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CHEMICAL COMPOSITION, FUNCTIONAL AND PASTING PROPERTIES OF YELLOW MAIZE, FERMENTED AFRICAN YAM BEAN SEEDS AND RICE BRAN COMPOSITE FLOUR BLENDS

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ABSTRACT

Common grains consumed in diets to supply energy mainly are usually deficient in important amino acids which call for fortification. Composite flour blends from yellow maize grain, African yam bean seeds and rice bran were produced using a D-optimal design and 100% yellow maize serving as control. Chemical composition, functional properties (bulk density, loose density, dispersibility, oil absorption capacity (OAC), water absorption capacity (WAC), wettability and swelling index) and pasting properties of fifteen (15) formulated experimental trial blends were analyzed. The proximate composition of the composite flour ranged from 3.67 - 7.92 % moisture content; 92.09 - 96.34 % dry matter; 3.45 - 4.74 % crude fat; 1.26 - 1.82 % total ash; 7.53 - 8.94 % crude protein; 6.12 - 7.11 % crude fibre and 72.35 - 73.80 % carbohydrate. The mineral composition (mg/100g) of flour samples ranged from 118.93 -131.66 Sodium; 311.42 - 381.12 potassium; 316.39 - 341.31 Calcium; 178.93 - 185.32 Magnesium; 233.71 - 267.31 Phosphorus; 2.61 - 2.98 Iron; 1.09 - 1.19 Manganese and 0.91 -1. 11 Zinc. The anti-nutritional composition of samples were 0.67 - 1.04 % tannin; 4.91 - 5.59 % Phytate; 1.28 - 1.72 % trypsin inhibitor, and 2.06 - 2.64 % Saponin. The functional properties ranged from 1.40-1.96 % for WAC; OAC: 0.92-1.25 %; loose density: 0.38-0.52 g/ dm^3; bulk density: 0.66-0.80 g/dm^3; dispersibility: 61-70 %; wettability: 15.35-34.59 s; swelling index: 0.89 -1.02 g/ml. An increment in the amount of African yam bean flour, led to increased functionality of the composite flours in terms of WAC and OAC, as well as loose and bulk densities, when compared to yellow maize flour and rice bran flour. When rice bran was added to the flour blends, the wettability and dispersibility of the blends improved. Pasting properties of the flour blends revealed that peak viscosity varied from 668.50-1193.50 RVU; trough viscosity-657.50-1113.50 RVU; break down viscosity-13.50-81.00 RVU; final viscosity-1386.50-3667.50 RVU; setback viscosity-716.50-2746.50 RVU; peak time-5.14-7.00 min and pasting temperature-52.74-88.05 ℃. The results obtained from this study demonstrate increased functionality and high pasting properties and provide the basis for advancing the process of underutilized local crops in confectionery industries for protein/fibre enrichment.

Keywords: *Composite flour, Yellow maize, African yam bean seeds, Rice bran, Enrichment*

INTRODUCTION

Majority of Africans get more than 60% of their calories from one or more of three basic food groups: grains, roots, and tubers, with little or no animal protein (Galati *et al.* 2014). Maize, rice, sorghum, and millet are among Africa's most frequently-eaten grains. These grains provide substantial quantities of fibre, minerals and vitamins in addition to being an energy source. However, they are deficient in the important amino acid: lysine. They include anti-nutritional elements that restrict their use. Despite this, diets based only on cereals are incapable of providing nutritional security (Sarwar *et al.* 2013). Legumes, on the other hand, are low-cost excellent sources of protein that are higher in lysine content but a lower amount of methionine and cysteine. They are nevertheless important in increasing the protein quality of cereal-based meals. Igbabul *et al.* (2015) found that products made from a mix of cereals and legumes had higher nutritional and calorific value than those made just from cereals or legumes.

Composite flour is obtained from the combination of flours from different plant materials sources such as cereals, roots, legumes, and tubers and may or may not contain wheat flour (Kalu *et al.* 2019). It is popularly employed in the confectionery industry for product development. Composite flour has a complete essential amino acid profile, since the flour is made from a combination of cereal and leguminous plants with different protein profile contents (George *et al.* 2020). The percentage ratio of the flour proportion determines the overall nutrient profile of foods made from composite flours (Meka *et al.* 2019). Some of the basic characteristics of composite flour include easy accessibility, culturally acceptable, affordable, and nutritionally and functionally equivalent to wheat flour (Igbabul *et al.* 2014). Combining cereals and legumes boosts the food's protein and calorie value since most African diets consist mostly of cereals as staple foods (Banerjee and Maitra, 2020). Composite flour formulation provides a critical solution to malnutrition in Africa. The importance of such crops in relieving malnutrition cannot be overstated.

African yam bean (*Sphenostylis stenocarpa*) (AYB), also known as Odudu or Azuma, is an underutilized, lesser-known leguminous plant species cultivated widely in various tropical regions of Africa (Enujiugha *et al.* 2012; Uchegbu, 2015). It is a perennial crop that belongs to the leguminous family and sub-family *papilonacea sp.* It is mostly cultivated for household uses (Enujiugha *et al.* 2012). AYB has high nutritional value; as the seed is high in protein and ranged from 19 to 30% (George *et al.* 2020). About 50 % of the seed nutritional composition is mainly carbohydrates (George *et al.* 2020) and some vital minerals include calcium, iron, zinc, and magnesium, potassium, sodium (Anjorin, *et al.*, 2019; Okolie *et al.*, 2022)

Yellow maize (Zea mays) is a popular tropical grain crop that is rich in carbohydrates and some other important nutrients (Igbabul *et al.* 2014; Meka *et al.* 2019). However, yellow maize is low in lysine and tryptophan contents but contains a higher amount of methionine and cysteine (Dabel *et al.* 2016). As a result, maize-based diets necessitate protein-rich foods as a supplement. Consumption of yellow maize in Nigeria is mainly in the form of roasted fresh maize, popcorn and boiled maize. Maize is an excellent source of Vitamin A, in the form of β-carotene a yellow-orange colour pigment (Nagarajaiah and Prakash, 2015). Inclusion of yellow maize in composite flour production improves its nutritious value (Bukuni *et al.* 2022). Rice (*Oryza sativa* L.) bran is regarded as an underused by-product of rice milling, commonly utilized in animal feed formulation due to its high dietary fibre content. Reports have shown the production of gluten-free products from rice bran sources (Raungrusmee *et al.* 2020; Skendi, *et al.* 2021). Rice bran has some important health-promoting advantages for animals. The presence of fibre in it has helped to alleviate some gastrointestinal diseases. Lipoxygenases and lipases are important rancidity-inducing enzymes in rice bran during storage. Heat conditioning of rice bran before its usage helps to overcome the storage difficulty; the enhanced shelf life and maintained bioactivity have increased the use of rice bran for human health and nutrition (Prasad *et al.* 2011). Rice bran is rich in vitamins and minerals such as vitamin E, thiamin, niacin, calcium, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc. Other important nutrients in rice bran include protein, fibre, ash, essential oil and minerals (Omarini *et al.*, 2019; Manzoor *et al.*, 2023).

The total behaviour or performance of proteins in food is referred to as functional characteristics, and they represent the many interactions in which proteins participate (Onwuka, 2005). The structure/conformation of the protein and other dietary components such as water, carbohydrates, fats, and vitamins might also be considered functional properties. Proteins react well with reducing sugars, lipids, other oxidation products, and phenols and a variety of other dietary ingredients. Functionality, according to Okaka (1997), can be defined as any physicochemical feature that influences the processing and behaviour of a component in a food product. The acceptability of flour, protein, or paste as an ingredient in food preparation is mostly determined by functional qualities (Onimawo and Egbekun, 1998). Pasting is an important parameter of a starch molecule that provides it with the ability to form a paste-like structure. Pasting is defined as the phenomenon that occurs after application of heat to starch granules in the presence of water and is characterized by swelling and, finally, total disarrangement of the starch granules. In view of the importance of functional and pasting characteristics of flour in the overall performance of food product development and consumer acceptance, there is a need to generate an adequate pool of data on the functional and pasting properties of any new composite flour blends.

