to 100 ml volumetric flasks and the volume was made to 100 ml with distilled water. The resulting digest was filtered with ashless Whatman filter paper. Filtrate from each sample was analyzed for mineral, phosphorus (P), potassium (K), magnesium (Mg) and iron (Fe) contents using an Atomic Absorption Spectrophotometer (Spectrumlab 21, India).

2.2.6 Determination of anti-nutritional factors

2.2.6.1 Determination of phytate content

Phytate was determined by the method described by Latta & Eskin (1980). Samples were accurately weighed (2 g) and transferred into 100 ml conical flask. A total of 40-50 ml of Na₂SO₄ was added. The flasks were then capped and shaken vigorously for 2 hr at ambient temperature. The supernatant was then filtered through qualitative filter paper (No 4). A total of 10 ml of filtrate was collected and diluted to 30 ml with distilled water after mixing with 1 ml of 0.75 ml NaOH. The extract was passed through Ag 1- 48 anion - exchange resin, permitting the removal of inorganic phosphorus as well as other

interfering compounds. Three milliliters of the eluent was put into 15 ml conical centrifuge tube, and 1 ml of modified Wade reagent (0.03 % FeCl₃.6H₂O and 0.3 % sulphur salicylic acid in distilled water) was added and the solution was mixed on a vortex mixer for 5 seconds. The mixture was centrifuged at 3000 rpm for 10 min and absorbance of the supernatant was read at 500 nm using a spectrophotometer (SECOMAM CE, France). The concentration of the phytate in the sample was extrapolated from the standard curve. Phytic acid standard curve was prepared by dissolving phytic acid in water. Three (3) ml of each standard solution (0, 1.0, 2.0, 3.0, 4.0, and 5.0 mg/ml) was pipetted into 15 ml centrifuge tubes. To each tube, 1 ml of wade reagent was added and the solution was mixed using vortex mixer for 5 sec. The mixture was centrifuged at 3000 rpm for 10 min and absorbance of the supernatant was read at 500 nm.

2.2.6.2 Determination of tannin content

Tannin content was determined by the method described by Kirk & Sawyer (1998). Five grams (5 g) of the sample was dispersed in 50 ml of distilled water and agitated. The mixture was allowed to stand for 30 min at room temperature and shaken every 5 min, centrifuged and the supernatant was obtained. Two milliliters (2 ml) of the supernatant was put into 50 ml volumetric flask. Similarly, 2 ml standard tannin solution (Tannic acid) and 2 ml of distilled water were put into a different volumetric flask and the second flask served as the standard. Then 1.0 ml of Folin-Denis reagent was added to each of the flask, followed by addition of 2.5 ml of saturated sodium carbonate solution. The content of each flask was made up to 50 ml with distilled water and allowed to incubate for 90 minutes at room temperature. Their respective absorbance was

read in a spectrophotometer at 260 nm using reagent blank to calibrate the instrument at zero. The tannin content was calculated using the formula

$$\% \text{ Tannin} = \frac{A_n}{W} \times \frac{C}{V_a} \times V_f \times 100/1$$

Where: A_n = absorbance of test sample, W = weight of sample used; C = concentration of standard solution; V_f = total volume of supernatant, V_a = volume of supernatant analyzed.

2.2.7 Microbial analysis of formulated breakfast product

2.2.7.1 Determination of total viable count

According to Prescott *et al.* (2005), 26 g of nutrient agar was dissolved in 500 ml of distilled water and sterilized. One millimeter (1 ml) of the sample and 9 ml of ringer solution was made for serial dilution, and was then pipetted into marked petri dishes, swirled to mix and incubated at 37 °C for 24 hours. After incubation, the number of colonies was counted and reported in colony forming unit per milliliters.

