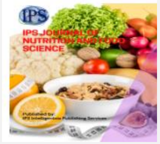
IPS Journal of Nutrition and Food Science
IPS J Nutr Food Sci, 4(1): 313-323 (2025)
DOI: https://doi.org/10.54117/ijnfs.v4i1.75



Proximate, Mineral, Microbial and Sensory Evaluation of Enriched Poundo-Breadfruit Meals with African Yam Bean, Wheat Bran and Rice Bran

Oluwakemi Florence Falana[1*], Sunday Abiodun Malomo[1,2], Oluwole Steve Ijarotimi[1,2]

[1]Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
[2]Department of Nutrition and Dietetics, Federal University of Technology, Akure, Nigeria.

*****Correspondence author: florenceakinyele@gmail.com; +2348038612484

Abstract

Poor diets devoid of nutrient causes health-related problem and the utilization of rich composite crops could help to reduce these global shortcomings. Hence, the proximate, mineral and microbial analysis of poundo-breadfruit flours and meals were done. Four different formulated poundo-breadfruit meals (PBM) were developed from the selected crops viz: BAWR 1 (70:30:0:0), BAWR 2 (70:25:0:5) BAWR 3 (70:25:5:0) and BAWR 4 (70:25:5:5) were developed while 100% breadfruit flour (BF) and 100% poundo yam flour (PYF) are control samples. The poundo-breadfruit meals had protein (9.45-15.20%), crude fibre (5.89-10.69%), ash (2.43-3.91%) and energy values (366.93-397.75 kcal/100 g). The protein content of poundo-breadfruit meals from BAWR 1 and 3 was significantly higher than the control samples. The Na/K (0.70-0.78) meet the recommended value (<1) for food in managing degenerative diseases. In addition, the poundo- breadfruit meals had low microbial count which makes it safe for consumption and the overall acceptability scores revealed that samples BAWR 1 and 4 were in preferential order when compared with the control sample PYF.

Keywords: *Poundo meal, African yam bean, proximate properties, mineral composition, sensory evaluation*

Article History
Received: 05 Feb 2025
Accepted: 12 Feb 2025
Published: 14 Feb 2025

Scan QR code to view•

How to cite this paper: Falana, O. F., Malomo, S. A., & Ijarotimi, O. S. (2025). Proximate, Mineral, Microbial and Sensory Evaluation of Enriched Poundo- Breadfruit Meals with African Yam Bean, Wheat Bran and Rice Bran. *IPS Journal of Nutrition and Food Science*, *4*(1), 313–323. https://doi.org/10.54117/ijnfs.v4i1.75.

1. Introduction

The impoverished monotonous diets, which were devoid of nutritional qualities have been the primary cause of poor human health in many developing countries, for example, in Nigeria (Nnamani *et al.*, 2021). Therefore, the nutritionally-dense diets with different crops proportion offered better and greater health benefits for human productivity. Besides, protein-rich foods were usually on the high-cost side and not as abundant as carbohydrate foods, thus this has greater impact on people whose physical and mental development required nutritionally balanced diets. Therefore, enriching carbohydrate starchy based food (breadfruit) with plant by-products from legume and cereal can provide the required balanced nutrients to combat certain health challenges in humans.

For instance, breadfruit (*Artocarpus altilis*) is an excellent dietary staple fruit with moderate glycaemic index, rich in fibre, and a good source of vitamins B_1, B_2, C, potassium, magnesium and calcium, with small amounts of thiamine, riboflavin, niacin and iron (Carmen and Diane, 2019). Apart from being a good source of calories and other nutrients, it is considered nutritionally low in fat and protein (Abegunde *et al.*, 2019). Thus, it can be processed into many forms for utilization in many households. Specifically, after peeling, the fruits are boiled, pounded and eaten with soups just like pounded yam otherwise known as '*iyanjaloke*' or '*gbere* 'fruit among Yoruba tribes of Nigeria (Akinyele *et al.*, 2020a), Therefore, enriching breadfruit with other nutritious plant sources could provide the required balanced nutrients that have greater impact on human health.

African yam bean (*Sphenostylis stenocarpa* Harms) (AYB) is an indigenous legume of the humid tropics of Africa with its edible pulse and tuber showing great significance for food, nutrition, and health security (Adewale and Nnamani, 2022). The analytical comparison of nutritional values of the AYB and other grain legumes demonstrated the significant place of the crop among its counterparts. With the growing consumer awareness of the need to consume healthy foods, Agunwah *et al*. (2019) stressed that AYB represented alternative source of protein supplements while possessing certain characteristics that helped in protein enrichment for some food products. The presence of fibre and essential fatty acids it possessed made it a good candidate in the development of new functional foods for consumer health (George *et al.*, 2020). Past works have combined AYB flour with cassava to produce *pupuru* (Isaac-Bamgboye *et al.*, 2020), enriched *fufu* (Aniedu and Aniedu, 2014) and breakfast meal (Babarinde *et al.*, 2019).

The brans from cereals such as wheat, rice, maize, barley etc were sources of bioactive compounds and dietary fibres, which posed positive impact on human's health (Awofadeju and Olapade, 2020; Muhammad, 2019). For instance, wheat bran helped to prevent the pathogenesis of some diseases like diabetes, colon cancer, cardiovascular diseases (Chalamacharla *et al.*, 2018). Moreso, rice bran, which is the brown outer layer of the rice kernel composing of the pericarp, aleurone, seed coat, and germ contained 50% carbohydrate (mainly starch), 20% fat, 15% protein, and 15% insoluble dietary fibre (Suwimol *et al.*, 2021). Study (Faustino *et al.*, 2019) revealed that rice by-products from the milling process still possessed certain nutrients and bioactive compounds, which exhibited beneficial health effects that could be used or added to food products to promote the yield and food sustainability of rice production.

Therefore, the aim of the present study was to investigate the proximate, mineral and the microbial contents as well as the evaluating the sensory attributes of the poundo-breadfruit meals obtained from the breadfruits enriched with African yam bean, wheat bran and rice bran.

2. Materials and Methods

Materials

Breadfruit was obtained from Mosarajo, Ile Ife, Nigeria. AYB was obtained from King's market, Ado Ekiti, Nigeria. Wheat (*Triticum aetivum*) bran and rice (*Oryza sativa*) bran were obtained from Cereal Mills (Army Barrack 2nd Gate), Akure, Nigeria. The plant materials were authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria. All other chemicals and reagents were of analytical grades and were obtained from Sigma Aldrich Chemical Company, MO, USA.

Methods

Production of breadfruit (BF)

BF was produced according to the method of Malomo *et al.* (2011) with slight modification by Abegunde *et al.* (2019). Matured unripe BF were peeled, washed in clean water to remove dirt, decored and sliced into 5 cm pieces with a stainless-steel knife, blanched (100 ºC, 5 min), drained and dried in a cabinet dryer at 60 ºC for 8 h. The dried chips were then milled, sieved through a 0.35 mm mesh size to obtain fine flour, which was packaged in polyethylene bags for further use.

Production of African yam beans flour (AYBF)

The method of Oluwamukomi and Akinlabi (2011) as adopted by Isaac-Bamgboye *et al.* (2020) with slight modifications was used to produced AYBF. The seeds were sorted manually to remove dirt, stones, defective seeds, dead insects, and other unwanted materials. The cleaned seeds were washed and soaked in clean tap water for 8 h, manually dehulled, rinsed and oven dried at 60 ºC for 8 h. The dried bean was milled into flour using attrition mill. The flour obtained was sieved to pass through a 250 µm sieve to obtain flour of uniform size and packaged in an airtight container for further use.

Production of wheat bran flour (WBF) and rice bran flour (RBF)

The wheat and rice bran were oven dried at 60 ºC for 2 h, milled and sieved through 200 mm wire-mesh to obtain WBF and RBF, respectively using the previous method of Awolu *et al.* (2015) with slight modification and the flour samples were packed until further use.

Flour Blends Formulation

The breadfruit flour (BF), African yam bean flour (AYBF), wheat bran flour (WBF) and rice bran flour (RBF) flour samples were blended using Nutrilab linear software (in reference to 26% protein and 15% fibre required for the management of diabetic patients) to formulate composite flour blends viz:

Table 1: Formulation of flour blends (%)

Samples	BF	AYBF	WBF	RBF	PYF
BAWR 1	70	30	0	0	0
BAWR 2	70	25	5	0	0
BAWR 3	70	25	0	5	0
BAWR 4	70	20	5	5	0
BF	100	0	0	0	0
PYF	0	0	0	0	100

KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), **BAWR 2** (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), **BAWR 3** (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), **BAWR 4** (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), **BF** (100% Breadfruits flour), **PYF** (100% Poundoyam flour).

Preparation of Dough Meal

The dough meals were prepared by stirring the flour blends in boiling water at the ratio 1:4 (flour/water dispersion) at 100 ºC for 10 min.