The objective of this study was to determine the chemical composition, functional and pasting properties of composite flour blends from yellow maize, fermented African yam bean seeds and rice bran flour as an alternative source of confectionery flour from underutilized local raw materials.

MATERIALS AND METHODS

Source of raw materials

African yam bean seeds were obtained from a local market in Umuahia, Abia State while yellow maize (*Zea mays*) grains and food-grade rice bran were purchased from Lafenwa market, Abeokuta, Ogun State.

Preparation of Raw Materials

Fermented African yam bean flour (Submerged fermentation)

Fermented African yam bean (AYB) flour was prepared according to the method of Nwokeke *et al.* (2013) with some modifications. The AYB seeds which were sorted and cleaned to remove dirt and foreign materials, were subsequently steeped (to facilitate de-hulling) in water (1:4 w/v) for 48 h. The fermented seeds were then dehulled in water containing 0.1 per cent sodium metabisulphite (1:5 w/v) and were thoroughly rinsed for safe consumption. The fermented AYB seeds were dried for 12h at 50 °C., using a cabinet oven dryer (Genlab Drying cabinet). The dried dehulled seeds were milled using an attrition mill (Model 3511A) and sieved using a mesh size 500 µm to obtain fermented African yam bean (AYB) flour. The flour was stored in an airtight container for further use.

Preparation of yellow maize flour

Production of yellow maize flour was done following the method of Adegunwa *et al.* (2014). The yellow maize grains were sorted; plant debris, stones and other foreign materials were removed by washing. The cleaned yellow maize grains were dried in a cabinet oven dryer (Genlab Drying cabinet) for 2 days at 50 °C and before being milled (attrition mill) and sieved with a mesh size of 500 µm to obtain a fine ground maize flour and packed in a high-density polyethene bag.

Preparation of rice bran flour

The modified method of Oluwajuyitan *et al.* (2021) was adopted in preparing the rice bran flour. The ofada rice bran was conditioned for 1 h and 30 min in a water bath at 80 °C. The conditioned rice bran was dried at 50°C for 12 h with a cabinet dryer at the Food processing laboratory of the department of Food science and technology, FUNAAB. The dried rice bran was milled and sieved with a mesh size of 500µm, and packaged in an airtight polythene bag and stored until needed.

Formulation of composite flour blends

D-optimal mixture design (Design expert 9.0) was used to generate different composite blends. The design was based on yellow maize seed (55-60%), African yam bean seed (25-30%), and rice bran (10-15%) Table 1.

Table 1: Experimental design for Composite Flour Blends using D-optimal design

SAMPLE CODE	YMF (%)	AYBF (%)	RBF (%)
A	60.00	25.00	15.00
B	60.00	27.50	12.50
C	59.17	29.17	11.67
D	58.33	28.33	13.33
E	57.50	27.50	15.00
F	60.00	30.00	10.00
G	59.17	26.67	14.17
H	60.00	30.00	10.00
I	57.50	30.00	12.50
J	55.00	30.00	15.00
K	57.50	27.50	15.00
L	60.00	25.00	15.00
M	55.00	30.00	15.00
N	56.67	29.17	14.17
O = (Control)	100	-	-

YMF = Yellow maize flour; AYB = African yam bean; RBF = Rice bran flour

Analyses on flour blends

Determination of Proximate composition

Moisture content, protein, crude fat, crude fibre, ash and carbohydrate were determined by standard methods according to AOAC (2012) as described by Dendegh *et al.* (2019).

Determination of Mineral composition

Manganese, Potassium, Sodium, Magnesium, Calcium, Iron, Zinc were determined using Atomic Absorption Spectrophotometer (Buck Scientific Model 2010 VGP) and Phosphorus was determined with a UV-Visible Spectrophotometer (LaboMed SPECTRO SC) as described by Nwachukwu *et al.*, (2017) following a dry ashing method with HNO_3 solution.

Determination of Anti-Nutritional *Composition*

Trypsin inhibitor was determined according to AOAC (2012) method. The phytate content of the flours was determined using method described by Oladele *et al.*, (2009). Tannin content was determined by the method described by Mugabo *et al.* (2017). Total saponin content was determined through spectrophotometry, as described by Medina-Meza *et al.*, (2016).

Determination of Functional Properties

The bulk and lose densities of flour blends were estimated using the method described by Makinde and Ladipo (2012). About 10 g of flour sample was measured in measuring cylinder (50 ml) before and after repeatedly tapping the base of the cylinder on a laboratory wooden bench several times until there was no further reduction in volume. The bulk and lose densities were calculated and presented in g/ml.

The method of Kulkarni *et al.* (1991) as described by Adeola *et al.* (2020) was used in determining the dispersibility of the flour blends. About 10g of the sample was weighed into a measuring cylinder (100 ml) and mixed with distilled water up to the 100 ml mark. The cylinder was thoroughly shaken and set out to stand for 3 h. The volume of settled particles was measured and subtracted from 100. The percentage dispersibility of the flour was calculated as the difference.

The determination of flour wettability was done according to AOAC (2006) methods as described by Peter-Ikechukwu *et al.* (2020). One gram of flour was added into a 25 ml graduated measuring cylinder of 1 cm diameter. The cylinder was inverted with a finger covering the lid and clamped at about 10 cm above the surface of a beaker containing 500 ml distilled water. The finger was removed, and the flour sample was emptied into the distilled water. The wettability was calculated as the time taken for the flour to become wet after its dumping.

The swelling index was determined as described by Abbey and Ibeh (1988). One gram of the flour sample was weighed into a 10 ml graduated cylinder with the dry bulk volume noted. Five milliliters of distilled water was added, and the volume occupied by the sample was recorded. The sample was allowed to stand undistributed in water for 1hr and the volume was again recorded.

The method of Beuchat (1977) was adopted for the determination of water absorption capacity (WAC) and oil absorption capacity (OAC). About one gram of flour sample was mixed with 10 ml of distilled water (oil) in a 25 ml centrifuge tube. The mixture was shaken thoroughly and stationed at a fixed place at room temperature (30±2 °C) for 1 hr. The suspensions were centrifuged for 30 min at 2000rpm. The water (oil) on the sediment was measured. The water (oil) absorption capacity is expressed as the percentage of water (oil) absorbed.

Determination of pasting properties

The pasting properties of the composite flours were examined with a Rapid Visco Analyzer (RVA TECMASTER, Perten Instrument-2122833, Australia). About 3.00 g of the composite flour was added into a metal RVA canister containing 25 ml of distilled water and properly mixed to form a uniform suspension with any lump. The canister was lowered into the Rapid Visco Analyser according to recommended instruction and the suspension was subjected to the following temperature profile of 50 °C for 1min, 95 °C with a holding time of 2 min and final cooling to 50 °C with 2 min holding time. The pasting profile was recorded in triplicate under a constant shear rate 160 rpm (AACC, 2000). The starch Pasting parameters were recorded from the RVA curve and include pasting temperature, peak viscosity, breakdown viscosity, final viscosity, trough viscosity setback viscosity and peak time. The results were reported in RVU for all the parameters except for pasting temperature, which is expressed in ° C.