2.2.7.2 Determination of mould count of formulated breakfast product

This was carried out according to Prescott *et al.* (2005), Sabouraud dextrose agar (SDA) (32.5g) was diluted in 500 ml conical flask containing distilled water and sterilised. The SDA media was added to 1 ml of the sample in the petri dish and allowed to set before incubating at 37 °C for 48 hours. After incubation, the number of colonies was counted and reported as colony forming unit per milliliters

2.2.8 Sensory evaluation

Products were evaluated by twenty (20) semi trained panelist, drawn from the Department of

Food Science and Technology, University of Nigeria, Nsukka. Scoring was done on a nine-point Hedonic scale for colour, taste, texture, flavour, and overall acceptability, (where “9” represents extremely like and “1” represents extremely dislike) according to Ihekoronye & Ngoddy (1985).

2.2.9 Experimental design and Data analysis

The results were laid out in completely randomized design. Data were subjected to one-way analysis of variance (ANOVA) using the statistical package for social sciences (SPSS) and means were separated using Duncan’s new multiple range test. Differences between means were accepted at $p < 0.05$ (Steel & Torrie, 1980).

3. Results and Discussion

3.1 Selected functional properties of the flour blends for the formulation of RTE breakfast

The selected functional properties of the flours are shown in Table 2. The bulk density of the sample ranged from 0.52 to 0.59 g/ml. The highest value (0.59 g/ml) was observed in SAUP₃ and the lowest value (0.52g/ml) was observed in sample SORG (control). Mbaeyi-Nwaoha & Onweluzo (2013), and Okafor & Usman (2013), reported values similar to those obtained in the study 0.53- 0.73 g/ml and 0.29 to 0.71 g/ml, respectively. The lower the bulk density, the more packaging space is required (Agunbiade & Ojezele, 2010). The low bulk density value could imply that more quantity of the food samples could be packaged ensuring economical packaging.

The reconstitution time of the product varied significantly ($p < 0.05$), ranging from 18.33 to 40.53 seconds, with sample SORG having the lowest time of 18.33 seconds and SAUP₅ had the

highest time of 40.53 seconds. The reconstitution time increased as the level of plantain increased and these might be caused by the fibre structure or the type of starch granules produced after toasting (Okafor & Usman, 2015). Similar values of 20.33 to 33.33 seconds were reported by Mbaeyi-Nwaoha & Onweluzo (2013) for a breakfast cereal from sorghum - pigeon pea blend.

value of the products varied significantly ($p < 0.05$) from 60 % for sample SORG to 74 % for SAUP₅. Sample SORG had the least value (60 %) and SAUP₅ the highest value (74 %). Addition of African yam bean and unripe plantain flour caused an increase in the IVPD of the sample. This may be connected to the fact that fiber is known to aid digestion, and this might have led to the increase in digestibility of the proteins while a low protein digestibility could be as a result of interaction between anti nutrient such as Tannin and proteins forming complexes, which decreases solubility of proteins thereby limiting its digestibility (Ali et al., 2010). The high level of in-vitro protein digestibility of the samples indicates the availability of proteins as well as its utilization on consumption.

The wettability of the formulated product (SORG - SAUP₅) varied significantly ($p < 0.05$) from 16.50 to 28.50 seconds. SORG had the lowest wettability of 16.50 secs while SAUP₅ had the highest wettability. The wettability reduced with increase in plantain flour, and this may be due to increased fibre content of the product that has been shown to retain water as reported by Okafor & Usman (2013).

3.2 Proximate composition and Dietary fiber of the formulated breakfast product

The proximate composition (%) and dietary fiber of the breakfast product from blends of sorghum, African yam beans and unripe plantain is presented in Table 3. The moisture content of the product varied significantly ($p < 0.05$) ranging from 3.03 to 4.67 %. Sample SAUP1 showed the highest moisture value of 4.67 % while the control (SORG) has the lowest moisture value of 3.03%. The moisture content of the product decreased slightly with increase in unripe

Table 2: Selected functional properties of the flour blends for the formulation of RTE breakfast