Proximate Composition Analysis

The proximate compositions of the samples were determined using standard methods of AOAC (2012). The samples were analysed for moisture, ash, crude fibre, protein, crude fat and carbohydrate contents were obtained by difference. Energy value was calculated using Atwater factors; the sum of 4 × percentage of Protein, 4 × percentage of carbohydrate, and 9 × percentage of fat as described by Onoja *et al.* (2014).

Determination of Mineral Contents

Mineral contents in the flour blends and the dough meals were determined by using the dry ash determination method described by Alabi and Aletor (2011). Two (2) grammes of the sample were heated on a bunsen burner in a fume cupboard and the residue was transferred into a porcelain crucible and incinerated in a muffle furnace at 550 ºC for 5 h to a constant weight. The resulting ash was dissolved in nitric acid (2%, v/v; 50 ml) and made up with deionized water. Minerals such calcium, iron, magnesium, manganese, zinc, copper, lead, and cadmium were determined using an atomic absorption spectrophotometer (AAS; Model SP9 Series; Pye Unicam, Cambridge, UK). Sodium and potassium were determined with a flame 73 photometer (Sherwood Flame Photometer 410, Sherwood Scientific, Cambridge), while phosphorous was determined by the vanado-molybdate method (AOAC, 2012).

Microbial Analysis

One (1) gram each of the poundo-breadfruit meals was blended with 9 ml of sterile water and shaken very well for 2 min to form a suspension. The microbial load of the poundo-breadfruit meals was determined by performing a ten-fold serial dilution of each of the samples in test tubes containing sterile distilled water up to 10^{-3} dilution factor. The total viable bacteria and fungi count were determined using the pour plate technique culture for each of the sample. The plates were incubated at 37 °C for 24 h for bacteria, 25 °C for 72 h for fungi. The colonies were counted and expressed as ''colony forming unit per gram (cfu/g)'' as previously described by Ukpong *et al.* (2021).

$$\text{Cfu/g} = \frac{number\ of\ count}{volume\ plated\ x\ dilution}$$

Sensory Evaluation

Sensory evaluation was conducted in the laboratory with adequate lighting and no odour environment. Panelists were selected based on their familiarity with control samples, recognition and perception of common odour. The flour samples were prepared in the form of dough meal (dough) by stirring flour in boiling water 1:4 (w/v) at 100 °C for 30 min. The reconstituted formulated food samples and the controls were coded and presented to 50 untrained panelists. The panel members were assigned individually to well illuminate laboratory booths, and the prepared dough meals were served at 40 °C coded with random three-digit numbers. Water at room temperature was provided for mouth rinsing in-between successive evaluation. Sample attributes (colour, texture, taste, aroma, mouldability, etc.) were rated on a nine-point Hedonic scoring scale, where 1 = dislike extremely and 9 = like extremely, in line with the test procedures reported by Olapade (2014).

Statistical Analysis

All determinations were carried out in triplicates. Data was subjected to analysis of variance (ANOVA) using Statistical Package for Social Scientists (SPSS Version 22.00, USA) while means were separated using New Duncan Multiple Range Test (NDMRT) at 5% level of significant (p<0.05).

3. Results and Discussion

Proximate composition of poundo-breadfruit flours and meals

The results of the proximate compositions of raw and poundo-breadfruit flours are presented in Table 2. The protein content of poundo-breadfruit flours and meals significantly (p<0.05) ranged between (9.60-15.24%) and (9.54-15.20%) respectively. The increase in the protein content of the poundo-breadfruit flour may be due to the inclusion of legumes. This finding was similar to the report of Salome *et al* (2021) and Oluwajuyitan and Ijarotimi (2019) who observed a significant increase in protein content of '*Amala*' produced from unripe plantain- African yam bean (AYB) composite flour and plantain, tigernut and defatted soybean flour by Oluwajuyitan and Ijarotimi (2019) respectively. Moreover, sample BAWR 1 had higher value than 4.89% reported for 70:30% instant yam-breadfruit flour (Adebowale *et al.* 2008) but lower than 17.50% reported for soy-enriched poundo yam blends (Oluwamukomi and Adeyemi, 2015), respectively. Besides, the protein content of 100% BF (9.60%) in this study was lower than 11.46% (Abegunde *et al.*, 2019) but higher than 3.35% (Malomo *et al.* 2011) and 5.49% (Adepeju *et al.* 2011) previously reported for 100% breadfruit pulp flour, respectively. The poundo-breadfruit meals BAWR 1 and 3 showed no significant differences (p>0.05) in protein content as well as its flours but differed significantly (p<0.05) from the control sample BF and PYF in term of the flours and meals. In addition, decreases were observed in the protein content of the poundo-breadfruit meal when compared with the flour blends, this may be due to the effects of processing conditions during cooking that resulted into moisture loss and denaturation of protein. Hence, the study of oluwajuyitan *et al.* (2020) and owuno *et al.* (2021) observed similar reduction in the meals than in the flour blends. Despite this, the protein content of the meals was still reliable and will be of importance in reducing health-related diseases where many people can hardly afford animal proteins

The crude fibre of the poundo-breadfruit flours and meals significantly (p < 0.05) ranged from 5.92-10.75% and 5.90-10.69% respectively. Among all the samples, RBF and PYF had the highest and lowest crude fibre contents when compared to the formulated samples. Suwimol *et al.* (2021) submitted that the relatively high fibre content observed in rice bran variedly depend on the rice cultivar, environmental conditions, degree of milling and analytical method. The crude fibre obtained both in the flours and meals was higher than 5.03-7.47% reported for dough meal from cereal-based soy-fortified flours (Akinjayeju *et al.* 2020), which may be as a result of increase in the level of substitution of cereal and legume. More so, there was no significant difference (p > 0.05) between the crude fibre of BAWR 1 and 3 in term of flours and meals but differed (p<0.05) from other samples respectively. In addition, the relatively higher fibre content in BAWR 2 and 3 for flour and meals may be due to inclusion of BF, AYB, and RB when compared to flour and meals of PYF (2.52%, 2.39%). Higher level of fibre in the poundo-breadfruit meals will make it a good choice for diabetic people, as this will result into reduced weight gain, lipid level and blood pressure as reported by some researchers (Ardiansyah *et al.*, 2019; Escobar *et al.*, 2019). Crude fibre helped in maintaining normal peristaltic movement of the intestinal tract by preventing diseases such as piles, cancer, or appendicitis (Famurewa and Oluwalana, 2007).

The fat content of all the flour blends ranged from 1.77-9.04% with no significant difference (p > 0.05) among the samples BAWR 1, 3, 4 as well as BAWR 2 and RBF but differed significantly (p < 0.05) from BF and PYF. The value obtained was comparable with 8.00-10.89% reported for '*amala*' from unripe plantain and AYB flour (Salome *et al.* 2021) but higher than 0.56-1.8% reported for wheat-breadfruit composite flour (Abegunde *et al.* 2019), respectively. Sample BAWR 2 had the highest fat content (7.92%) which might be as a result of the inclusion of rice bran. Comparatively, the poundo-breadfruit flour ranged from 0.68-7.55% with significant difference ($p < 0.05$). There was reduction in the fat content of the poundo-breadfruit meals when compared to its flours, this may be as result of cooking in which the meal is subject to. The present fat content reported will make handling, processing and storage of the products easy because high fatty foods are prone to rancidity, which decreased shelf-life and sensory qualities (Baiyeri *et al*., 2018).

The ash content of a food product is the inorganic residue that remained after the removal of water and organic matter by the action of heat in the presence of oxidizing agents, and is a measure of the total amount of minerals in it (Ismail, 2017). The ash content of the poundo-breadfruit flours and meals increased with increased in the inclusion of BF, AYB, RB and WB. It values ranged from 2.58-3.94% (poundo-breadfruit flour) and 2.43-3.91% (poundo-breadfruit meal) with significant difference ($p < 0.05$). For instance, All the flour blends (1.78 - 18.23%) was higher than 2.43-6.57% and 2.91-3.93% reported for plantain and African yam beans flour blends (Salome *et al.* 2021) and *pupuru* flour (Isaac-Bamgboye *et al.* 2020), respectively. The variation in the results might be as a result of different crops used for the food products. Likewise, the ash content of poundo-breadfruit meal BAWR 4 marked the highest value while PYF had the lowest value. Moreso, the ash content of poundo-meals was higher than 0.36-1.17% earlier reported for *pupuru* and *pupuru* analogues (Akinyele *et al.,* 2020) but comparable with the value 1.93-3.52% for dough meal from unripe plantain marble vine (Ajatta *et al.,* 2021). Sample BAWR 1, 3 and BF were not significant different ($p > 0.05$) but differed significantly ($p<0.05$) from PYF, this is I n line with the findings of Oyeyinka *et al.* (2023) that yam is low in ash, fat and protein when compared with BF as reported for ash content of poundo-yam (1.12%). Tsehayneh *et al.* (2020) reported that combination of two or more food materials such as cereals and legumes usually increased nutritional properties of the final food products.

