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RESEARCH ARTICLE

AMINO ACID, PASTING AND SENSORY PROPERTIES OF "POUNDO" YAM ENRICHED WITH FERMENTED BAMBARA GROUNDNUT FLOUR

A.K. Arise*, O.T. Esan and T. R. Famakinde

Samples	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Fibre (%)	Carbohydrate (%)
A	$68.63^{a} \pm 0.01$	$1.06^{a} \pm 0.20$	$1.49^{a} \pm 0.04$	$6.55^{a} \pm 0.01$	$2.00^{a} \pm 0.20$	$20.27^{g} \pm 0.40$
B	$71.22^{b} \pm 0.02$	$1.12^{a} \pm 0.03$	$1.63^{a} \pm 0.50$	$10.03^{b} \pm 0.03$	$2.01^{a} \pm 0.02$	$13.99^{f} \pm 0.20$
C	$71.63^{b} \pm 0.05$	$1.13^{a} \pm 0.40$	$1.66^{a} \pm 0.10$	$12.26^{c} \pm 0.10$	$2.05^{a} \pm 0.10$	$11.27^{e} \pm 0.40$
D	$72.63^{c} \pm 0.03$	$1.15^{a} \pm 0.02$	$1.74^{a} \pm 0.01$	$13.27^{d} \pm 0.04$	$2.10^{a} \pm 0.01$	$9.11^{d} \pm 0.03$
E	$73.71^{c} \pm 0.10$	$1.24^{a} \pm 0.06$	$1.75^{a} \pm 0.02$	$14.26^{e} \pm 0.30$	$2.11^{a} \pm 0.40$	$6.93^{c} \pm 0.20$
F	$74.81^{d} \pm 0.05$	$1.32^{a} \pm 0.30$	$1.76^{a} \pm 0.30$	$15.26^{f} \pm 0.01$	$2.13^{a} \pm 0.02$	$4.72^{b} \pm 0.08$
G	$74.82^{d} \pm 0.10$	$1.55^{a} \pm 0.10$	$1.87^{a} \pm 0.40$	$16.24^{g} \pm 0.10$	$2.22^{a} \pm 0.10$	$3.30^{a} \pm 0.01$

Mean ± SD. Means with the same superscript within the same column are not significantly ($p<0.05$) different.
Keys: A= Control (100%) "poundo" yam ; B= (95:5%) yam- fermented Bambara flour; C = (90:10%) yam-fermented Bambara flour; D= (85:15%) yam-fermented Bambara flour; E= (80:20%) yam- fermented Bambara flour; F= (75:25%) yam-fermented Bambara flour; G= (70:30%) yam- fermented Bambara flour.

Highlights

- Fermented Bambara flour can be used to enrich yam for 'poundo'
- It increases the levels of essential and nonessential amino acid in 'poundo' yam
- It also enhances pasting property in 'poundo' yam

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AMINO ACID, PASTING AND SENSORY PROPERTIES OF "POUNDO" YAM ENRICHED WITH FERMENTED BAMBARA GROUNDNUT FLOUR

Arise A.K.[a]*, Esan O.T.[b] and Famakinde T. R.[a]

[a]*Department of Home Economics and Food Science, University of Ilorin, P.M.B. 1515, Ilorin, Kwara State, Nigeria*
[b]*School of Health Administration, Dalhouse University, Halifx, Nova Scotia, Canada.*

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Abstract: The study investigated the effect of fermented Bambara flour to enrich amino acid profile of 'poundo' yam flour and other physico-chemical, pasting and sensory properties of the dough. The yam flours were enriched with fermented Bambara flour in ratios of 100:0, 95:5, 90:10, 85:15, 80:20, 75:25 and 70:30, respectively. 'Poundo' yam samples were prepared using the blends and evaluated for sensory attributes. Enrichment has increased the protein content and fat while it decreased the carbohydrate content following the inclusion of fermented Bambara flour. The amino acid content of the enriched poundo yam samples showed a significant increase in the essential and non-essential amino acid contents. The bulk density, swelling power and oil absorption capacity of the flour samples decreased while the water absorption capacity increased with the enrichment. The pasting characteristics data revealed an increase in pasting temperature, breakdown, peak time and setback viscosity and a decrease in peak, final and trough viscosities with increasing addition of fermented Bambara flour. Sensory evaluations indicated that at 15% level of enrichment, there was no significant difference in the overall acceptability of the poundo yam dough enriched with Bambara flour and the dough obtained from the control. Hence, acceptable poundo yam dough with improved nutritional value can be obtained by enriching with fermented Bambara- yam flour.