Samples	Bulk density (g/ml)	Reconstitution time (s)	Wettability (s)	In-vitro protein Digestibility (%)
SAUP ₁	0.54 ^{bc} ± 0.99	23.67 ^d ± 1.00	20.50 ^c ± 2.00	67.24 ^{cd} ± 0.25
SAUP ₂	0.57 ^{ab} ± 0.24	24.50 ^{cd} ± 1.00	22.50 ^{bc} ± 2.00	69.14 ^{bc} ± 0.11
SAUP ₃	0.59 ^a ± 0.01	27.50 ^c ± 0.57	24.50 ^b ± 2.00	68.41 ^{bc} ± 0.05
SAUP ₄	0.56 ^b ± 0.06	30.33 ^b ± 2.00	27.50 ^a ± 1.00	72.85 ^{ab} ± 0.25
SAUP ₅	0.53 ^c ± 0.02	40.53 ^a ± 2.00	28.50 ^a ± 1.00	74.82 ^a ± 1.15
SORG	0.52 ^c ± 0.05	18.33 ^e ± 2.00	16.50 ^d ± 1.00	60.11 ^e ± 1.52

Values are means of triplicate determinations ± SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. Keys: SORG = 100% Sorghum; SAUP₁ = 65:30:5; Sorghum:African yam bean:unripe plantain blend; SAUP₂ = 60:30:10; Sorghum:African yam bean:unripe plantain blend; SAUP₃ = 55:30:15; Sorghum:African yam bean:unripe plantain blend; SAUP₄ = 50:30:20; Sorghum:African yam bean:unripe plantain blend; SAUP₅ = 45:30:25; Sorghum:African yam bean:unripe plantain blend; IVPD=In-vitro protein digestibility

Table 2 shows the in-vitro protein digestibility (IVPD) of the formulated products. The IVPD

plantain flour added. The moisture content observed in the present study also compared with the value (3.38-4.20 %) recorded by [Okafor & Usman \(2013\)](#) on breakfast cereal from blends of African yam bean, maize and defatted coconut. The low moisture content of the sample is an advantage because it would enhance the storage ability of the product as moisture values higher than 12 % facilitates microbial growth and spoilage ([Sanful, 2013](#)).

The ash content of the breakfast product varied significantly ($p < 0.05$) with increase in unripe plantain flour ranging from 1.67 to 3.86 %. With sample SAUP4 and SAUP5 formulation having the higher value of 2.72 and 3.86 %, respectively and the control formulation (SORG) had the least value of 1.67 %. The increase in ash may be attributed to increase in unripe plantain which is a rich source of mineral. Similar ash values of 1.36 % was reported by [Agunbaide & Ojezele \(2010\)](#) for bambara groundnut fortified with maize - sorghum mix, and 1.50-2.50 % by [Mbaeyi \(2005\)](#) for breakfast cereal from sorghum and pigeon pea.

The protein content of the breakfast product ranged from 8.87 to 19.74 %, except for sample SORG with a protein content of 8.87 %, there was no significant difference in the protein content of the formulated product, as this might be due to same quantity of African yam bean used. A range of 15.68-18.26 % was reported for breakfast cereal from blend of African yam beans maize and coconut by [Okafor & Usman, \(2013\)](#). The protein content of the breakfast product in the present study compares with the value (15-29 %) recommended for diabetics but higher than the FAO/WHO minimum recommended protein of 10 % for normal individual ([FAO/WHO, 1996](#)). This implies that

the formulated product can provide almost all the protein needs of a diabetic patient.

The fat content of the product (SORG-SAUP5) varied significantly ($p < 0.05$) with values ranging from 0.79 to 1.48. Sample SORG having the lowest fat content could be as a result of absence of both African yam bean and unripe plantain and SAUP5 has a higher value of 1.48. There was gradual increase in fat content as level of unripe plantain flour increases. The values could be compared to the values (1.84-2.02 %) obtained by [Okafor & Usman \(2013\)](#), on breakfast cereal from maize, African yam bean and defatted coconut. Higher fat values (3.70 %) were recorded for fortified breakfast cereals made from African yam bean, maize and soybean ([Agunbaide & Ojezele, 2010](#)), and 7.80 – 17.5 % reported by [Kanu *et al.* \(2009\)](#) for sesame and pigeon pea breakfast cereal. The fat content of the product was quite low as this may be due to the fact that cereals, legumes and tubers store energy in the form of starch rather than lipids. The low fat levels are beneficial as it ensures longer shelf life for the products ([Reebe, *et al.*, 2000](#)) because all fats and fat containing foods contain some unsaturated fatty acids and hence are potentially susceptible to oxidative rancidity. [Khan & Safdar \(2003\)](#) reported that diets that enhance glycemic control are high in dietary fibre, moderate in fat and moderate in protein. The low fat content of the developed products makes it suitable for weight watchers.