The result of the moisture content (MC) of all the flour blends ranged from 4.50- 11.79%. The value obtained were higher than 5.81-8.67% reported for gari fermented with maize (Owuno *et al.* 2021). It was observed that the BF from the poundo-breadfruit flour had MC compared with 10.52% reported for 100% breadfruit flour (Abegunde *et al.* 2019). Regarding the poundo-breadfruit meals, its MC ranged from 9.89-10.48% with significant difference (($p<0.05$). The value obtained were higher than 6.09 -7.37% reported for 'amala' from unripe plantain and African yam beans (Salome *et al.*, 2021) but comparable with 11.47-12.98% reported for *pupuru* and *pupuru* analogues (Akinyele *et al.,* 2020a). It has been known that higher MC of food materials resulted to the lower shelf-life stability; whereas MC largely depended on postharvest drying, handling and storage conditions (Aluge *et al.,* 2016). Generally, the moisture content of the products obtained in this study was below the acceptable levels (10–14%) for flours (Abioye *et al.,* 2015).

The carbohydrate (CHO) of the flour and meals reduced as the formulations readily increased with increasing content of AYBF, RBF and WBF when compared with the carbohydrate content PYF (85.95%) for flour and (93.07%) meal respectively. The present observation was similar to the previous report on '*amala*' from unripe plantain and African yam beans (Salome *et al.* 2021). The reduced CHO obtained in this study will make the poundo-breadfruit meals good for obese individual as well as in managing diabetes. The energy value of the flour samples ranged from 354.18-396.58 kcal/100g with significant difference ($p<0.05$) while the energy value of the poundo-breadfruit meals ranged from 366.93-397.75kcal/100g with the highest and lowest values in samples BAWR 3 and BF, respectively. The observation could be as a result of low carbohydrate content observed in the blends of breadfruit, African yam beans, rice bran and wheat bran.

Minerals composition of poundo-breadfruit flours and meals

The mineral composition of the poundo-breadfruit flour and meals was presented in Table 3. The results revealed an enhancement and reduction in some of the micronutrients at the varied addition of proportions of African yam beans, rice bran and wheat bran flours to breadfruit flour. For instance, the calcium (Ca) and Magnesium (Mg) values of poundo-breadfruit flours ranged significantly between 4.03-6.91 and 7.25-7.34 mg/100 g respectively whereas, the Ca and Mg of the poundo-breadfruit meals ranged (3.58-5.56) mg/100g and (6.89-7.27) mg/100g respectively. There was no significant difference between the Mg of poundo-breadfruit meal BAWR 1, 2 and 3 as well as BAWR 4 and BF but differed from PYF meal. The magnesium content in this study was within the recommended range. The increase in Ca and Mg contents of the poundo-breadfruit meals, an indication that African yam beans added more micronutrients to the meals, has been earlier submitted for dough meals. Calcium help with pancreatic insulin secretion while Magnesium is involved in the regulation of blood sugar and blood pressure together with bone, muscle and nerve function (Minisola *et al.,* 2023).

The Zinc (Zn) component of the poundo-breadfruit flours regarded as essential element for good immune system, hormone secretion, mental wellbeing, foetus growth and normal development of humans (Rohit *et al.,* 2023) ranged from 0.89 to 1.48 mg/100 g with highest and lowest values observed in BAWR 4 (1.48 mg/100 g) and BF (0.89 mg/100 g), respectively. Breadfruit is known to have little or no zinc and the inclusion of AYB, RB and WB, therefore slightly and significantly ($p<0.05$) boosted the Zn contents of the flour blends (Ajifolokun and Adeniran, 2018). Interestingly, the Zn content obtained in this study is within the FAO (2010) recommended ranges (0.23-3.2 mg/100 g) to aid the production of insulin by the pancreas while the deficiency of Zn in the body led to a diminished sensitivity to taste (hypogausia) and odour (Ajifolokun and Adeniran, 2018). Comparing the Zn content of the flour with the meal, there was slight reduction in the Zn content of the meal with value ranging from 0.71-1.12mg/100g. This may be as a result of further processing method adopted. There was no significant difference between the Zn content of poundo-breadfruit meal BAWR 1 and PYF.

Table 2: Proximate composition of poundo-breadfruit flours and meals (% dry basis)

Samples	Moisture content	Ash	Fat	Crude fibre	Protein	CHO	Energy value (kcal/100g)
Poundo-breadfruit flours							
BAWR 1	11.29 ± 0.62^{ab}	2.78±0.05^{de}	5.82±0.04b	5.92±0.05^{e}	15.24±0.66^{c}	69.90±0.14^{c}	392.93±2.29^{a}
BAWR 2	10.21 ± 1.16^{bc}	3.42±0.67^{bcd}	8.51±0.48^{a}	7.90 ±0.37^{d}	9.60±0.42^{e}	70.39±1.64^{c}	396.53± 0.64^{a}
BAWR 3	10.96 ± 0.69^{abc}	2.79±0.06^{de}	6.55±0.43^{b}	5.94±0.61^{e}	15.13±0.64^{c}	69.27±0.48^{c}	396.58±2.63^{a}
BAWR 4	11.79± 1.08^{a}	3.96±0.36^{bc}	6.39±0.26^{b}	9.59±0.35^{ab}	11.88±0.13^{d}	68.18±0.36^{c}	377.77±1.38^{b}
BF	10.02 ± 0.62^{bc}	2.58±0.82^{de}	3.97±1.00^{c}	10.75±0.59^{b}	9.60±0.08^{e}	73.10±0.94^{b}	366.53±5.88^{c}
RBF	5.28 ± 0.09^{e}	18.23±0.54^{a}	9.04±0.03^{a}	24.39±2.42^{a}	7.84±0.44^{f}	40.50±2.25^{f}	266.16±10.05^{e}
WBF	4.50 ± 0.62^{e}	4.38±0.51^{b}	3.33±0.67^{c}	8.44±0.87^{cd}	21.67±0.56^{b}	62.19±1.02^{e}	354.18±4.82^{d}
AYBF	9.69 ± 0.45^{c}	3.14±0.52^{cd}	4.08±0.03^{c}	2.67±0.17^{f}	25.53±0.57^{a}	64.58±1.23^{d}	372.12±1.28^{bc}
PYF	6.89± 0.01^{d}	1.78±1.10^{e}	1.77±0.04^{d}	2.52±0.05^{f}	2.21±0.04^{g}	85.95±2.09^{a}	368.65± 8.31^{bc}
Poundo-breadfruit meals							
BAWR 1	10.48 ±0.09^{bc}	2.75±0.09^{c}	5.79±0.03^{d}	5.89±0.62^{c}	15.20±0.03^{a}	69.68±1.05^{b}	391.61±3.98^{b}
BAWR 2	11.17± 0.73^{a}	3.35±0.01^{b}	7.55±1.22^{a}	7.89±0.03^{c}	9.45±0.63^{c}	71.76±0.50^{c}	392.79± 0.51^{b}
BAWR 3	9.89 ± 0.04^{c}	2.78±0.04^{c}	6.49±0.01^{b}	5.90±0.07^{d}	15.10±0.01^{a}	69.73±0.11^{d}	397.75±0.41^{a}
BAWR 4	10.61±0.30^{ab}	3.91±0.52^{a}	6.11±0.13^{c}	9.58±0.06^{b}	11.80±0.02^{b}	68.58±0.41^{e}	376.59±2.60^{d}
BF	10.50± 0.18^{bc}	2.43±0.05^{c}	3.88±0.02^{e}	10.69±0.05^{a}	9.54±0.04^{c}	73.46±0.09^{b}	366.93±0.47^{e}
PYF	7.02 ± 1.63^{d}	1.69± 0.03^{d}	0.68±0.22^{f}	2.39±0.02^{e}	2.18±0.01^{d}	93.07±0.28^{a}	387.09± 0.95^{c}

Mean values with different superscript in a column are significantly different. Values are mean ± standard deviation from triplicate determinations. KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundo-yam flour), RBF (Rice bran flour), WBF (Wheat bran flour), AYBF (African yam bean flour).

The iron (Fe) content of the poundo-breadfruit flours and meals ranged from (4.34 - 5.47 mg/100 g) and (4.24 - 4.89 mg/100 g) respectively. The values obtained were higher than 1.56-2.23 mg/100 g previously reported for soy-poundo yam flour (Okoye *et al*. 2024). There was no observable significant difference ($p > 0.05$) between the Fe content of BAWR 3 and 4 for poundo-breadfruit flours but there was observable significant difference ($p<0.05$) among the poundo-breadfruit meals. The obtained values fell within the FAO (2010) and USDA (2010) recommended iron limits of 1 and 5.6 mg/day, respectively. Thus, iron is best supplied through composite blends though, phytate has strong negative effect on the Fe absorption. Fe is a protein that supplied haemoglobin and oxygen to the muscles and as well supported metabolism in humans with its inadequate intake resulting to iron deficiency anaemia (Okoye *et al.*, 2024).