Keywords: Bambara groundnut flour, poundo yam, amino acid, proximate analysis, sensory properties

INTRODUCTION

Yam (*Dioscorea* species) is an important tropical root crop. It is ranked as the fourth major root crop in the world after cassava, potatoes and sweet potatoes (Darkwa *et al*., 2020, Padhan and Panda, 2020). It is also an important source of carbohydrate for many people of the Sub-Sahara region, especially in the yam zone of West Africa (Padhan and Panda, 2020). Nigeria is the world largest producer of edible yam with *D. rotundata* and *D. alata* as the two most cultivated yam species in the country. It was reported that yam contributes more than 200 dietary calories per capital daily for more than 150 million people in West Africa and serves as an important source of income to the people (Darkwa *et al*., 2020). Yams are characterized by high moisture content, which renders the tubers more susceptible to microbial attacks and brings about high perish ability of the tubers (Jeannette *et al*., 2020). Nutritionally, yam considers as significant carbohydrate and fiber food sources. Other nutrients present in yam are caloric proteins, minerals and vitamins. The yam is important in household food security, diet diversification, employment and income generation as well as alleviation of poverty (Jeannette *et al*., 2020). Industrial processing and utilization of yam includes starch, poultry and livestock feed, production of yam flour and instant pounded yam flour production. Traditionally, the processing of pounded yam using pestle and mortar is highly valued but it is generally being replaced in the market with the instant pounded yam flour. Instant pounded yam flour requires short processing time and less energy (Akinoso and Olatoye, 2013). Poundo yam which is referred to as instant pounded yam flour (IPYF) is a processed white powdery form of yam (dehydrated yam flour) which is produced in a desiccating machine (Olaoye and Oyewole, 2012, Akinoso and Olatoye, 2013). It is a fast mean of making pounded yam which is done by pouring a measured quality of the yam flour into boiling water, and stirred continuously until the required texture and taste is achieved (Akinoso and Olatoye, 2013).

Protein energy malnutrition is a major problem in Africa as a result of high cost of animal protein (Arise *et al.,* 2018a, Arise *et al.,* 2021, Arise e*t al.,* 2022b). Therefore, the use of legume as an alternative to high cost animal protein is been researched profusely. Compositional evaluations of leguminous seeds as well as studies on the enrichment of local starchy foods with legumes such as soybean, cowpea, groundnut, pigeon pea, chicken pea and red gram have been carried out in different locations by many investigators (Olu *et al.,* 2012; Oluwamukomi *et al.,* 2005). However, Bambara groundnut has not been use for yam enrichment in the poundo yam production.

Bambara nut (*Vigna subterranean*) is a legume crop of African origin used locally as a vegetable or snack. Bambara nut is one of the most adaptable of all plants and it tolerates harsh conditions better than most other crops. It is cultivated principally by farmers as a "famine culture" crop because it has numerous agronomic advantages including good resistance to pest and drought tolerance (Arise *et al.,* 2015). It is unfortunately one of the neglected and under-utilized crops in sub Saharan Africa. In addition, Bambara nut is rich in protein (15-27%) and carbohydrate (56-68%) (Arise *et al.,* 2018a, Arise e*t al.,* 2021). Bambara protein contains high levels of lysine (6.5–6.8%) and a reasonable

**Corresponding Author's Email: abimbolatemi@gmail.com; arise.ak@unilorin.edu.ng*
https://orcid.org/0000-0003-2446-526X

amount of methionine (1.8 g per 100 g) which is normally limiting in legumes (Arise *et al*., 2016, Ijarotimi and Esho, 2009). Hence, it can be potentially used in food products as a protein supplement. Bambara groundnut has been used to supplement various food products such as croissant snacks, maize snacks, biscuit, custard, indomine (Arise *et al.,* 2020, Arise *et al.*, 2018a, Arise *et al.*, 2021, Arise *et al.,* 2022a, Arise *et al.*, 2022b). Therefore the objective of the study was to investigate the effect of fermented Bambara flour on the amino acid profile of poundo yam flour, and its other physico-chemical, pasting and sensory properties.

MATERIALS AND METHODS

Source of materials

The yam tuber (*Dioscorea alata*) and Bambara groundnut used for this study were obtained from Oja- Oba market in Ilorin, Kwara state, Nigeria.

Methodology

Preparation of instant yam flour

The method described by Olumurewa and Alejolowo (2020) was employed with slight modifications. Thirty kilograms (30 kg) of yam tubers were peeled and washed to get rid of all dirt. The peeled yam was sliced and cut into chips with a slicer to 0.2mm thickness. The chips were immediately soaked in an already prepared 0.5% solution of sodium metabisulfite for 15 minutes. The chips were then drained and parboiled by steaming for 15 minutes so as to allow partial gelatinization to occur which is known as parboiling. After the parboiling stage, the chips were weighed to be 27 kg and spread out uniformly on a stainless steel perforated tray and dried in a cabinet dryer (DHG-9053A, Hangzhou, Zhejiang, China) at 65°C for 8 hours. The dried chips were finally milled into flour using a hammer mill and sieved to obtain flour particle size range from 50-70µm. The weight of the flour after sieving was 6 kg and it was packaged in a zip lock bag and stored prior to analysis.