The crude fibre content of the breakfast product (SORG-SAUP5) varied significantly ($p < 0.05$) with values ranging from 0.46 to 0.58 %. The crude fibre content increased as the level of plantain flour increased in the blend with the control (SORG) having the least value, while high value of 1.54-4.00 % ([Mbaeyi, 2005](#)) and 3.10-3.80 % ([Aguibaide & Ojezele, 2010](#)) were

previously reported for other breakfast formulations from blends of sorghum and pigeon pea, and bambara groundnut fortified with maize - sorghum mix, respectively.

The dietary fibre content of the breakfast product SORG - SAUP5 increased significantly from 1.27 % to 5.40 %. There was a progressive increase in fibre as the proportion of plantain flour increased in the blend. There was no significant difference between sample SAUP2, SAUP3, and SAUP4 Researchers like [Rehinan *et al.* \(2004\)](#) reported that dietary fibre in human nutrition lowers serum cholesterol, reduces the risk of heart attacks and other metabolic diseases. The bulking effect of fibre in the diet, especially its effects on stool volume, softness frequency and regularity of elimination are thought to be the results of high water binding capacity of roughage provides which contributes to a healthy condition of the intestine ([Odom *et al.*, 2013](#)).

As a result, [Codex \(2009\)](#) associated dietary fibre with properties such as decrease intestinal transit time and increases in stools bulk, fermentable by colonic microflora, reduce blood total and LDL cholesterol levels, and reduce post-prandial blood glucose and /or insulin levels. Fibre is important for the removal of waste from the body, thereby preventing constipation and many health disorders. The viscose and fibrous structure help control the release of glucose with time in the blood, which helps in proper control and management of Diabetes mellitus ([Aleixandre & Miguel, 2008](#)).

The carbohydrate content of the products varied significantly ($p < 0.05$) ranging from 69.58 to 85.18 %. This implies that the formulated products were good sources of energy needed for normal body metabolism. The relative high

carbohydrate content of the formulations could be attributed to the high contents of the cereals and legumes used as the principal ingredients in the formulations ([Kanu *et al.*, 2009](#)). A similar value of 75.08 to 78.00 % was recorded by [Agunbaide *et al.* \(2013\)](#) for Bambara nut and groundnut blend, fortified with maize.

Table 3: Proximate composition of the formulated breakfast product

Samples	Moisture (%) (wet basis)	Ash (%)	Fat (%)	Crude Fibre (%)	Protein (%)	Carbohydrates (%)	Dietary fibre (%)
SAUP ₁	4.67 ^a ± 0.01	2.27 ^c ± 0.01	0.84 ^c ± 0.01	0.53 ^c ± 0.01	19.70 ^a ± 0.01	71.99 ^b ± 0.19	3.27 ^c ± 0.58
SAUP ₂	4.65 ^a ± 0.01	2.46 ^d ± 0.00	1.23 ^b ± 0.01	0.53 ^c ± 0.00	19.71 ^a ± 0.01	71.42 ^b ± 0.02	4.21 ^b ± 0.31
SAUP ₃	4.06 ^b ± 0.00	2.51 ^c ± 0.00	1.22 ^b ± 0.00	0.56 ^b ± 0.00	19.72 ^a ± 0.01	71.93 ^b ± 0.01	4.70 ^b ± 0.20
SAUP ₄	3.77 ^c ± 0.01	2.72 ^b ± 0.01	1.45 ^a ± 0.00	0.55 ^b ± 0.01	19.73 ^a ± 0.00	71.78 ^b ± 0.01	4.93 ^b ± 0.30
SAUP ₅	3.76 ^c ± 0.00	3.86 ^a ± 0.00	1.48 ^a ± 0.00	0.58 ^a ± 0.00	19.74 ^a ± 0.00	69.58 ^c ± 0.01	5.40 ^a ± 0.20
SORG	3.03 ^d ± 0.37	1.67 ^f ± 0.05	0.79 ^d ± 0.00	0.46 ^d ± 0.00	8.87 ^b ± 0.02	85.18 ^a ± 0.38	1.27 ^d ± 0.20