The manganese (Mn) content of the poundo-breadfruit flour falls within 0.11and 0.21 mg/100 g with the control sample PYF having the highest Mn than the formulated flour samples. Comparatively, the poundo-breadfruit meals obtained in this study (0.01-0.21mg/100g) was lower than 20.48-125.53 mg/100 g reported for soy-poundo yam flour (Okoye *et al*. 2024) with samples PYF and BF having the significant ($p<0.05$) highest and lower values, respectively. In addition, the phosphorus content of the poundo-breadfruit flour significantly ($p<0.05$) ranged from 9.38 to 24.65mg/100g and the meal ranged from 8.13-19.69mg/100g. The phosphorus content of BAWR 3 and 4 for both flour and meal samples were in abundance when compared with other poundo-breadfruit flours and PYF, due to inclusion of wheat bran that is rich in phosphorus, which helped the body to store and used energy at the same time, in filtering out waste in the kidneys (Juan and Clemens, 2020). The phosphorus content in poundo-breadfruit meals BAWR 3 and 4 were higher than its flour, an indication that the food antinutrient (Phytic acid) that chelate micronutrients has been dealt with during reconstitution of the meals which make the mineral readily available, as supported by Ayaka *et al*. (2020).

Table 3: Mineral composition of poundo-breadfruit flours and meals (mg/100g)

Elements	BAWR 1	BAWR 2	BAWR 3	BAWR 4	BF	PYF	Ref
Poundo-breadfruit flours							
Ca	6.91±0.06[a]	4.03 ± 0.00[e]	4.36± 0.01[f]	5.57±0.00[d]	6.64±0.00[b]	4.54±0.08[e]	
Mg	7.34±0.01[a]	7.27±0.01[b]	7.27±0.02[b]	7.25±0.01[c]	7.27±0.01[ab]	6.74±0.00[d]	4.5-452
Zn	1.12±0.00[b]	1.12±0.00[a]	1.22±0.01[b]	1.48±0.06[a]	0.89±0.01[e]	1.13±0.01[c]	0.23-3.2
Fe	5.47±0.03[a]	4.34±0.12[d]	4.79±0.02[b]	5.39±0.01[b]	5.21±0.03[c]	4.67±0.02[e]	1-5.6
Mn	0.11±0.00[d]	0.17±0.00[c]	0.14±0.01[d]	0.21±0.01[b]	0.18±0.00[b]	0.32±0.42[a]	1.5
P	13.12±0.01[d]	13.43±0.01[c]	21.69±0.01[b]	24.65±0.02[a]	9.38±0.01[f]	9.48±0.01[e]	
K	5.64±0.01[a]	4.90±0.01[e]	5.16±0.01[c]	5.16±0.01[c]	5.35±0.01[b]	3.45±0.01[f]	
Na	3.93±0.01[b]	3.83±0.01[c]	3.75±0.01[c]	3.75±0.01[c]	3.97±0.01[a]	2.69±0.01[f]	
Cu	ND	ND	ND	ND	ND	ND	
Na/K	0.7	0.78	0.73	0.77	0.74	0.78	<1
Ca/P	0.53	0.3	0.2	0.23	0.71	0.48	>1
Poundo-breadfruit meals							
Ca	4.03±0.00[e]	5.42±0.05[b]	4.36±0.01c	5.56±0.03[a]	3.58±0.03[f]	4.22±0.00[d]	
Mg	7.27±0.01b	7.26±0.01[b]	7.26±0.01[bc]	7.23±0.02[c]	7.23±0.02c	6.89±0.00d	4.5-452
Zn	1.12±0.00a	0.99±0.00[c]	1.09±0.00[b]	1.10±0.02[ab]	0.71±0.01[d]	1.11±0.00[a]	0.23-3.2
Fe	4.34±0.12[d]	4.89±0.02[a]	4.44±0.00[c]	4.72±0.03[b]	4.24±0.03[f]	4.29±0.02[e]	1-5.6
Mn	0.07±0.00[e]	0.13±0.00[c]	0.12±0.00[d]	0.21±0.00[a]	0.01±0.00[e]	0.01±0.00[f]	1.5
P	13.43±0.01[d]	15.48±0.01[c]	19.89±0.01[a]	19.69±0.01[b]	8.13±0.02[f]	9.43±0.01[e]	
K	4.90±0.01[e]	5.01± 0.01[d]	5.08±0.01[c]	5.19±0.01[b]	6.07±0.01[a]	2.91±0.01[f]	
Na	3.83±0.01[c]	3.77± 0.01[d]	3.69±0.01[e]	3.99±0.01[a]	3.91±0.01[b]	2.26±0.01[f]	
Cu	ND	ND	ND	ND	ND	ND	
Na/K	0.78	0.75	0.73	0.77	0.64	0.78	<1
Ca/P	0.3	0.35	0.22	0.28	0.44	0.45	>1

Mean values with different superscript in a row are significantly different. Values are mean ± standard deviation from triplicate determinations KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundoyam flour), ND (Not Detected). Ref- (FAO 2010, USDA, 2010 limits in mg/day), FAO/WHO (1991).

The potassium (K) and sodium (Na) content of the poundo-breadfruit flours showed significant increase when compared to the sample PYF. The K and Na values of the flour in the present study were 4.90-5.64 and 3.79-3.97 mg/100 g, respectively. The K value in this study is lower than 20.15-48.5 mg/100 g for 'gari' and 'gari' analogues (Ajifolokun and Adeniran, 2018). The K, Fe, Mg and Ca content of BAWR 1 (5.64, 5.47, 7.34 and 6.91 mg/100 g, respectively) were significantly higher than other flour blends due to the fact that breadfruit and African yam beans were found to be rich in these minerals (USDA, 2010). Concerning the poundo-breadfruit meals, the K and Na values in the present study were 2.91-6.07 and 2.26-3.99 mg/100 g, respectively. High potassium intake is important in regulating the body fluid balance required for the transmission of nerves impulse in the body, lowering blood pressure (Zoroddu *et al.*, 2019). Diets low in sodium but high in potassium, calcium and magnesium had been associated to lower the rate of cardiovascular diseases (Parpia *et al.*, 2018). Moreover, sodium helped in the maintenance of fluid, acid-base balance, absorption of glucose, relaxation of the muscles and in the maintenance of cell membrane permeability in the body (Alli, 2023). Notably, copper was not detected in all the experimental samples.

Furthermore, the Na/K ratio of the poundo-breadfruit flours (0.70-0.74) and meals (0.64-0.78) was within the FAO/WHO (1991) recommended value (< 1) while the Ca/P ratio of flour blends (0.22-0.82) and poundo- breadfruit meals (0.20-0.40) was lower than the recommended value (>1) respectively. Obviously, the considerable high potassium content in relation to the considerable low sodium content is an indication that the flours would be suitable for addressing cardiovascular functions (Alli, 2023). Study has revealed that calcium is required for building up tissues and in conjunction with phosphorus, which is largely responsible for the hardness of the bones and teeth as well as coagulation of blood; whereas its deficiency in the body led to rickets in infants/ children and osteonecrosis in adults (Gemede, 2020).

Functional properties of poundo-breadfruit flours

The functional properties of food product determined the application of food, its interaction with other food and the end usage. So, food items with good functionality could be incorporated into other food products to yield good quality and acceptable end products. Hence, the functional properties of poundo-breadfruit flours were presented in Table 4. From the result, the bulk density (BD) of the poundo-breadfruit flours ranged from 0.53 to 0.92 g/ml with no significant difference (p>0.05) between the BD of BAWR 1 and 3 as well as BAWR 2 and 4, respectively. However, the BD of the poundo-breadfruits flour blends (BAWR 1, 2, 3 and 4) were significantly lower than the commercial sample (PYF), which had the highest BD (0.92g/ml), to connote denser nature when compared to other samples. Although, the BD in this study was slightly higher than 0.52 - 0.72 g/ml for 'lafun'-pigeon pea flour (Bolaji *et al.*, 2021) but lower than 0.92-3.34 g/ml reported for 'amala' made from unripe plantain and African yam beans (Salome *et al.*, 2021). Generally, high BD is desirable for ease of dispensability and reduction of paste thickness, which is an important factor in convalescent child feeding while low BD is beneficial in the complementary foods/flour blends formulation by contributing to lower dietary bulk, ease of packaging and transportation (Aluge *et al.*, 2016). Study has shown that, BD is influenced by particle size of the flour and is important in determining the packaging requirement and material handling (Ahemen *et al.*, 2018).