Preparation of fermented Bambara groundnut flour

Bambara groundnut flour was produced using the method of Arise *et al.* (2020), with slight modifications. Briefly, Bambara groundnut was sorted and cleaned to be free from foreign materials. The cleaned Bambara was soaked in water for 72 hrs and allowed to ferment at room temperature (32 ± 2˚C). It was then de-hulled manually to remove the seed coat. The de-hulled seeds were oven-dried for 3 days at 35˚C. The dried seeds were then ground in a Warring laboratory mill blender (HGBTWTS3, Torrington, CT, USA) and sieved through a screen mesh of 355 µm to obtain fine Bambara flour.

Formulation of Yam-Bambara flour blends

The instant yam flour and fermented Bambara flour were milled to fine powder separately, the fine powders were sieved, and the various blends were made. A quantity of the flour blend i.e. 95% yam flour: 5% Bambara flour, 90% yam flour: 10% Bambara, 85% yam Flour: 15% Bambara flour, 80 yam flour: 20% Bambara flour, 75% yam flour: 25% Bambara flour, 70% yam flour: 30% Bambara flour and the control which is 100% instant yam flour were prepared.

Determination of the functional properties of yam-Bambara flour blends.

The functional properties of yam-Bambara flour blends such as water absorption capacity (WAC), oil absorption capacity (OAC), bulk density and swelling capacity were determined. WAC and OAC were determined according to the method of Arise *et al.* (2015), with slight modifications. One gram of each sample was dispersed in 10 ml of distilled water (or sunflower oil) in a 50-mL pre-weighed centrifuge tube. The dispersion was vortexed for 1 min, allowed to stand for 30 min and then centrifuged at 4,000 rpm for 30 min at room temperature. The supernatant was decanted, excess water (or oil) in the upper phase was drained for 15 min, and the tube containing the residue was weighed again to determine the amount of water or oil retained per gram of the sample. The Bulk Density of the flour sample was determined as previously described by Arise *et al.* (2019),with slight modification. A measuring cylinder (100 ml) was filled with flour to mark (100 ml), and the content weighed. The tapped bulk density was also obtained by following the same procedure but tapping for 50 times prior to weighing. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (g/ml). The swelling power of flour was determined based on a modified method of Julianti *et al.* (2017). Briefly, approximately 0.1 g of sample was transferred into a weighed graduated 50 ml centrifuge tube. Distilled water was added to give a total volume of 10 ml. The sample in the tube was stirred gently by hand for 30 sec at room temperature, and then heated at 60^{o}C for 30 min. After cooling to room temperature, the samples were centrifuged for 30 min at 3,000 rpm. The weight of the sediment was recorded.

Pasting properties of yam-Bambara flour blends

The pasting properties was done according to the method used by Arise *et al.* (2018) which includes pasting temperature, peak viscosity, time to peak, temperature at peak, hot and cold viscosity breakdown, set back and final viscosity. Three and half gram (3.5 g) of sample was weighed and 25 mL of water was dispensed into the canister. Paddle was placed inside the canister, this was placed centrally onto the paddle coupling and then inserted into the rapid visco analyzer (RVA) machine. (Starch master 2, Newport Scientific Pvt. Ltd.,Warriewood, Australia) The measurement cycle was initiated by pressing the motor tower of the instrument. The profile can be seen as it is running on the monitor of a computer connected to the instrument. The 13 minutes profile was used, the time-temperature regime used was; idle temperature 50℃ for 1 min, heated from 50℃to 95℃ in 3 min 45 sec, then held at 95℃ for 2 min 30 sec, the sample was subsequently cooled to 50℃ over a 3 min 45 sec period followed by a period of 2 min where the temperature was controlled at 50℃.

Determination of the amino acid content of the flour blends

Amino acid content was determined using Pico-Tag method

(Bidlingmeyer *et al.* 1984). Briefly, the known (2.0 g) sample was hydrolyzed, evaporated in a rotary evaporator and loaded into Technicon Sequential Multi-Sample Amino Acid Analyzer (TSM-1) (Technicon Instruments Corporation, New York, USA). Ten micro liters (10 µL) of each hydrolysate was dispensed into the cartridge of the analyzer. The analyzer was separated and analyzed free acidic, neutral and basic amines, which will last for 76 h. Norleucine was employed as the internal standard. Ten micro liters (10 µL) of the standard solution mixture of the amino acid was also loaded into the analyzer. Values of both the standard and samples was recorded and printed out as chromatogram peaks by the chart recorder.