Values are means of triplicate determinations ± SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. **Keys:** SORG = 100% Sorghum; SAUP₁ = 65:30:5; Sorghum: African yam bean: unripe plantain blend; SAUP₂ = 60:30:10; Sorghum: African yam bean: unripe plantain blend; SAUP₃ = 55:30:15; Sorghum: African yam bean: unripe plantain blend; SAUP₄ = 50:30:20; Sorghum: African yam bean: unripe plantain blend; SAUP₅ = 45:30:25; Sorghum: African yam bean: unripe plantain blend

3.3 Mineral composition of the formulated breakfast product

Table 4 shows the mineral contents of the formulated breakfast products. The magnesium content of the breakfast product varied significantly ($p < 0.05$) from 13.00 in sample SORG to 19.00 % in sample SAUP₅. It was observed that the Mg content increased with increase in the proportion of unripe plantain in the blend. The magnesium content of the formulated samples was lower than the value (19.00 mg/100 g) reported by Okafor & Usman (2013) for maize, African yam bean and defatted coconut blend. The unblended Sample (SORG) sample had the least (13.00 mg/100 g) magnesium content. Magnesium helps in muscle contraction and blood clotting of wounds thereby aiding faster healing of wounds and regulation of blood pressure.

The Potassium content of the breakfast product SORG-SAUP₅ ranged from 10.00 to 22.00 % with sample SAUP₅ showing the highest value and sample SORG had the least value of 10.00 mg/100g. However, progressive increase was observed in the potassium content of all the blends as the quantity of plantain and African yam bean increased. Higher values of 70.19 mg/100g were reported for breakfast cereal from for maize, sorghum, soybean and African yam bean blend by Agunbiade & Ojezele (2010). Potassium is primarily an intercellular cation, which is bound to protein and contributes to normal pH of the body.

The Iron content of the breakfast products ranged from 0.95 to 3.51 mg/100g. There were significant ($p < 0.05$) differences observed in all the formulations as the level of plantain flour increased. The level of iron in the present study compare with the range of values (0.67-4.78

Table 4: Mineral composition of the formulated breakfast product (%)

Samples	Magnesium	Potassium	Iron	Phosphorus
SAUP ₁	15.00 ^{bc} ± 1.00	11.00 ^c ± 0.00	1.66 ^d ± 0.20	62.00 ^{cd} ± 1.00
SAUP ₂	16.00 ^{ab} ± 0.00	17.00 ^b ± 0.00	1.68 ^d ± 0.10	64.00 ^c ± 1.00
SAUP ₃	18.00 ^b ± 0.03	17.00 ^b ± 0.01	2.00 ^c ± 0.10	64.00 ^c ± 1.00
SAUP ₄	18.00 ^b ± 1.00	16.00 ^b ± 0.20	2.43 ^b ± 0.25	68.00 ^b ± 2.00
SAUP ₅	19.00 ^a ± 2.00	22.00 ^a ± 0.00	3.51 ^a ± 0.25	72.00 ^a ± 2.00
SORG	13.00 ^c ± 1.00	10.00 ^c ± 0.00	0.95 ^f ± 0.10	22.00 ^e ± 1.00

Values are means of triplicate determinations ± SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. **Keys:** SORG= 100% Sorghum; SAUP₁ = 65:30:5; Sorghum; African yam bean; unripe plantain blend; SAUP₂ = 60:30:10; Sorghum; African yam bean; unripe plantain blend; SAUP₃ = 55:30:15; Sorghum; African yam bean; unripe plantain blend; SAUP₄ = 50:30:20; Sorghum; African yam bean; unripe plantain blend; SAUP₅ = 45:30:25; Sorghum; African yam bean; unripe plantain blend.