Water absorption capacity (WAC) of poundo-breadfruit flour blends, is the ability of flour to absorb water and swell for improved consistency in food, increased with increase in the variation of substitutions and found significantly (p<0.05) ranged from 140.87-245.24% for the present poundo-breadfruit flour blends. The present result was lower than 260.62-267.76% reported for soy-poundo yam flour (Malomo *et al.* 2012) but comparable with 120.79-229.41% reported for instant poundo yam flour (Kosoko *et al.*, 2023), respectively. The sample BAWR 4 had highest WAC of 245.24% when compared to other blends and the commercial sample PYF (140.87%). This indicated that BAWR 4 had more hydrophilic constituents than the other samples, which might be as a result of the differences in fibre, protein and carbohydrate content in the formulations (Adegunwa *et al.*, 2011). Other reason could be the degree of availability of water binding site, which might be due to factors like particle size and molecular structure (Kosoko *et al.*, 2023). Therefore, higher WAC showed a greater amount of polar amino acid residues in a protein thereby causing the flour to have a higher affinity to water molecules (Kambabazi *et al.*, 2022). The present observation agreed with the past finding (Oyeyinka *et al.* 2023) on poundo-yam flour supplemented with cassava flour but contradicted the report on reduction of WAC of yam flour with increased level of substitution with soy flour (Malomo *et al.*, 2012). Hence, the poundo-breadfruit flours developed in this study had good WAC that made it suitable for dough or bakery products.

Table 4: Functional properties of poundo-breadfruit flours

Samples	BD (g/ml)	WAC (%)	OAC (%)	SP (g/g)	SC (%)	FC (%)	EC (%)	LGC (%)
BAWR 1	0.56±0.00^{c}	162.65±0.09^{d}	164.18±0.82^{a}	7.35±1.44^{d}	382.3±1.46^{a}	27.37±0.29^{b}	275.92±5.33^{a}	5.33±1.15^{b}
BAWR 2	0.59±0.00^{b}	212.63±0.31^{c}	156.54±2.46^{b}	7.39±2.81^{c}	281.56±0.98^{c}	17.84±1.77^{d}	122.88±0.65^{d}	2.67±1.15^{c}
BAWR 3	0.56±0.00^{c}	228.65±1.25^{b}	163.84±1.84^{a}	7.36±1.01^{d}	196.5±0.50^{f}	20.21±1.06^{c}	177.5±2.50^{b}	5.33±1.15^{b}
BAWR 4	0.59±0.00^{b}	245.24±1.97^{a}	158.18±2.22^{b}	7.91±0.96^{b}	269.90±0.99^{d}	37.76±1.02^{a}	145.21±1.46^{c}	2.67±1.15^{c}
BF	0.53±0.00^{d}	214.35±0.70^{c}	155.39±4.04^{b}	8.52±1.44^{a}	206.93±1.50^{e}	26.33±1.33^{b}	145.75±1.31^{c}	2.67±1.15^{c}
PYF	0.92±0.00^{a}	140.87±0.20^{e}	106.33±2.41^{c}	5.43±0.43^{e}	292 ±2.00b	4.40±0.05^{e}	106.07±0.18^{e}	11.33±1.15^{a}

Mean values with different superscript in a column are significantly difference. Values are mean ± standard deviation from triplicate. KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundoyam flour).

The oil absorption capacity (OAC) is a pointer to the rate at which protein adhered to fat in food product formulations (Isaac-Bamgboye *et al.*, 2020). The OAC ranges of the poundo-breadfruit flour blends were given as 106.33-164.18%. Interestingly, the OAC of the flour blends were significantly (p<0.05) different from the commercial sample (PYF) whereas, there is no significant different in OAC of BAWR 2, 4 and BF but differed significantly from BAWR 1 and 3. These variations in OAC might be responsive to the genetic factors and difference in the hydrophilic component of the samples, such that the increase in hydrophilic component (protein and carbohydrate) resulted to lower OAC (Ahemen *et al.*, 2018). The result (Table 2) further indicated that the addition of legume and cereal brans to the samples did not have much influence on the OAC when compared with sample BF. Therefore, the absorption of oil by the flour blends tended to improve the mouth feel and flavour retention of the end products. Moreover, a high OAC suggested the presence of a large proportion of hydrophobic components when compared with the hydrophilic components on the surface of protein (Olumurewa *et al.*, 2019).

The swelling power (SP) is an indication of presence of amylase, which influenced the quantity of amylose and amylopectin. The flour samples BF and BAWR 4 exhibited significant ability to swell more than the other flour samples. The variation in the swelling power might be as a result of the degree of exposure of the internal structure of the starch present in the flour to the action of water. The SP of the flour blends obtained ranged from 5.43-8.52 g/g, and found higher than 3.75–4.69 g/g for yam-bambara enriched flour (Arise *et al.*, 2023) but compared well to the 3.12– 8.5 g/g for *pupuru* analogues (Akinyele *et al.* 2020). BF had the highest swelling power while the commercial sample (PYF) had the lowest swelling power as previously reported for instant poundoyam/plantain flour by past study (Olumurewa *et al.*, 2019). Study (Moorthy *et al.* 1986) had reported SP of flour granules as an indication of the extent of associative forces within the granule. Therefore, the higher SP, the higher the associative forces (Loss *et al.*, 1981).

The solubility capacity (SC) of the poundo-breadfruit flour blends ranged from 196.50 to 382.30% with significant difference among the samples. The maximum and minimum values were BAWR 1 (382.30%) in BAWR 3 (196.50%), respectively. The present result is higher than 16.16-20.23% for soy-poundo yam flour (Malomo *et al.*, 2012). Notably, the SC of the poundo-breadfruit flours decreased in the blend except in BAWR 4, which experienced an increase. The differences recorded in the SC may be attributed to the differences in morphological structure of starch granules, as inter-associative forces, swelling power, presence of surfactants, and other associative compounds.

Foaming capacity (FC) is the ability of substance in a solution to release foam (presence of proteins) after vigorous shaking since due to their active surface (Tongpun, 2006). The FC of the flour blends ranged between 4.40-37.76% with significant difference. The FC were lower than 103.6-110.7% reported for Indonesia-varieties soybean flour (Astawan *et al.* 2023). The poundo-breadfruit blend BAWR 4 and PYF had the highest and lowest FC, respectively. The low FC seen in PYF showed that the flour possessed poor foaming agents caused by low protein contents. Akubor *et al*. (2023) associated good FC with protein molecules, which is easily denatured and conversely reduced surface tension as a result of highly ordered globular protein that is relatively difficult to denature by heat. Besides, the ability of food materials to foam varied with the types of protein, solubility, carbohydrates and additional factors (Astawan *et al.*, 2023).

The emulsion capacity (EC) of the poundo-breadfruit flour blends ranged from 106.07- 275.92%. Although, the EC of sample BAWR 4 did not significantly differ from BF (control 1) but differed from PYF (control 2). A sharp decrease in EC was observed in sample BAWR 2, which might be due to the inclusion of rice bran of low protein content. The higher EC of the poundo-breadfruit flour blends over the PYF indicated better flavour retention, mouth feel and taste, making the blends better emulsifiers in food systems, since EC measured the maximum amount of oil emulsified by protein per flour (Akubor *et al.*, 2023).

The least gelation concentration (LGC) is the lowest protein concentration required for inverting a tube without producing sliding of the gel in the walls (Akinsola *et al.*, 2021). The LGC of poundo-breadfruit flours blends ranged between 2.67-11.33%, hence, higher than 0.80-1.40% for *pupuru* flour blends (Isaac-Bambgoye *et al.*, 2020) but comparable with 8-10% reported forinstant yam-breadfruit flour (Adebowale *et al.*, 2020). The LGC of poundo-breadfruit flour blends BAWR 1 and 3 were not significantly different from each other, as well as that of BAWR 2, 4 and BF. However, the sample PYF has the highest (11.33%) LGC among all the experimental samples, thus making it experiencing difficulties to form thick gels easily on reconstitution as compared with other samples with low LGC. This may be due to the relative proportion of different flour constituents such as carbohydrates, proteins, lipids, fibres and the interactions among the components (Aremu *et al.*, 2007).

Pasting properties of poundo-breadfruit flours

Table 5 showed the pasting properties of poundo-breadfruit flours with peak viscosity (PV) range of 1586-5986 RVU whereby samples BF and BAWR 2 had the highest and lowest PV, respectively. PV, the maximum viscosity arrived at after the heating aspect of the test, reflected the maximum swelling of the poundo-breadfruit flours before disintegration, thus could be useful in preparation of low viscous food (Sandhu and Singh, 2007; Oyeyinka *et al.*, 2023). Hence, reduction in the peak viscosity of the poundo-breadfruit samples could be due to the reduction in starch contents since BF has more starch than AYB (Arise *et al.*, 2023). Moreso, it might be due to the different behaviour of fat and protein contents in rice bran and African yam beans as previously observed for instant yam – breadfruit flour (Adebowale *et al.* 2008). The trough (1454-5875 RVU) and final viscosities (2761.00-9763.00 RVU) of the formulated meals were good enough to make them form a viscous paste or gel after cooking and cooling as well as resisting shear stress during stirring (Oluwalana and Oluwamukomi, 2011).