Statistical Analysis

Triplicate tests were performed. The data was analysed using ANOVA (SPSS version 25.0) for statistical purposes. The post-doc analysis was done with Duncan's multiple range test at $p<0.05$ for the separation of the Means.

RESULTS AND DISCUSSION

Proximate composition of composite flour blends

The moisture content of the flour blends ranged from 3.67 to 7.92 % with sample blend C (59.17:29.17:11.67) having the highest while sample blend G (59.17:26.67:14.17) had the least (Table 2). The difference in the moisture content may be due to variation in blend proportion ratios. No definite trend was observed on moisture content. High moisture content is not desirable. The moisture content of any food also indicates its level of water activity and thus, be used to measure its stability and susceptibility to microbial contamination (Edem and Dosunmu, 2011). However, the moisture content of the sample blends was low for a longer storage period depending on the packaging material and storage condition. The mean separation by Duncan's multiple range test indicated a significant difference between the mean values. High-moisture products (>12/100 g) usually have shorter shelf stability compared with lower moisture products (<12/100 g). The results obtained are comparable with the values of 4.07%-8.69% reported by Idowu (2014) for the African yam seed bean maize flour blend (Table 2).

The dry matter content of the sample blends also varied between 92.09% and 96.34 %. Sample blend C (59.17:29.17:11.67) had the least dry matter content while sample blends G (59.17:26.67:14.17) had the highest. There was a significant difference in sample blends. These results are in line with a similar study on nutritional contents of processed local food flours by Isong (2018).

Fat is one of the major components of food that provides essential lipids and energy and contribute to food flavour during food preparation. The crude fat content varied between 3.45 and 4.86 % with sample blend C (59.17:29.17:11.67) having the least while sample blend G (59.17:26.67:14.17) had the highest and significant difference was observed among the flour blends. Similar values (2.90%-5.69%) with the flour blends were reported by Ishiwu and Onyeji (2004) for instant gruel based on blends of maize and African yam bean but lower values were reported by Zanna and Milala (2005) on cowpea-millet mixes. Furthermore, fat plays a significant role in the shelf life of food products and as such relatively high-fat content could be undesirable in food products. This is because fat can promote rancidity in foods, leading to the development of unpleasant and odorous compounds.

The ash content of any given food sample is a measure of the mineral level that the food contains (Godswill, 2019). Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agent (Sanni *et al.* 2008). Mean values of the total ash contents varied with sample blend I (57.50:30:12.50) having the highest (1.82 %) while sample blend K (57.50:27.50:15) had the least (1.26 %). There was a progressive increase in ash content with the addition of

Africa yam bean and rice bran, which implies that the composite blend with higher Africa yam bean and rice bran had more nutrients and this is beneficial to the health of the consumer. The post-doc result showed a significant difference between samples of the total ash content (Table 2).

The crude fibre content of the flour blends ranged from 6.12 to 7.11%, with sample blend B (60:27.50:12.50) having the highest while sample blend G (59.17:26.67:14.17) had the least. According to studies, it is now accepted that fibre plays a significant role in the prevention of several pathological diseases such as cardiovascular diseases, diverticulosis, constipation, irritable colon, cancer and diabetes (Slavin (2005); Elleuch *et al.*, 2011; Mazzocchi, *et al.* 2023). The post-doc result indicated a significant difference between the mean values of the flour blends. Generally, Proteins help to build and repair worn out tissues in the body.

The crude protein content of the sample blends also varied and the value ranged from 7.53 to 8.94%. Sample blend K (57.50:27.50:15) had the least crude protein content while sample blends G (59.17:26.67:14.17) had the highest. There were significant differences in the flour blends. The increases in crude protein could be due to enzyme hydrolysis of the insoluble proteins and attributed to the fact that some amino acids are produced in an excess amount of the requirement during protein synthesis and these tend to accumulate in the free amino acids pool (Echendu *et al.*, 2009).

The carbohydrate content result is comparable with those from Sagbo *et al.*, (2017) and Shaista *et al.*, (2017). The carbohydrate content varied between 72.35 and 73.73% with sample blends C (59.17:29.17:11.67) having the least while sample blend B (60:27.50:12.50) had the highest and significant difference was observed (Table 2). Awolu and Oseyemi, (2016) reported that high carbohydrate content is directly proportional to the energy content of the food product.

Table 2: Proximate composition of yellow maize, rice bran and fermented African yam bean composite flour blends

Yellow maize (%)	Africa Yam Bean (%)	Rice Bran (%)	Sample code	Moisture Content (%)	Dry Matter (%)	Crude Fat (%)	Total Ash (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate Content (%)
60.00	25.00	15.00	A	6.24^{f} ± 0.02	93.76^{e} ± 0.02	4.13^{e} ±0.01	1.64^{ef} ±0.01	6.36^{d} ±0.00	8.14^{d} ±0.03	73.50^{c} ± 0.04
60.00	27.50	12.50	B	7.05^{h} ± 0.04	92.95^{c} ± 0.04	3.84^{c} ± 0.03	1.33^{b} ±0.01	6.12^{a} ±0.01	7.87^{c} ±0.01	73.80^{f} ± 0.02
59.17	29.17	11.67	C	7.92^{j} ± 0.02	92.09^{a} ± 0.02	3.45^{a} ± 0.01	1.43^{c} ±0.01	6.23^{b} ±0.01	8.63^{g} ±0.01	72.35^{a} ± 0.03
58.33	28.33	13.33	D	5.05^{d} ± 0.03	94.85^{g} ± 0.17	4.55^{g} ± 0.02	1.67^{f} ±0.01	6.81^{g} ±0.01	8.51^{f} ±0.01	73.32^{b} ± 0.11
57.50	27.50	15.00	E	7.44^{i} ± 0.02	92.57^{b} ± 0.02	3.77^{c} ± 0.01	1.27^{a} ±0.02	6.30^{c} ±0.02	7.54^{a} ±0.01	73.70^{def} ± 0.05
60.00	30.00	10.00	F	4.24^{bc} ±0.02	95.77^{h} ± 0.02	4.71^{hi} ± 0.00	1.75^{g} ±0.01	6.88^{h} ±0.01	8.80^{i} ±0.02	73.63^{de} ± 0.03
59.17	26.67	14.17	G	3.67^{a} ± 0.02	96.34^{i} ± 0.02	4.86^{j} ± 0.00	1.80^{h} ±0.01	7.11^{i} ±0.01	8.94^{i} ±0.01	73.62^{d} ± 0.01
60.00	30.00	10.00	H	4.23^{b} ± 0.02	95.76^{h} ± 0.02	4.70^{h} ± 0.00	1.74^{g} ±0.01	6.87^{h} ±0.01	8.79^{i} ±0.02	73.62^{d} ± 0.03
57.50	30.00	12.50	I	4.29^{c} ± 0.04	95.73^{e} ± 0.02	4.74^{i} ± 0.01	1.82^{h} ±0.02	6.73^{f} ±0.01	8.70^{h} ±0.03	73.74^{ef} ± 0.04
55.00	30.00	15.00	J	5.55^{e} ± 0.01	94.45^{f} ± 0.01	4.19^{f} ± 0.01	1.67^{f} ±0.01	6.59^{e} ±0.01	8.27^{e} ±0.01	73.74^{ef} ± 0.04
57.50	27.50	15.00	K	7.43^{i} ± 0.02	92.56^{b} ± 0.02	3.76^{b} ± 0.01	1.26^{a} ±0.02	6.29^{c} ±0.02	7.53^{a} ±0.01	73.69^{def} ± 0.05
60.00	25.00	15.00	L	6.23^{f} ± 0.02	93.76^{e} ± 0.02	4.12^{e} ± 0.01	1.63^{e} ±0.01	6.35^{d} ±0.00	8.13^{d} ±0.03	73.49^{c} ± 0.04
55.00	20.00	15.00	M	5.54^{e}±0.01	94.44^{f} ±0.01	4.18^{f} ± 0.01	1.66^{ef} ±0.01	6.58^{e} ±0.01	8.26^{e} ±0.01	73.73^{def} ± 0.04
56.67	29.17	14.17	N	6.52^{g} ± 0.01	93.48^{d} ± 0.01	3.95^{d} ± 0.01	1.51^{d} ±0.01	6.60^{e} ±0.01	7.78^{b} ±0.03	73.65^{de} ± 0.05