mg/100g) reported by Chinma *et al.* (2012) for breakfast products from unripe plantain and sesame flour blends. Iron in the body is vital as it helps to prevent incidence of anemia in diabetic patients especially women in developing countries. The phosphorus content of the breakfast products ranged from 22.00 to 72.00 mg/100g with sample SORG having the lowest content and sample SAUG₅ having the highest. Phosphorus plays an important role in how the body uses carbohydrates and fats. It is also needed for the body to make protein for the growth, maintenance and repair of cells and tissues.

Generally, the increase in blending ratio with unripe plantain is directly proportional to the mineral content of the formulated breakfast products. Supplementation of the sorghum flour

with African yam bean and unripe plantain increased the magnesium, potassium, phosphorus and iron contents.

3.4 Anti-nutritional contents of the formulated ready-to-eat (RTE) breakfast product

The anti-nutritional contents of the breakfast products are shown in Table 5. The haemagglutinin content of the formulated breakfast products (SORG-SAUP₅) ranged from 0.00 to 0.80 hu/g. However, there were no significant ($p > 0.05$) differences among samples due probably to the fact that same ratio of African yam bean (a legume that is generally associated with haemagglutinin) used, while no haemagglutinin was detected in Sample SORG due to the absence African yam bean flour. The phytate content of the product ranged from 0.20 mg/100g in SORG to 0.49 mg/100g in SAUP₅. The phytate content of the blends increased slightly and these values were similar to 0.38 – 1.25 mg/100g reported by Okafor & Usman (2013) for breakfast cereal from blends of maize, African yam bean and coconut but lower than 0.56-0.70 mg/100g reported by Okpala & Okoli (2011). The values obtained were below the acceptable limit of 22.10 mg/100g phytate concentration in ready-to-eat foods (WHO 2003b).

The tannin content of the formulated product varied significantly ($p < 0.05$), ranging from 1.16 mg/100 g in SAUP₅ to 2.42 mg/100 g in SORG. There was reduction in the tannin content of the samples as plantain flour increased. It was observed that the tannin contents of the samples were less than the safe level of 4.00 – 9.00 mg/100 g as reported by Siddharuji & Becker (2001). The value tannin obtained in this study is comparable to the values (0.14 ± 0.02 to 0.50 ± 0.01 mg/100g) reported by Enujiugha (2006), for

maize instant food supplemented with African oil bean seed. Tannins are located in the seed coat of grains and are known to have deleterious effects due to their strong interactions with proteins which results to complexes that are not readily digested by monogastriacs leading to low protein digestibility.

Table 5: Anti-nutritional content of the formulated breakfast product

Samples	Haemagglutinin (hu/g)	Phytate (mg/100g)	Tannin (mg/100g)
SAUP ₁	0.80 ^a ± 0.01	0.24 ^d ± 0.00	1.32 ^{bc} ± 1.50
SAUP ₂	0.80 ^a ± 0.01	0.29 ^c ± 0.00	1.29 ^{bc} ± 1.85
SAUP ₃	0.80 ^a ± 0.00	0.29 ^c ± 0.00	1.22 ^c ± 2.11
SAUP ₄	0.80 ^a ± 0.00	0.46 ^b ± 0.00	1.19 ^{cd} ± 1.12
SAUP ₅	0.80 ^a ± 0.00	0.49 ^a ± 0.00	1.16 ^d ± 3.10
SORG	0.00 ^b ± 0.00	0.20 ^f ± 0.00	2.42 ^a ± 1.89

Values are means of triplicate determinations ± SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. **Keys:** SORG = 100% Sorghum; SAUP₁ = 65:30:5; Sorghum: African yam bean: unripe plantain blend; SAUP₂ = 60:30:10; Sorghum: African yam bean: unripe plantain blend; SAUP₃ = 55:30:15; Sorghum: African yam bean: unripe plantain blend; SAUP₄ = 50:30:20; Sorghum: African yam bean: unripe plantain blend; SAUP₅ = 45:30:25; Sorghum: African yam bean: unripe plantain