The breakdown viscosity (BV) of the poundo-breadfruit flours (95-230 RVU) was reportedly higher than 47-74 RVU obtained for *Dioscorea alata* and *Vernonia amygdalina* flour blends (Adeloye *et al.* 2021). Meanwhile, another study (Adebowale *et al.* 2008) reported a BV of 85.58 RVU for 100% breadfruit flour, which is similar to 95.00 RVU currently obtained for BF in this study (Table 6). The low BV obtained for blends BAWR 1, 2 and 3 when compared to BAWR 4 implied that their pastes would have better stability than BAWR 4, since BV is an index of starch stability or measure of cooked starch disintegration in foods (Adeloye *et al.*, 2021). Furthermore, the ability of starches to gel into semi solid pastes and the difference between final viscosity and trough is regarded as setback (Adeloye *et al.*, 2021). Hence, the setback viscosity (SV) of the flour blends ranged from 1483.00 to 2919.00 RVU with BF and PYF having the highest and lowest SV, respectively. The decreased SV of the composite flours compared to 100% BF might be attributed to the addition of varied proportions of AYBF, WBF and RBF, respectively. The samples BAWR 1, 2, 3 and PYF had significantly ($p<0.05$) lower SV than BAWR 4 and BF, hence, their pastes would have better stability, high resistance to retrogradation, no syneresis/weeping and high digestibility than BAWR 4 and BF. This is because a high SV implied high rearrangement, less resistance to retrogradation and less paste stability during cooling **(**Olumurewa *et al.* 2019).

The peak time of the poundo-breadfruit flours is a measure of its cooking time (Akinyele *et al.*, 2020), which happened to occur at 6.07-7.00 min. This present finding is considerably higher than the 5.13–5.80 min reported for instant yam-breadfruit flour (Adebowale *et al.* 2020) but comparable with 5.00–7.00 min reported for lafun-pigeon pea flour (Bolaji *et al.* 2021), respectively. However, the pasting temperature of the samples ranged between 71.75 -88.80 ºC with PYF and BF having the highest and lowest pasting temperatures, respectively. It is noteworthy that the present range in this study was lower than 92.24-94.45 ºC reported for water yam flour substituted with rice bran (Egbedike *et al.* 2016) but found similar to 70.95-82.48 ºC for garri fermented with maize residue (Owuno *et al.* 2021), respectively. Moreso, the pasting temperature gave an indication of the gelatinization time during processing. That is, a higher pasting temperature implied higher water binding capacity, higher gelatinization and lower swelling property of starch (Table 4) due to a high degree of association between the starch granules (Adebowale *et al.*, 2020).

Table 5: Pasting properties of poundo-breadfruit flours

Samples	Peak viscosity (cP)	Trough (cP)	Breakdown (cP)	Final viscosity (cP)	Set back (cP)	Peak time (min)	Peak temp (°c)
BAWR 1	1980	1879	101	3563	1687	7.00	79.80
BAWR 2	1586	1454	132	3016	1562	7.00	80.75
BAWR 3	1701	1593	108	3076	1483	6.87	79.05
BAWR 4	2590	2360	230	5279	2919	6.93	79.00
BF	5970	5875	95	9763	3888	6.07	71.75
PYF	1794	1606	188	2761	1155	6.53	88.80

Mean values with different superscripts in a column are significantly different. Values are mean ± standard deviation from triplicates. KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundo-yam flour).

Microbial Counts

The microbiological quality of re-constituted poundo-breadfruit meals was presented in Table 6. The total bacterial count of the re-constituted poundo-breadfruit meals ranged from1.10- 2.60 x 10^2 cfu/g with highest and lowest bacterial counts in BAWR 2 and PYF, respectively. The bacterial count was found within the ICMSF (2011) acceptable limit (<10^5). The staphylococcus aureus of the re-constituted poundo-breadfruit meals ranged from 0.20 -1.30 x 10^1 cfu/g with no detectable growth in the commercial sample (PYF). The value obtained was below ICMSF (2011) acceptable level of staphylococcus aureus (10^3 cfu/g) in ready-to-eat foods. More so, there was no detectable growth of Salmonella, Coliform, *Escherichia coli* and fungi recorded on the reconstituted poundo-breadfruit meals and the commercial sample (PYF) plates. Past study reported that microbes evenly distributed in the environment could be found on the skin and human nostrils, where they were prone to contaminate food (Ahemen *et al*. 2018). Therefore, the microbial growth seen in the samples might have evolved during processing probably from the raw materials or from the environment.

Table 6: Microbiological quality of re-constituted poundo-breadfruit meals (Cfu/g)

Samples	NA (bacteria)	DCA (Salmonella)	MCA (Coliform)	MSA (Staph. aureus)	EMB (E. coli)	PDA (fungi)
BAWR 1	$2.3x10^1$	NG	NG	$0.4x10^1$	NG	NG
BAWR 2	$2.6x10^2$	NG	NG	$0.3x10^1$	NG	NG
BAWR 3	$2.2x10^1$	NG	NG	$1.3x10^1$	NG	NG
BAWR 4	$2.1x10^2$	NG	NG	$1.1x10^1$	NG	NG
BF	$1.4x10^1$	NG	NG	$0.2x10^1$	NG	NG
PYF	$1.1x10^1$	NG	NG	NG	NG	NG

KEY: NA-nutrient agar, DCA-Deoxycholate citrate agar, MCA-MacConkey agar, MSA-Mannitol salt agar, EMB- eosin methylene blue agar, PDA- potato Dextrose Agar, NG-No growth BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundoyam flour).

Sensory Attributes of Poundo-Breadfruit Meals

Table 7 showed the result of the sensory evaluation of poundo-breadfruit meals. The choice for commercial product (PYF) by the panelist showed higher significance and the variation in the preference given to it over other formulated blends may be as a result of the its composition, processing technique and familiarity with the panelists. This observation has been earlier reported that commercial food products were usually rated higher over newly developed food products because of the methods of processing and closeness of the products (Oluwajuyitan and Ijarotimi, 2019). It is noteworthy that there existed no significant difference (p>0.05) between all the formulated meals in their appearance, aroma, taste, mouldability and overall acceptability. Among the blended meals, sample BAWR 2 was scored higher value in appearance and taste but BAWR 4 got higher score in aroma. Although, samples BAWR 3 was 1 had the highest and the lowest mouldability among the formulated meals, respectively but lower than PYF. The reason for the higher mouldability may be because of the starchy content of breadfruit as well as the gluten content of wheat, which has affinity to bind flour together. Study had shown that the process of adding legume flour to wheat flour has effects on the functional and viscoelastic characteristics of wheat flour dough resulting in higher protein content of the flour (Maray, 2023). Besides, the overall acceptability scores revealed that samples BAWR 1 and 4 were in preferential order when compared with the control sample PYF.

Table 7: Sensory evaluation of poundo-breadfruit meals

Samples	Appearance	Aroma	Taste	Texture	Mouldability	Acceptability
BAWR 1	6.42 ± 1.42^b	5.70 ± 1.88^b	5.60 ± 1.83^b	6.10 ± 1.78^c	6.40 ± 1.84^b	6.30 ± 1.45^b
BAWR 2	6.46 ± 1.23^b	5.60 ± 1.92^b	6.18 ± 1.42^b	6.38 ± 1.68^{bc}	6.76 ± 1.65^b	6.20 ± 1.54^b
BAWR 3	6.10 ± 1.68^b	5.76 ± 1.90^b	5.98 ± 1.71^b	6.38 ± 1.34^{bc}	6.78 ± 1.50^b	6.06 ± 1.54^b
BAWR 4	6.30 ± 1.76^b	5.82 ± 1.87^b	5.86 ± 1.90^b	6.56 ± 1.4^{bc}	6.66 ± 1.56^b	6.22 ± 1.88^b
BF	6.62 ± 1.44^b	5.88 ± 1.64^b	6.32 ± 1.61^b	6.86 ± 1.47^b	6.80 ± 1.84^b	6.50 ± 1.62^b
PYF	8.46 ± 0.07^a	7.62 ± 1.34^a	7.44 ± 1.54^a	7.92 ± 0.99^a	7.84 ± 1.22^a	8.26 ± 0.96^a

Mean values with different superscript in a column are significantly different. Values are mean ± standard deviation from triplicate determinations .KEY: BAWR 1 (70% Breadfruit flour, 30% African yam beans flour, 0% wheat bran flour,0% rice bran flour), BAWR 2 (70% breadfruit flour, 25% African yam beans flour,0% wheat bran flour, 5% Rice bran flour), BAWR 3 (70% Breadfruits flour, 25% African yam beans flour, 5% Wheat bran flour, 0% rice bran flour), BAWR 4 (70% Breadfruits flour, 20% African yam beans flour, 5% Wheat bran flour, 5% Rice bran flour), BF (100% Breadfruits flour), PYF (100% Poundoyam flour).