Mean values with different superscript within a column are significantly different ($p \leq 0.05$)

Mineral composition of yellow maize, rice bran and fermented African yam bean composite flour blends

The sodium content of the flour blends ranged from 118.9 to131.66 mg/10g with sample blend N (56.67:29.17:14.17) having the highest while sample blend D (58.33:28.33:13.33) had the least (Table 3). The post-hoc results indicated a significant difference between the mean values. Potassium has been reported to be an important mineral that helps in maintaining electrolyte balance in humans (Kumar *et al.* 2022). The potassium content of the sample blends also varied, and the value ranged from 311.42 to 381.12 mg/100g. Sample blend B (60:27.50:12.50) had the least potassium content while sample blends D (58.33:28.33:13.33) had the highest. There was no significant difference in sample blends with F (60:30:10) and H (60:30:10) while other flour blends were not different. The calcium content varied between 316.74 and 341.31mg/100g with sample blend G (59.17:26.67:14.17) having the least while samples F (60:30:10) and H (60:30:10) had the highest and significant difference was observed among the flour blends. Mean values of the magnesium content varied with sample blend D (58.33:28.33:13.33) having the highest (185.32mg/100g) while sample blend K (57.50:27.50:15) had the least (178.92mg/100g). Magnesium is essential in enzyme systems and helps maintain electrical potential in nerves (Ferrao *et al.*, 2017). Since the flour blend had high magnesium content, the blend could be considered a high source of magnesium. The post-hoc results showed a significant difference between samples of magnesium content. The phosphorus content of the flour blends ranged from 267.31 to 233.71 mg/100g with sample blend D (58.33:28.33:13.33) having the highest while sample blend C (59.17:29.17:11.67) had the least. Calcium and phosphorous has been reported to be necessary for supporting bone, teeth formation and growth in children. However, food products containing a Calcium or Phosphorus ratio of >100 mg/100g are rated well while <0.50 mg/100g is rated poor (Nieman et al., 2012). The post-hoc results indicated a significant difference between the mean values of the flour blends (Table 3).

The iron content of the sample blends also varied and the value ranged from 2.61 to 2.98 mg/100g. Sample blends E (57.50:27.50:15) and K (57.50:27.50:15) had the least iron content while sample blends A (60:25:15) and L (60:25:15) had the highest. Iron is an essential macro-nutrient required for human growth. Iron is required for the synthesis of haemoglobin and myoglobin which is an oxygen carrier in the blood and muscle respectively and this suggests that samples A (60:25:15) and L (60:25:15) would serve as a good source of iron. There were significant differences in the flour blends. The manganese content varied between 1.09 and 1.19 mg/100g, with sample blends E (57.50:27.50:15) and G (59.17:26.67:14.17) having the least while sample blend C (59.17:29.17:11.67) had the highest and significant difference was observed. Mean values of the zinc content varied, with sample blend H (60:30:10) having the least (0.90 mg/100g) while sample blend A (60:25:15) had the highest (1.11mg/100g). The post-hoc results showed a significant difference between the zinc content.

The mineral contents of the flour blends show that AYB flour had higher values for most of the minerals analysed, this thereby buttressing the fact that AYB is nutrient-dense (Idowu, 2014). Significant increase for the mineral elements (P, Fe, Na, Ca, Mn, Mg, Cu) was obtained in the composite flour blends, with increasing values of the mineral content with increasing quantity of AYBF (Table 3). Ijarotimi and Famurewa (2006) also reported increasing values of mineral content with the increasing quantity of fermented African yam bean seed flour in composite flour.

Anti-Nutritional Composition of Yellow Maize, Rice Bran and Fermented African Yam Bean Composite Flour

One of the major benefits of composite flour is the ability to enrich and improve the nutritional status of food. The tannin content of the flour blends ranged from 0.67% to 1.04%, with sample blend E (57.50:27.50:15) having the highest while sample blend A (60:25:15) had the least (Table 4). Tannins impart dark colour, bitterness, and astringency in the prepared food, thus affecting the sensory quality of food (Kobue-Lekalake *et al.* 2007). The post-hoc results indicated a significant difference between the flour blends. The saponin content of the sample blends also varied and the value ranged from 2.06% to 2.64%. Sample blend L (60:25:15) had the least saponin content while sample blends I (57.50:30:12.50) had the highest. There was no significant difference between sample blend B (60:27.50:12.50), C (59.17:29.17:11.67) and N (56.67:29.17:14.17). The phytate content varied between 4.91% and 5.59%, with sample blend I (57.50:30:12.50) having the highest while sample blend L (60:25:15) had the least and significant difference was observed among the mean values. In addition, phytic acid has been recognized as a major inhibitor of iron and zinc absorption. However, there was no significant difference between sample blend F (60:30:10), G (59.17:26.67:14.17) and H (60:30:10). Mean values of the trypsin inhibitor content varied, with sample blend I (57.50:30:12.50) having the highest (1.72%) while sample blend B (60:27.50:12.50) had the least (1.28%). Table 4 showed a significant difference between the trypsin inhibitor content. The low values of anti-nutritional factors have been reported by (Ijarotimi and Kcshinro, 2013) on the supplementation of flours with underground beans. The low levels in these anti-nutrients are due to heat treatments during the processing of the composite flour. Several authors have reported the values of treatments (physical, biochemical, and thermal) in reducing and eliminating these anti-nutrients factors and in improving the digestibility of these seeds (Ijarotimi and Kcshinro, (2013).

Table 3: Mineral composition of yellow maize, rice bran and fermented African yam bean composite flour blends