3.5 Microbial count of the formulated breakfast product

The microbial counts of the formulated breakfast product from blends of sorghum, African yam bean and unripe plantain are shown in Table 6. The viable count of the product ranged from 5.7×10^4 to 1.4×10^5 cfu/g. Sample SORG had the

lowest value of 5.7×10^4 cfu/g and sample SAUP₂ had a high TVC value of 1.4×10^5 cfu/g, respectively, while mould count ranged from 1.00×10 to 2.0×10 cfu/g for sample SAUP₃ to SAUP₂.

Table 6: Microbial count (cfu/g) of the formulated breakfast products

Samples	Total viable count (cfu/g)	Mould count (cfu/g)
SAUP ₁	6.3×10^4	NG
SAUP ₂	1.4×10^5	2.0×10
SAUP ₃	1.0×10^5	1.0×10
SAUP ₄	8.9×10^4	NG
SAUP ₅	1.2×10^5	NG
SORG	5.7×10^4	NG

Values are means of triplicate determinations \pm SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. Keys: SORG= 100% Sorghum; SAUP₁ = 65:30:5; Sorghum:African yam bean:unripe plantain blend; SAUP₂ = 60:30:10; Sorghum:African yam bean:unripe plantain blend; SAUP₃ = 55:30:15; Sorghum:African yam bean:unripe plantain blend; SAUP₄ = 50:30:20; Sorghum:African yam bean:unripe plantain blend; SAUP₅ = 45:30:25; Sorghum:African yam bean:unripe plantain blend; NG = No Growth

The values obtained from the study were similar to the values (1.51×10^2 cfu/g for viable count) reported by Okafor & Usman (2013) but no growth was reported by Mbaeyi-Nwaoha & Onweluzo (2013), for a breakfast cereal from sorghum - pigeon pea blend. According to ICMSF (2000), ready to eat foods with plate count between $0-10^3$ is acceptable, 10^4 to 10^5 is tolerable and 10^6 and above is unacceptable. Hence, the microbial load of the breakfast products ranged between the acceptable and tolerable limit.

3.6 Sensory scores of the formulated breakfast products

The sensory scores of the formulated product from blends of sorghum, African yam bean and unripe plantain are shown Table 7. The breakfast product had very good sensory ratings for appearance, flavour, taste, texture and overall acceptability. The samples were significantly ($p < 0.05$) different from each other in colour scores. Sample SAUP₁ differed significantly ($p < 0.05$) in colour scores, having the highest mean value of 7.20. This could probably be due to 5% addition of unripe plantain flour in the blend, while the SORG (6.95) ranked next to sample SAUP₁ in rating.

There were significant ($p < 0.05$) differences in the flavour of the formulations as the ratio of plantain flour increased. Sample SAUP₅ formulation had the highest mean score (6.95) probably due to the desirable flavour of the unripe plantain when toasted. The addition of the unripe plantain to the blend increased the flavour sensation of the product thereby masking the beany flavour of African yam bean.

Sample SAUP₂ and SORG had the highest mean score of 6.95 in taste which differed significantly ($p < 0.05$) from the other samples. The taste was also improved as the proportion of unripe plantain increased.

Except the control sample, (SORG, 100 % sorghum) which differed significantly ($p < 0.05$) in texture no significant differences were observed in the texture scores among the samples (SAUP₁-SAUP₅). The scores for texture of the samples did not differ significantly ($p > 0.05$).

In overall acceptability, significant ($p < 0.05$) difference existed in all the samples, with sample SAUP₁ having the least mean value (6.25) which was significantly ($p < 0.05$) different from sample SAUP₂, SAUP₅. Although, no particular trend

was followed, sample SAUP₅ (45:30:25) was consistent in its rating for most preferred choice for colour, flavour, and taste.