4. Conclusion

It can be deduced from the study that the physical appearance and the proximate composition of the poundo-breadfruit meals was influenced by the varied substitution of AYBF, WBF and RBF when compared to the commercial sample PYF. BAWR 1 and BAWR 3 showed higher percentage of protein (14.22 and 13.32%) than other blends, respectively. The Na/K of the poundo-breadfruit meals obtained (0.70-0.74) was <1, thereby connoting that the formulated products could be used as a therapeutic food to combat cardiovascular diseases. Factually, the microbial counts of the meals fell within ICMSF (2011) acceptable limit set, which made it regarded as safe for human consumption. The sensory qualities of samples BAWR 1 and 4 showed the highest overall acceptability among the blends and a comparative rating with the well-known control sample PYF.

Authors' contributions

Falana Oluwakemi Florence: Formal analysis, Investigation, Writing - original draft, Resources; **Malomo Sunday Abiodun:** Supervision, Investigation, Writing - review and editing; **Ijarotimi Oluwole Steve:** Conceptualization, Supervision, Formal analysis

Conflict of interest

The authors declare that they do not have any conflict of interest.

References

Abbaspour, N. Hurrell, R. and Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of Research in Medical Science*, 19(2):164-174.

Abegunde, T. A., Bolaji, O. T., Adeyeye S. A., Peluola-Adeyemi, O. A. (2019). Quality evaluation of baked cake from wheat breadfruit composite flour. *American Journal of Food Science and Technology*. Vol. 7, No. 1, 31-39, DOI:10.12691/ajfst-7-1-6.

Abioye, V. F., Olanipekun, B. F. and Omotosho, O. T. (2015). Effect of varieties on the proximate, nutritional and antinutritional composition of nine variants of African yam bean seeds (*Sphenostylis stenocarpa*). *Donnish Journal of Food Science and Technology*, Vol. 1(2), pp.017-021.

Adebowale, A. A., Sanni, S. A. and Oladapo, F. O. (2008). Chemical, functional and sensory properties of instant yam – breadfruit. *Nigerian Food Journal*, VOL.26, NO.1.

Adeloye, J. B., Aluko, P. A. and Oluwajuyitan, T. D. (2021). In vitro α-amylase and α-glucosidase inhibitory activities, antioxidant activity, in vivo glycaemic response and nutritional quality of dough meals from *Dioscorea alata* and *Vernonia amygdalina. Journal of Food Measurement and Characterization*, https://doi.org/10.1007/s11694-021-00965-z.

Adepeju, A. B., Gbadamosi S. O., Adeniran A. H. and Omobuwajo T. O. (2011). Functional and pasting characteristics of breadfruit (*Artocarpus altilis*) flours. *African Journal of Food Science*. 5:529–535.

Adewale, B. D. and Nnamani, C. V. (2022). Orphan plant species for food security and nutrition: successes, challenges, and a way forward (Review article). *Front. Sustainable Food System*, https://doi.org/10.3389/fsufs.2022.726458.

Agunwah, I. M., Olawuni, I. A., Ibeabuchi, J. C., Uzoukwu, A. E and Alagbaoso, S. O. (2019). Evaluation of the proximate and functional properties of flours from brown variety of African yam bean (*Sphenostylis stenocarpa*) Seeds, *Current Journal of Applied Science and Technology* 38(6): 1-8.

Ahemen, S. A., Shima, A. N. and Acham, I. O. (2018). Evaluation of the physical, functional and microbiological properties of composite bread from wheat, tigernut and defatted sesame flour blends. *Asian Food Science Journal*, 4(2): 1-10.

Ajatta, M. A., Akinola, S. A., Osundahunsi, O. F. and Omoba, O. S. (2021). Effect of roasting on the chemical activities of three varieties of marble vine (Dioclea reflexa): An underutilised plant. *Heliyon*, http:doi.org/10.1016/j.heliyon.2021. e07107.

Ajifolokun, O. M. and Adeniran, H. A. (2018). Proximate and mineral composition of co-fermented breadfruit and cassava into gari analogue. *Journal of Nutrition and Food Science*,8:1, DOI:10.4172/2155-9600.1000658.

Akinjayeju, O., Fagbemi, T. N., Ijarotimi, O. S and Awolu, O. O (2019). Optimization and evaluation of some physicochemical and nutritional properties of cereal-based soya-fortified flours for dough meal. *Journal of Advances in Food Science and Technology*, 6(1): 40-59, *ISSN: 2454-4213*.

Akinyele, O. F., Omobuwajo, T. O. and Ikujenlola, A. V. (2020a). Physico-chemical and sensory properties of *pupuru* and *pupuru* analogues from co-fermented cassava (*Manihot esculenta* Crantz) and breadfruit (*Artocarpus altilis*) blends. *Acta Univ. Sapientiae, Alimentaria*, 13 (2020) 32–50, DOI: 10.2478/ausal-2020-0002.

Alabi, O. O. and Aletor, O. (2011). Nutritional, antinutritional composition and invitro protein digestibility of tropical edible pulse. Journal of Sustainable Technology, Volume 2(1)

Alli, A. A. H. (2023). Overview of the vital roles of macro minerals in the human body. *Journal of Trace Elements and Minerals*. Volume 4, 100076. https://doi.org/10.1016/j.jtemin.2023.100076.

Alozie, Y. E. and Ekerette, N. N. (2017). Proximate compositions, physicochemical and sensory properties of gari fortified with soybean, melon seed and moringa seed flours. *International Journal of Nutritional and Food Science*, 6 (2), 105–110.

Aluge, O. O., Akinola, S. A. and Osundahunsi, O. F. (2016). Effect of malted sorghum on quality characteristics of wheat-sorghum-soybean flour for potential use in confectionaries. *Food and Nutrition Sciences*, 7:1241-1252.

Aniedu, C. and Aniedu, O. C. (2014). Fortification of cassava fufu flour with African yam bean flour: implications for improved nutrition in Nigeria. *Asian Journal of Plant Science. Res*. 4, 63–66.

Anya, M. I. and Ozung, P. O. (2019). Proximate, mineral and anti-nutritional compositions of raw and processed African yam bean (*Sphenostylis stenocarpa*) seeds in Cross River State, Nigeria. *Global Journal of Agricultural Science* 18, 19.

AOAC. (2012). Official Methods of Analysis of AOAC International. 19th Edition. Association of Official Analytical Chemists, Virginia, USA

Ardiansyah, D. W., Handoko, D. D., Kusbiantoro, B., Budijanto, S. and Shirakawa, H. (2019). Fermented rice bran extract improves blood pressure and glucose in stroke-prone spontaneously hypertensive rats. *Nutrition and Food Science*, Vol. 49 No. 5, pp. 844-853, doi:10.1108/NFS-12-2018-0340.

Awofadeju, O. F. J. and Olapade A. A. (2020). Nutritional and sensory evaluation of wheat-maize cookies enriched with African walnut (*Tetracarpidium conophorum*) seed protein isolate. *Croatian Journal of Food Technology, Biotechnology and Nutrition,* vol.15: 1-2.

Awolu O. O., Oluwaferanmi P. M., Fafowora O. I., and Oseyemi G. F. (2015). Optimization of the extrusion process for the production of ready-to-eat snack from rice, cassava and kersting's groundnut composite flours. *LWT-Food Science and Technology*, vol. 64, pp. 18-24, https://doi.org/10.1016/j.lwt.2015.05.025.

Awuchi, C. (2019). Proximate composition and functional properties of different grain flour composites for industrial applications. *International Journal of Food Sciences*, Vol. 2, Issue 1, No. 4, pp 43 – 63.

Ayaka, F., Gun, U., Tatsuki, A., Ayaka, A., Ishara, P. and Naoki, H. (2020). Phytic acid in brown rice can reduced by the increasing soaking temperature. *Foods,* 10(1):23

Babarinde, G., Adeyanju, J. and Omogunsoye, A. (2019). Protein enriched breakfast meal from sweet potato and African yam bean mixes. *Bangladesh Journal of Science Ind. Res*. 54, 125–130.

Baiyeri, S., Uguru, M., Ogbonna, P., Samuel-Baiyeri, C. C., Okechukwu, R., Kumaga, F. and Amoatey, C. (2018). Evaluation of the nutritional composition of the seeds of some selected African yam bean (*Sphenostylis stenocarpa*). *Agro-Science Journal of Tropical Agriculture, Food Environment Ext*. 17, 37–44.

Bolaji, O. T., Kamoru, M. A. and Adeyeye, S. A. O. (2021). Quality evaluation and physicochemical properties of blends of fermented cassava flour (lafun) and pigeon pea flour. Volume 12, e00833,http://doi.org/10.1016/j.sciaf.2021.e00833.

Carmen and Diane (2019). Development of a breadfruit flour pasta product. Breadfruit Institute, National Tropical Botanical Garden, Kalaheo, HI 96741, USA. DOI:10.3390/foods8030110.

Chalamacharla, R. B., Harsha, K., Sheik, K. B. and Viswanatha, C. K. (2018). Wheat bran-composition and nutritional quality: A review. *Advances in Biotechnology and Microbiology*, Volume 9 Issue 1, ISSN 2474-7637. DOI: 10.19080/AIBM.2018.09.555754,

Chatterjee, R., Colangelo, L. A., Yeh, H. C., Anderson, C. A., Daviglus, M. L., Liu, K. and Brancati, F. L. (2012). Potassium intake and risk of incident type 2 diabetes mellitus: the coronary artery risk development in young adults (CARDIA) study. *Diabetol*, 55, 1295–1303.