Yellow maize (%)	Africa Yam Bean (%)	Rice Bran (%)	Sample Code	Na mg/100g	K mg/100g	Ca mg/100g	Mg mg/100g	P mg/100g	Fe mg/100g	Mn mg/100g	Zn mg/100g
60.00	25.00	15.00	A	121.14^{c} ±0.00	372.18^{ab} ±0.00	332.42^{g} ±0.00	180.42^{f} ±0.00	240.18^{c} ±0.00	2.98^{g} ±0.00	1.11^{c} ±0.00	1.11^{c} ±0.00
60.00	27.50	12.50	B	122.62^{e} ±0.00	311.42^{a} ±70.70	316.74^{b} ±0.00	179.25^{c} ±0.01	242.32^{e} ±0.00	2.94^{f} ±0.00	1.14^{f} ±0.00	0.91^{ab} ±0.00
59.17	29.17	11.67	C	124.61^{g} ±0.00	379.32^{b} ±0.00	334.11^{i} ±0.00	181.42^{h} ±0.00	233.71^{a} ±0.00	2.81^{d} ±0.00	1.19^{h} ±0.00	0.96^{e} ±0.01
58.33	28.33	13.33	D	118.93^{a} ±0.00	381.12^{b} ±0.00	322.63^{f} ±0.00	185.32^{i} ±0.00	267.31^{i} ±0.01	2.91^{f} ±0.00	1.18^{g} ±0.00	0.93^{cd} ±0.00
57.50	27.50	15.00	E	128.97^{h} ±0.00	355.45^{ab} ±50.91	334.67^{h} ±0.00	178.93^{a} ±0.00	258.13^{h} ±0.00	2.61^{a} ±0.01	1.09^{ab} ±0.00	0.91^{ab} ±0.00
60.00	30.00	10.00	F	122.93^{f} ±0.00	361.74^{ab} ±0.01	341.31^{j} ±0.01	179.34^{d} ±0.00	251.11^{f} ±0.00	2.82^{d} ±0.00	1.11^{c} ±0.00	0.91^{ab} ±0.01
59.17	26.67	14.17	G	121.46^{d} ±0.00	374.11^{ab} ±0.00	316.39^{a} ±0.00	181.40^{g} ±0.01	241.16^{d} ±0.00	2.91^{e} ±0.01	1.09^{b} ±0.00	0.91^{b} ±0.01
60.00	30.00	10.00	H	122.93^{f} ±0.00	361.74^{ab} ±0.00	341.31^{j} ±0.01	179.34^{d} ±0.00	251.11^{f} ±0.00	2.82^{d} ±0.00	1.11^{c} ±0.00	0.90^{a} ±0.00
57.50	30.00	12.50	I	130.60^{i} ±0.00	369.11^{ab} ±0.01	321.73^{d} ±0.00	180.21^{e} ±0.00	251.53^{g} ±0.30	2.62^{b} ±0.00	1.12^{d} ±0.00	0.92^{c} ±0.00
55.00	30.00	15.00	J	120.07^{b} ±0.00	366.78^{ab} ±0.00	320.45^{c} ±0.00	178.93^{a} ±0.00	236.16^{b} ±0.00	2.91^{e} ±0.00	1.13^{f} ±0.00	0.93^{d} ±0.00
57.50	27.50	15.00	K	128.97^{h} ±0.00	355.45^{ab} ±50.91	334.67^{h} ±0.00	178.92^{a} ±0.00	258.13^{h} ±0.00	2.61^{a} ±0.01	1.09^{a} ±0.02	0.91^{ab} ±0.00
60.00	25.00	15.00	L	121.41^{c} ±0.00	372.18^{ab} ±0.00	332.42^{g} ±0.00	180.42^{f} ±0.00	240.18^{c} ±0.00	2.98^{g} ±0.00	1.11^{c} ±0.00	0.91^{eab} ±0.00
55.00	20.00	15.00	M	120.07^{b} ±0.00	366.78^{ab} ±0.00	320.45^{c} ±0.00	178.93^{a} ±0.00	236.16^{b} ±0.00	2.91^{e} ±0.00	1.14^{f} ±0.00	0.93^{cd} ±0.00
56.67	29.17	14.17	N	131.66^{j} ±0.01	372.16^{ab} ±0.00	322.41^{e} ±0.01	179.16^{b} ±0.00	241.17^{d} ±0.01	2.74^{c} ±0.00	1.13^{e} ±0.03	0.91^{ab} ±0.00

Mean values with different superscript within a column are significantly different ($p \leq 0.05$)

Table 4: Anti-Nutritional Composition of Yellow Maize, Rice Bran and Fermented African Yam Bean Composite Flour

Yellow Maize (%)	African Yam Bean (%)	Rice Bran (%)	Sample code	Tannin (%)	Saponin (%)	Phytate (%)	Trypsin Inhibitor (%)
60.00	25.00	15.00	A	0.67^{c} ±0.01	2.07^{a} ±0.04	4.92^{b} ±0.01	1.39^{c} ±0.04
60.00	27.50	12.50	B	0.88^{ab} ±0.04	2.14^{b} ±0.04	5.14^{e} ±0.04	1.28^{a} ±0.01
59.17	29.17	11.67	C	0.94^{c} ±0.01	2.19^{b} ±0.01	5.03^{d} ±0.01	1.50^{d} ±0.01
58.33	28.33	13.33	D	0.93^{bc} ±0.01	2.42^{e} ±0.01	5.22^{f} ±0.01	1.58^{ef} ±0.01
57.50	27.50	15.00	E	1.04^{d} ±0.02	2.30^{cd} ±0.01	4.97^{c} ±0.01	1.30^{ab} ±0.14
60.00	30.00	10.00	F	0.84^{a} ±0.03	2.35^{d} ±0.02	5.33^{g} ±0.01	1.67^{g} ±0.01
59.17	26.67	14.17	G	0.93^{bc} ±0.02	2.52^{f} ±0.01	5.33^{g} ±0.04	1.55^{e} ±0.01
60.00	30.00	10.00	H	0.83^{a} ±0.03	2.34^{cd} ±0.02	5.32^{g} ±0.01	1.66^{g} ±0.01
57.50	30.00	12.50	I	0.84^{a} ±0.03	2.64^{g} ±0.04	5.59^{h} ±0.04	1.72^{h} ±0.01
55.00	30.00	15.00	J	0.88^{ab} ±0.02	2.56^{f} ±0.03	5.17^{ef} ±0.01	1.60^{f} ±0.01
57.50	27.50	15.00	K	1.03^{d} ±0.02	2.29^{c} ±0.01	4.96^{bc} ±0.01	1.29^{ab} ±0.01
60.00	25.00	15.00	L	0.96^{c} ±0.01	2.06^{a} ±0.04	4.91^{a} ±0.01	1.59^{c} ±0.01
55.00	20.00	15.00	M	0.87^{a} ±0.02	2.55^{f} ±0.03	5.16^{e} ±0.01	1.32^{ef} ±0.01
56.67	29.17	14.17	N	0.97^{c} ±0.02	2.16^{b} ± 0.01	5.59^{h} ±0.01	1.48^{b} ±0.15

Mean values with different superscript within column are significantly different ($p \leq 0.05$).

Functional properties of composite flour blends

The functional qualities of food ingredients are the characteristics that govern how they are used in different food items. Sample blends E (57.50:27.50:15) and K (57.50:27.50:15) had the highest water absorption capacity (1.92%), whereas the control sample had the lowest (1.01%), with sample D (58.33:28.33:13.33) having 1.48% (Figure 1). Water absorption capacity is the ability of flour products to take in water when immersed in water under saturated conditions (Ajatta *et al.* 2016). The water absorption capacity of the blends improved increases with the addition of African yam bean flour. However, the blends had a significantly inverse trend when rice bran content increased. In a similar trend, inclusion of African yam bean flour improved oil absorption ability. The oil absorption capacity ranged from 0.92 to 1.25%. Sample blend I (57.50:30:12.50) had the lowest OAC value of 0.92 % while sample A recorded the highest value of 1.25 % (Figure 1). These values are slightly below the range of values reported by Idowu, (2015). The higher the oil in the flour the lower the affinity to absorb oil. The composite flour blends and the control flour was significantly different. The result from this study compares favourably with the finding of Inyang and Ekop, (2015) on composite flour from unripe banana and African yam bean flour. The high values in water absorption and oil absorption capacities could be attributed to an increase in protein content of the flour blends with an increase in the level of African yam bean flour substitution. The high-water absorption capacity of the flour blends is an indication that the flours will perform a useful function in baked products during dough making stage (Inyang and Ekop, 2015). Henshaw and Sobowale (1996) noted that the water absorption and oil absorption capacities are believed to be influenced by the nature and behaviour of seed macromolecules especially, protein. The hydrophilic and hydrophobic parts of protein molecules affect the oil absorption capacity of flour blends. Mohamed *et al.* (1995) hypothesized that the rate of protein denaturation affects oil absorption and that denatured proteins constitute a fat-resistant barrier. The oil absorption index plays an important role in flavour retention in confectionery products (Aremu *et al.* 2007). The nature of starch has also been found to have varying effects on water absorption capacity. Adebowale *et al.* (2005) and Oladipo and Nwokocha (2011) attributed high water absorption capacity to lose the structure of starch polymers while a low value indicates compactness of the structure.