Table 7: Sensory scores of the formulated breakfast product

Samples	Colour	Flavour	Taste	Texture	Mouthfeel	Overall acceptability
SAUP ₁	7.20 ^a ± 1.44	6.02 ^{ab} ± 1.40	5.90 ^b ± 1.97	5.95 ^a ± 2.01	5.60 ^b ± 2.26	6.25 ^c ± 1.48
SAUP ₂	6.85 ^b ± 1.63	6.05 ^{ab} ± 1.28	6.95 ^a ± 1.23	5.45 ^a ± 1.70	6.70 ^a ± 1.84	7.20 ^{ab} ± 1.36
SAUP ₃	6.40 ^{bc} ± 1.60	6.20 ^{ab} ± 1.94	5.95 ^b ± 2.21	5.40 ^a ± 1.39	5.95 ^b ± 1.54	6.40 ^{bc} ± 1.27
SAUP ₄	6.50 ^{bc} ± 1.76	6.30 ^{ab} ± 1.59	6.10 ^{ab} ± 1.52	5.60 ^a ± 1.57	6.75 ^a ± 1.25	6.60 ^{abc} ± 1.31
SAUP ₅	6.00 ^c ± 1.38	6.95 ^a ± 1.36	6.85 ^a ± 1.66	5.60 ^a ± 1.76	6.70 ^a ± 1.63	7.10 ^{ab} ± 1.07
SORG	6.95 ^a ± 1.36	6.55 ^a ± 1.23	6.95 ^a ± 1.19	6.85 ^b ± 1.62	6.75 ^a ± 1.62	7.30 ^a ± 1.17

Values are means of triplicate determinations ± SD. Means within a column with same superscripts are not significantly ($p > 0.05$) different. Keys: SORG= 100% Sorghum; SAUP₁ = 65:30:5; Sorghum: African yam bean: unripe plantain blend; SAUP₂ = 60:30:10; Sorghum: African yam bean: unripe plantain blend; SAUP₃ = 55:30:15; Sorghum: African yam bean: unripe plantain blend; SAUP₄ = 50:30:20; Sorghum: African yam bean: unripe plantain blend; SAUP₅ = 45:30:25; Sorghum: African yam bean: unripe plantain blend.

4. Conclusion

Ready-to-eat breakfast product was formulated from flour blends of sorghum, African yam bean

and unripe plantain. The presence of African yam bean in the product increased the protein, fibre and mineral content of the product. Sample SAUP₁ (65:30:5) had the highest score for colour (7.20) while SAUP₅ (45:30:25) had the highest score for flavour (6.95), taste (6.95) and overall acceptability (7.10). The In-vitro protein digestibility and reconstitution time of the products increased with increase in the ratio plantain flour in the blend while the wettability of the product reduced. The control (SORG) product had the lowest mineral content (13 %) compared to the mineral contents of the products from the composite flour (SAUP₁ - SAUP₅). Sample SAUP₅ containing 45:30:25 ratio of sorghum, African yam bean and unripe plantain had the highest content of potassium (22 %), Iron (3.51 %) and phosphorus (72.00 %). All the breakfast products were low in mould count but sample SAUP₂ (60:30:10) had the lowest mould count (2.0×10^4 cfu/g). Sample SORG had the lowest total viable count (5.7×10^4 cfu/g), while sample SAUP₄ (50:30:20) had the highest count (1.2×10^5 cfu/g).

Conflict of interest

The authors declare that there are not conflicts of interest.

Ethics

This Study does not involve Human or Animal Testing.

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Cite this paper as: Mbaeyi-Nwaoha, I. E., Onuh, F.A., Ani, J.C. (2020). Quality Assessment of Formulated Ready-to-eat Breakfast Cereals from Blends of Sorghum (*Sorghum bicolor L.*), African yam bean (*Sphenostylis stenocarpa*) and Unripe Plantain (*Musa paradisiaca*) *Journal of Food Stability*, 3 (3), 23-39

[DOI: 10.36400/J.Food.Stab.3.3.2020-0027](https://doi.org/10.36400/J.Food.Stab.3.3.2020-0027)