Escobar, A., Rocha-Gomes, A., Reis, C. G. Md., Herrera, K. N. S., Guedes, T. d. J., Silva, A. A. d., Lessa, M.R., Dessimoni-Pinto, N.A.V. and Riul, T.R. (2019). Unripe banana flour (*musa cavendishii*) promotes decrease in weight gain and elimination of faecal cholesterol in wistar rats. *Nutrition and Food Science*, Vol. 50 No. 1, pp. 157-167, doi: 10.1108/NFS-12-2018-0337.

Famurewa, J. A. V. and Oluwalana, I. B. (2007). Interactive effect of processing and varietal differences on the proximate composition of soy flour. *Applied Tropical Agriculture*, 12. 1. 38–42.

FAO/WHO, Codex Alimentarius: Guidelines on Formulated Supplementary Foods for Older Infants and Young Children, (FAO/WHO Joint Publications. 1991) pp. 144 FAO, 2010. FAOSTAT. Food and Agriculture Organization of United Nations. http://faostat.fao.org/default.aspx.

Faustino, M., Veiga, M., Sousa, P., Costa, E. M., Silva, S., Pintado, M. (2019). Agro-food by products as a new source of natural food additives. *Molecules*, 24:1056, doi:10.3390/molecules2406105.

Gemede, H. F. (2020). Nutritional and antinutritional evaluation of complementary foods formulated from maize, pea, and anchote flours. *Food Science and Nutrition*, volume 8, issue 4, pp. 2156-2164.

George, T. T., Obilana, A. O. and Oyeyinka, S. A. (2020). The prospects of African yam bean: past and future importance, *Heliyon,* 6(11), e05458.

International Commission for the Microbiological Specifications for Foods (ICMSF) (2011). Microorganisms in food 8: Use of data for assessing process control and product acceptance. Springer, New York.

Isaac-Bamgboye1, F. J., Enujiugha, V. N. and Oluwamukomi, M O. (2020). In-vitro antioxidant capacity, phytochemical characterisation, toxic and functional properties of African yam bean (*Sphenostylis stenocarpa*) seed enriched cassava (*Manihot esculenta*) product *pupuru*. *European Journal of Nutrition and Food Safety* 12(3): 84-98.

Ismail, B. P. (2017). Ash content determination. In: Food analysis laboratory manual. Food science text series. Springer, Cham. https://doi.org/10.1007/978-3-319-44127-6_11.

Juan, S. and Clemens, B. (2020). Importance of dietary phosphorus for bone metabolism and healthy aging: A review. *Nutrients*, 12(10):3001, DOI:10.3390/nu12103001.

Malomo, S. A., Eleyinmi, A. F. and Fashakin, J. B. (2011). Chemical composition, rheological properties and bread making potentials of composite flours from breadfruit, breadnut and wheat. *African Journal of Food Science.* Vol. 5(7), pp. 400 – 410.

Maray, H. (2023). Physicochemical and functional properties, nutritional value and bioactive compounds of some composite flours. *Asian Journal of Agricultural Science*, 54(1):116-131.

Minisola, S., Fukumoto, S., Xia, W., Corsi, A., Colangelo, L., Scillitan, A., Pepe, J., Cipriani, C., Thakker, R.V. (2023). Tumor-induced ostemalacia: A comprehensive Review. *Endocrine Review*. 44(2):323-353. (PubMEd).

Muhammad, H. M. (2019). Effect of rice bran substitution on the physicochemical properties of water yam flour) (ameliorative role of composite flour against human maladies). *Biomedical Journal of Scientific and Technical Research*, volume 18,4, pp 13804-13811, DOI: 10.26717/BJSTR.2019.18.003193.

Nnamani, C. V., Adewale, B. D., Oselebe, H. O. and Atkinson, C. J (2021). African yam beans the choice for climate change resilience: need for conservation and policy. African Handbook of Climate Change Adaptation, pp. 453-469, DOI:10.1007/978-3-030-45106-6_203.

Okoye, J. I., Nwodo, J. I. and Eze, S. I. (2024). Evaluation of nutritional quality and organoleptic properties of soy-poundo yam flour. Volume 24, 71-82, DOI:10.9/34/acri/2024/v24i46661.

Olumurewa, J. A. V. and Alejolowo, I. A (2020). Evaluation of instant pounded yam flour produced from yellow yam (*Diocsorea cayenensis*). *Canadian Journal of Agriculture and crops*, vol. 5(1), pp 7-24.

Oluwajuyitan, T. D. and Ijarotimi, O. S. (2019). Nutritional, antioxidant, glycaemic index and antihyperglycaemic properties of improved traditional plantain-based (*Musa AAB*) dough meal enriched with tigernut (*Cyperus esculentus*) and defatted soybean (*Glycine max*) flour for diabetic patients. *Heliyon* ,5, e01504. doi: 10.1016/j.heliyon.

Oluwajuyitan, T. D. and Ijarotimi, O. S. and Fagbemi, T. N. (2020). Nutritional, biochemical and organoleptic properties of high protein-fibre functional foods developed from plantain, defatted soybean, rice bran and oat-bran flour. *Nutrition and Food Science*, 1-31.

Olapade, A., Babalola, Y. and Aworh, O. (2014). Quality attributes of fufu (fermented cassava) flour supplemented with bambara flour. *International Food Research Journal*, 21, 2025-2032.

Oluwamukomi, M.O and Adeyemi, A.O. (2015). Physicochemical, pasting and sensory properties of "poundo" yam enriched with defatted soybean flour. *Journal of Applied Tropical Agriculture*, 20(1): 89-95

Oluwamukomi, M. O. and Akinlabi, A. A. (2011) Nutritional enrichment of "pupuru" and smoked-dried cassava product with African yam beans seed flour. *Annals of Science and Biotechnology*. 2(1):26-35.

Oppong, D., Eric, A., Kwadwo, S. O., Badu, E. and Sakyi, P (2015). Proximate composition and some functional properties of soft wheat flour. *International Journal of Innovative Research in Science, Engineering and Technology*, 4, 753-758.

Owuno, F., David, B. K., Akusu, M. and Simeon, C. A. (2021). Nutritional, functional and sensory properties of gari enhanced with fermented maize residues flour. *International Journal of Food Science and Biotechnology*, 6(2):59, DOI: 10.11648/j.ijfsb.20210602.16

Oyeyinka, S. A., Taiwo, O. E, Abdul, H., Rustria, G. A., Oyedeji, A. B., Adebo, O. A., Gerrano, A. S., Amoo, S. O. Njobeh, P. B. (2023). Enhancement of the functional, pasting and textural properties of poundo yam flour through cassava flour supplementation. *Food Chemistry Advance*, Volume 3, 100372.

Ukpong, S. E., Njoku, H. O. and Ire, F. S. (2021). Production, sensory and microbiological properties of biscuits produced from African yam bean tempeh flour and wheat flour. *International Journal of Innovative Science and Research Technology*, Volume 6, Issue 10, ISSN No-2456-2165.

Rohit, P., Tejswini, S., Ashswini, B., Dinesh, N. (2023). Zinc: an essential trace element for human health and beyond. *Food and Health,* 5(3):13. http://doi.org/10.53388/FH2923013.

Salome, K. K., Awofadeju, O. F. J. and Olapade, A. A. (2021). Chemical and functional properties of blends made from unripe plantain (Musa paradisiaca) and African yam bean (Sphenostylis stenocarpa) flours for stiff dough (àmàlà) preparation, *Journal in Applied Science Environmental Management*, Vol. 25 (5) 741-749, DOI: https://dx.doi.org/10.4314/jasem.v25i5.8.

Suwimol, S., Weeraya, S. and Junaida, A. (2021). Biological functions and activities of rice bran as a functional ingredient: A review. *Nutrition and Metabolic Insights*. 14: 11786388211058559, doi: 10.1177/11786388211058559

Tsehayneh, G. Y., Anselimo, O. M., Okoth, J. K. and Mesfin, W. T. (2020). Developing and nutritional quality evaluation of complementary diets produced from selected cereals and legumes cultivated in Gondar province, Ethiopia. *Current Research in Nutrition and Food Science,* Vol. 8 No. 1, pp. 291-302.

USDA Nutrient Database, United State Department of Agriculture Nutrient Database Composition of Foods Raw, Processed, Prepared. (USDA National Nutrient Database for Standard Reference, 2010) http://www.ars.usda.gov/nutrientdata. Accessed 23 September 2010.

USDA (2015) NRCS (n.d.). "Treculia Africana". The plants Database (plants.usda.gov). Greensboro, North Carolina: National Plant Data Team. Retrieved 14 December 2015

U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015-2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at https://health.gov/our-work/foof-nutrition/previous-dietary-guidelines/2015.

•*Thank you for publishing with us.*