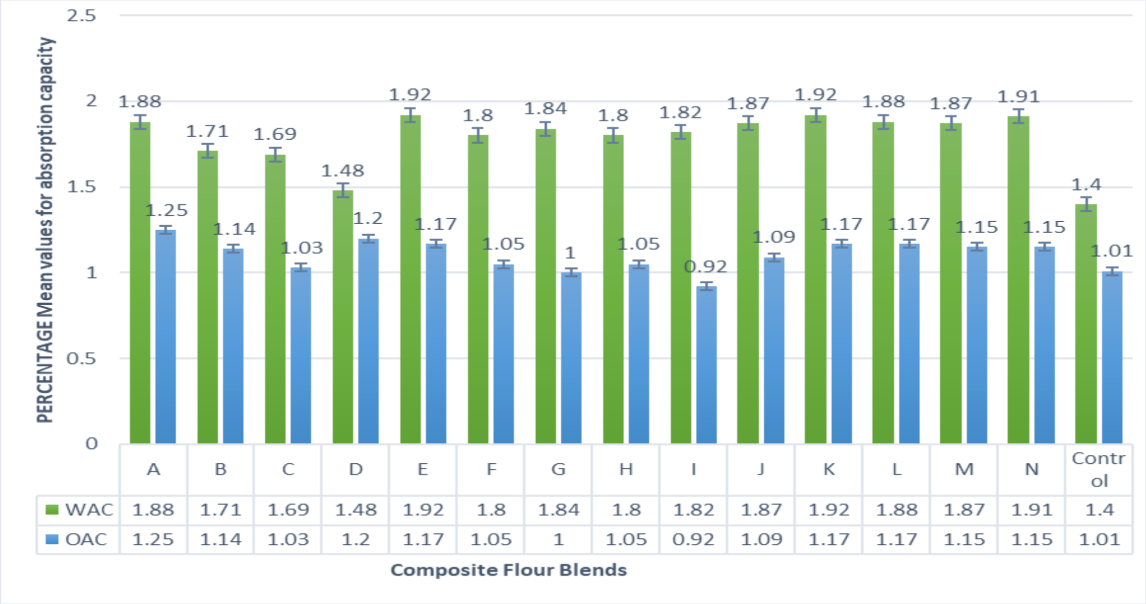
The bulk density of flour is a measure of its heaviness (Oladele and Aina, 2007). The control sample was bulkier (0.80 g/ml), while sample blends A (60:25:15) and N (56.67:29.17:14.17) had the least bulk densities of 0.66 g/ml (Figure 2). The values from this work were slightly below the report of Iyang and Ekop, (2015). There was a significant difference between the control and the composite flour blends (Figure 2). Bulk density forms a critical factor in determining the type of packaging requirements of a product. The bulk density decreases with an increase in African yam bean and rice bran. Bulk density describes how a product behaves in dry mixtures and changes with particle fineness. As a result, increasing bulk density is desirable because it provides a greater packaging advantage by allowing more volume to be packed within a given volume (Ogunmodimu *et al.* 2015). Loose density, which refers to the density of a powder after it is freely poured into a container, followed a similar reduction trend as the bulk density and ranged from 0.38 g/ml to 0.52 g/ml. The control sample had the highest loose density and sample blend L (60:25:15) had the lowest (Figure 2). The composite flour blends were significantly different from the control flour. An increment in the amounts of African yam bean flour, leads to a decrease in both bulk and loose density. The observed decrease in bulk and lose density with an increase in yam bean flour/rice bran substitution could be attributed to a decrease in carbohydrate content in the blends, and this is desirable in infant food formulation.

Sample blends A (60:25:15) and L (60:25:15) had the least dispersibility of 61.00, whereas sample blend I had the highest value of 70.00 (Table 5). The dispersibility index indicates the rate at which flour molecule separates and homogenizes in a medium (Olapade and Adeyemo, 2014). Samples with lesser dispersibility values will require lesser time to be reconstituted in water (Oladele and Aina, 2007). With more rice bran, dispersibility increased somewhat, but with African yam bean, it decreased. For each flour blend, the mean values were found to be significantly different.

The wettability improved considerably with yellow maize and rice bran, ranging from 15.35 to 34.59 seconds. The greatest value was in sample N (56.67:29.17:14.17), whereas the lowest was in the control sample. However, the African yam bean helps to lower the amount of sugar in the blood. Wettability is a measure of how easily flour samples dissolve in water, and the sample with the lowest wettability dissolves the fastest (Iwe *et al.* 2017). Between the composite mixes, there was a significant difference.

The water absorption index of starch-based flour during heating can also be used to calculate swelling capacity. The swelling index samples showed no statistically significant difference. Sample blend B (60:27.50:12.50) had the lowest concentration (0.89 g/ml), whereas samples E (57.50:27.50:15) and K (57.50:27.50:15) had the highest swelling index of 1.02 g/ml (Table 5). The amount of associative forces within the granules is indicated by swelling power (Adegunwa *et al.* 2014).

The swelling capacity is a measure of the water reconstitution capacity of any flour because of the presence of the starch granules and it determines sample consistency (Ayo-Omogie and Ogunsakin, 2013).



WAC: Water Absorption Capacity (ml)

OAC: Oil Absorption Capacity (ml)

Figure 1: Water and Oil Absorption Capacity of Composite Flour Blends from Yellow Maize, African Yam Bean Seeds and Rice Bran

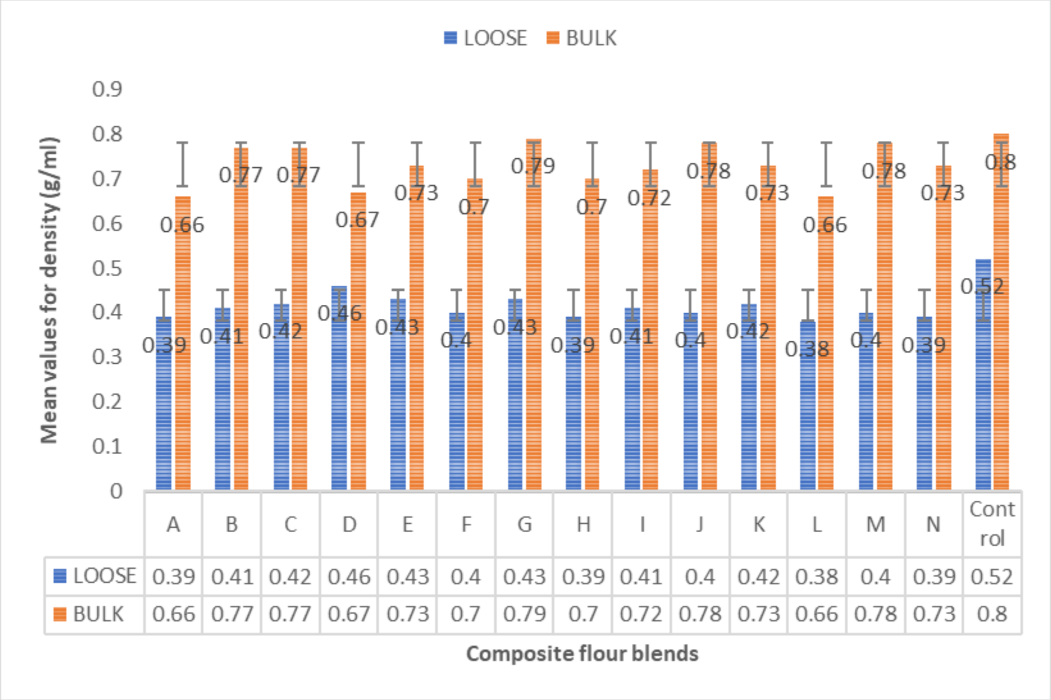


Figure 2: Loose and Bulk Density of Composite Flour Blends from Yellow Maize, African Yam Bean Seeds and Rice Bran

Table 5: Functional Properties of Yellow Maize, African Yam Bean Seeds, and Rice Bran Composite Flour

Yellow maize (%)	Africa Yam Bean (%)	Rice Bran (%)	SAMPLE CODES	DISPERSIBILITY (%)	WETTABILITY (seconds)	SWELLING INDEX (g/ml)
60.00	25.00	15.00	A	$61.00^{a} \pm 1.41$	$27.32^{b} \pm 2.79$	$0.94^{a} \pm 0.08$
60.00	27.50	12.50	B	$67.00^{ab} \pm 7.07$	$29.12^{bc} \pm 1.28$	$0.89^{a} \pm 0.03$
59.17	29.17	11.67	C	$69.50^{b} \pm 3.54$	$32.58^{cd} \pm 0.06$	$0.90^{a} \pm 0.09$
58.33	28.33	13.33	D	$63.50^{ab} \pm 3.54$	$30.78^{cd} \pm 1.10$	$0.92^{a} \pm 0.05$
57.50	27.50	15.00	E	$65.00^{ab} \pm 0.00$	$34.03^{cd} \pm 1.40$	$1.02^{a} \pm 0.02$
60.00	30.00	10.00	F	$68.50^{b} \pm 3.54$	$31.20^{bcd} \pm 0.66$	$0.96^{a} \pm 0.01$
59.17	26.67	14.17	G	$67.00^{ab} \pm 1.41$	$30.55^{bcd} \pm 0.89$	$0.92^{a} \pm 0.04$
60.00	30.00	10.00	H	$68.50^{b} \pm 3.54$	$31.19^{bcd} \pm 0.66$	$0.96^{a} \pm 0.01$
57.50	30.00	12.50	I	$70.00^{b} \pm 0.00$	$30.47^{bcd} \pm 2.69$	$0.90^{a} \pm 0.02$
55.00	30.00	15.00	J	$65.50^{ab} \pm 0.71$	$31.41^{bcd} \pm 1.61$	$0.92^{a} \pm 0.12$
57.50	27.50	15.00	K	$65.00^{ab} \pm 0.00$	$34.02^{cd} \pm 1.40$	$1.02^{a} \pm 0.02$
60.00	25.00	15.00	L	$61.00^{a} \pm 1.41$	$27.31^{b} \pm 2.79$	$0.94^{a} \pm 0.08$
55.00	20.00	15.00	M	$65.50^{ab} \pm 0.71$	$31.40^{bcd} \pm 1.61$	$0.92^{a} \pm 0.12$
56.67	29.17	14.17	N	$67.00^{ab} \pm 2.83$	$34.59^{d} \pm 4.65$	$0.98^{a} \pm 0.03$
100.00	-	-	O	$70.00^{b} \pm 0.00$	$15.35^{a} \pm 2.35$	$0.92^{a} \pm 0.04$

Mean values with a different superscript in the same column are significantly different ($p<0.05$).

PASTING PROPERTIES OF COMPOSITE FLOUR BLENDS

Pasting characteristics have an impact on food quality and processing concerns because they affect texture and digestibility, as well as the ultimate usage of starch-based food commodities (Adebowale *et al.* 2005). All pasting parameters of the flour blends differed significantly. The amylograph pasting profile is the most frequent objective method for evaluating the processing characteristics of starch-based foods. Such data have been utilized to link the functioning of starchy food components in processes including baking, cooking, frying and extrusion cooking (Ruales *et al.* 1993).

The trough viscosity ranged from 656.50 - 1113.50 RVU for the composite flours while the 100% maize flour (control) had a value of 920 RVU (Table 6). The trough viscosity is significantly different among the sample blends. Sample C (59.17:29.17:11.67) had the highest trough viscosity (1113.50) and sample E had the lowest (656.50). Increased rice bran reduced trough viscosity, whereas increased African yam bean substitution led to increase in trough viscosity. The minimal viscosity value is called the trough, and it indicates how well a paste can survive disintegration during cooling. The trough viscosity value showed a significant increase with an increase in the quantity of AYB flour. The value observed in this work was significantly higher than the finding of Atinuke (2015) and can be attributed to the varietal difference and planting location of the maize sample.

The peak viscosity index is always associated with the quality of the finished product and indicates the viscosity load that will be faced during mixing (Maziya-Dixon *et al.* 2004). The peak viscosity of the sample blends ranged from 668.50 to 1193.50 RVU, with the control sample (100% yellow maize flour) having 960.50 RVU which is fairly above the value reported by Atinuke (2015). Sample blend D (58.33:28.33:13.33) had the less peak viscosity of 668.50 RVU while sample blend C (59.17:29.17:11.67) had the highest value. The result of the peak viscosity index was significantly different among the blends (Table 6).

The breakdown viscosity values of sample blends ranged from 13.50 to 81.00 RVU. Sample blend B (60:27.50:12.50) recorded the least breakdown viscosity value while sample blend C (59.17: 29.17: 11.67) had the highest value. The control sample (100% yellow maize flour) had a breakdown viscosity value of 39.50 RVU and this value was significantly lower than the result reported by Atinuke (2015) on maize/ African yam bean composite flour and Olumurewa *et al.* (2019) on instant pounded yam/plantain composite flour. The lower breakdown viscosity of starch with blend B implies its higher ability to withstand heating and shearing during cooking and this give better rheological properties during handling process.

The final viscosity of the blends ranged from 1386.50 to 3667.50 RVU, with the control sample (100) having the highest value of 3667.50 RVU and sample blend D (58.33:28.33:13.33) having the lowest (Table 6). The result from this work followed the trend of findings from Atinuke (2015). Final viscosity defined the viscous paste forming ability of flour after its gelatinization. There was significant difference among the flour blends. This variation in final viscosity can be attributed to the starch content of the samples since final viscosity value indicates aggregation of amylose while a low final viscosity indicates the paste resistance to shear stress during stirring (Asaam, *et al.* 2018).

The set viscosity of the sample blends was significantly different from one another, with sample blend D (58.33:28.33:13.33) having the lowest set viscosity value of 716.50 RVU. The control sample had the highest setback viscosity value of 2746.50 RVU. The setback viscosity is a measurement of the flour's tendency to retrograde or syneresis as it cools. When the setback value is low, the starch exhibits a lower tendency to retrograde or undergo syneresis during freeze-thaw cycles (Ikujenlola and Fashakin, 2005). Higher setback values imply less dough

Peak time is commonly considered as a measure of how long it takes each blend to reach its peak viscosity (Awolu and Oseyemi, 2016). Except for the control sample, all sample mixes were under 6 minutes. As a result, food mixes with shorter peak times cook faster than those with longer peak times. The peak time was between 5.14 and 7.0 minutes. The peak time values were significantly similar, indicating that the composite flour had similar cooking characteristics. The composite flour blends had a pasting temperature ranging from 52.74 °C – 84.06 °C and these values are below boiling temperature. The composite blends can form flour paste in any hot water below boiling temperature. Sample blend C (59.17:29.17:11.67) had the lowest pasting temperature (52.74 °C), while the temperature of the control sample recorded the highest value of 88.05 °C. The result of this study is similar to the findings of Olumurewa *et al.* (2019) on instant pounded yam/plantain flour. Low pasting temperature indicates the less cooking temperature for a given sample, which can have an impact on energy consumption (Ragaee *et al.* 2006). Ocheme *et al.* (2010), observed a higher pasting temperature with increasing GPC and this was attributed to the higher water absorption capacity of the GPC in blends.

Generally, the pasting evaluation of the flour blends revealed a significant variation in the setback, peak, breakdown, trough and final viscosities as well as in pasting temperature of the flour blends with inclusion protein/fibre from AYB/Rice bran. This trend of result is similar to results reported by Ohizua *et al.* (2017).

Table 6: Pasting Properties of Composite Flour from Yellow Maize, African Yam Bean Seeds and Rice Bran

Yellow maize (%)	African Yam Bean (%)	Rice Bran (%)	Sample code	TROUGH VISCOSITY (RVU)	BREAKDOWN VISCOSITY (RVU)	PEAK VISCOSITY (RVU)	FINAL VISCOSITY (RVU)	SETBACK VISCOSITY (RVU)	PEAK TIME (MINUTES)	PASTING TEMPERATURE (° C)
60.00	25.00	15.00	A	$716.50^{e} \pm 0.71$	$23.99^{d} \pm 0.01$	$739.50^{f} \pm 0.71$	$1606.00^{f} \pm 1.41$	$888^{f} \pm 1.41$	$5.26^{b} \pm 0.01$	$83.20^{de} \pm 0.01$
60.00	27.50	12.50	B	$693.50^{d} \pm 0.71$	$13.50^{a}. \pm 0.71$	$706.50^{e} \pm 0.71$	$1500.50^{c} \pm .071$	$808^{c} \pm 0.000$	$5.34^{c} \pm 0.01$	$83.20^{de} \pm 0.01$
59.17	29.17	11.67	C	$1113.50^{k} \pm 0.71$	$81.00^{i} \pm 0.00$	$1193.50^{i} \pm 0.71$	$2120.50^{i} \pm 0.71$	$1008.50^{i} \pm 0.71$	$5.73^{g} \pm 0.00$	$52.74^{a} \pm 0.01$
58.33	28.33	13.33	D	$688.50^{c} \pm 0.71$	$19.00^{b} \pm 0.00$	$668.50^{a} \pm 0.71$	$1386.50^{a} \pm 0.71$	$716.50^{a} \pm 0.71$	$5.48^{e} \pm 0.01$	$83.95^{f} \pm 0.07$
57.50	27.50	15.00	E	$656.50^{a} \pm 0.71$	$21.50^{c} \pm 0.71$	$678.50^{c} \pm 0.71$	$1391.50^{b} \pm 0.71$	$735.50^{b} \pm 0.71$	$5.40^{d} \pm 0.01$	$84.06^{g} \pm 0.01$
60.00	30.00	10.00	F	$954.50^{j} \pm 0.71$	$33.00^{g} \pm 0.00$	$988.00^{k} \pm 0.00$	$2189.50^{j} \pm 0.71$	$1235.50^{j} \pm 0.71$	$5.27^{b} \pm 0.01$	$81.60^{c} \pm 0.01$
59.17	26.67	14.17	G	$673.50^{b} \pm 0.71$	$23.50^{d} \pm 0.71$	$696.50^{d} \pm 0.71$	$1508.50^{d} \pm 0.71$	$836.50^{d} \pm 0.71$	$5.54^{f} \pm 0.01$	$84.06^{g} \pm 0.01$
60.00	30.00	10.00	H	$955.00^{j} \pm 1.41$	$34.00^{g} \pm 0.00$	$987.00^{k} \pm 0.00$	$2190.50^{j} \pm 0.71$	$1234.50^{j} \pm 0.71$	$5.26^{b} \pm 0.00$	$81.61^{c} \pm 0.01$
57.50	30.00	12.50	I	$798.50^{h} \pm 0.71$	$39.00^{h} \pm 0.00$	$837.50^{i} \pm 0.71$	$1750.50^{h} \pm 0.71$	$951.50^{h} \pm 0.71$	$5.14^{a} \pm 0.01$	$81.45^{b} \pm 0.00$
55.00	30.00	15.00	J	$725.50^{f} \pm 0.71$	$31.00^{f} \pm 0.00$	$756.50^{g} \pm 0.71$	$1565.50^{e} \pm 0.71$	$839.50^{e} \pm 0.71$	$5.27^{b} \pm 0.00$	$83.25^{e} \pm 0.01$
57.50	27.50	15.00	K	$657.50^{a} \pm 0.71$	$20.50^{c} \pm 0.71$	$676.50^{b} \pm 0.71$	$1390.50^{b} \pm 0.71$	$734.00^{b} \pm 0.00$	$5.40^{d} \pm 0.02$	$84.05^{g} \pm 0.01$
60.00	25.00	15.00	L	$717.00^{e} \pm 0.00$	$23.98^{d} \pm 0.01$	$738.50^{f} \pm 0.71$	$1604.50^{f} \pm 1.41$	$887.50^{f} \pm 0.71$	$5.26^{b} \pm 0.01$	$83.18^{d} \pm 0.01$
55.00	20.00	15.00	M	$726.50^{f} \pm 0.71$	$31.50^{f} \pm 0.71$	$757.50^{g} \pm 0.71$	$1566.50^{e} \pm 0.71$	$839.50^{e} \pm 2.12$	$5.27^{b} \pm 0.01$	$83.24^{de} \pm 0.01$
56.67	29.17	14.17	N	$748.50^{g} \pm 0.71$	$29.50^{e} \pm 0.71$	$777.50^{h} \pm 0.71$	$1653.50^{g} \pm 0.71$	$904.50^{g} \pm 0.71$	$5.28^{b} \pm 0.01$	$83.20^{de} \pm 0.01$
100.00	-	-	O	$920.50^{i} \pm 0.71$	$39.50^{h} \pm 0.71$	$960.50^{j} \pm 0.71$	$3667.50^{k} \pm 0.71$	$2746.50^{k} \pm 0.71$	$7.00^{h} \pm 0.00$	$88.05^{h} \pm 0.07$

Mean values with different superscripts in the same column are significantly different ($p<0.05$).

CONCLUSION

Findings from this study suggested that substituting yellow maize flour with fermented African yam bean and rice bran flours would produce acceptable and nutritious composite flour. The varying proportion of yellow maize, Africa yam bean, and rice bran in the blends had a significant effect on pasting and functional properties. Increased inclusion of AYB and rice bran flours decreased the peak, final, setback, breakdown, and trough viscosities as well as the peak time and pasting temperature in all the sample blends expect for sample blends C (59.17:29.17:11.67), F (60:30:10) and H (60:30:10). African yam bean flour substitution increased the water and oil absorption capacity and swelling capacity of the flour blends. The mineral composition of the flour blends reduced with increasing proportion of Africa yam bean except for manganese and zinc. Also, increasing proportion of Africa yam bean reduced the proximate composition of the blends with the exception of moisture content. The result of this study will boost the economic power of local producers through encouragement for increased utilization of neglected rice bran and African yam bean flour in functional food production.

RECOMMENDATIONS

Further research into the shelf-life of composite flour and its and other applications in the production of ready-to-eat snacks like Kokoro is needed. More emphasis should be placed on raising awareness about the deliberate commercialization of African yam bean and rice bran, as well as elevating its status to that of a widely consumed food in all households throughout developing countries.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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