Calculation from the peaks: The net height of each peak produced on the chromatogram (each representing amino acid) was measured. The half-height of each peak was located and the width of the peak at half-height will accurately be measured. Approximate area of each peak was then obtained by multiplying the height with the width of the half height. All measurement was in millimetre (mm). The norleucine equivalent (NE) for each amino acid in the standard mixture was calculated as:

$$NE = \frac{Area\ of\ neulocine\ peak}{Area\ of\ each\ amino\ acid\ in\ the\ standard\ mixture}$$

Determination of proximate composition of Bambara enriched poundo yam dough

Ash, fat, fiber and moisture content were determined using AOAC methods (AOAC, 2000). The protein content was determined by Kjeldahl method (N × 6.25). Total carbohydrate was calculated by difference as expressed below:

% Total carbohydrate = 100 – (% moisture + % fat + % protein + % fibre + % ash content).

Sensory Evaluation of Bambara-enriched poundo yam dough

The prepared poundo yam dough from various samples were evaluated by a panel of fifty untrained judges drawn from the University of Ilorin, Nigeria for attributes of colour, texture, flavor, crispiness and general acceptability on a hedonic scale of 1-9, where 1 = dislike extremely and 9 = like extremely. Scores were collated and analyzed statistically.

Statistical analysis

Experiments were conducted in triplicates. Data obtained were subjected to Analysis of Variance (ANOVA) using SPSS version 16.0. The differences between the mean values were evaluated at 5% confidence level using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Functional properties of Yam and Bambara yam enriched flour

The water absorption capacity (WAC) and bulk density increased with an increased addition of fermented Bambara flour (Table 1). On the contrary, a decrease in oil absorption capacity (OAC) and swelling capacity was observed with increase in fermented Bambara groundnut inclusion. The increase in water absorption capacity and decrease in oil absorption capacity of the flour blends can be attributed to the presence of higher amount of hydrophilic amino acid in Bambara groundnut (Table 3) thereby absorbing more water (Arise *et al.,* 2017, Arise *et al.,* 2018b).The result obtained in this study, agreed with the findings of Ajatta *et al.* (2016). The authors reported an increase in WAC and bulk density (240 - 275% and 0.82 - 0.85 g/ml), respectively when bread fruit was incorporated into wheat for composite flour production. In the same vein, when Bambara groundnut flour was added to maize for abari production, an increase in water absorption (1.6 - 1.8 g/ml) and bulk density (0.84 - 0.99 g/ml) was observed (Arise *et al.,* 2019). Furthermore, when fermented Bambara flour was added to flour for croissant production , same increase in WAC and bulk density was reported by the author (Arise *et al.,* 2020).

Pasting properties of Yam and Bambara yam enriched flour

In this study, there was a decrease in peak and final viscosity with an increase in addition of Bambara groundnut flour (Table 2). Peak viscosity reduced significantly ($p < .05$) from 3301.50 to 139 Rapid-Visco Analyser units (RVU) with an increase in Bambara groundnut flour addition with an exception of sample F (75:25%). Final viscosity also reduced from 4870 - 320 RVU. The decrease in values of

Table 1: Functional properties of yam flour and yam-Bambara enriched flour.

Samples	Water Absorption capacity (g/ml)	Bulk density (g/cm^3)	Swelling capacity (g/g)	Oil absorption capacity (g/ml)
A	2.39^b±0.01	0.77^a±0.00	4.69^a±0.01	1.67^a±0.04
B	2.39^b±0.01	0.83^b±0.00	4.46^b±0.06	1.03^a±0.01
C	2.47^b±0.12	0.97^b±0.04	4.20^{cd}±0.14	1.05^e±0.0
D	2.79^a±0.04	1.03^a±0.04	4.09^d±0.04	1.32^c±0.00
E	2.43^b±0.00	1.07^b±0.05	4.36^{bc}±0.21	1.12^d±0.01
F	2.42^b±0.22	1.21^{bc}±0.00	4.19^{cd}±0.08	1.37^b±0.28
G	2.48^b±0.11	1.26^c±0.04	3.75^e±0.03	1.31^c±0.00

Mean ± SD. Means with the same superscript within the same column are not significantly (p<0.05) different.
Keys: A= Control (100%) "poundo" yam ; B= (95:5%) yam- fermented Bambara flour; C = (90:10%) yam- fermented Bambara flour; D= (85:15%) yam-fermented Bambara flour; E= (80:20%) yam- fermented Bambara flour; F= (75:25%) yam-fermented Bambara flour; G= (70:30%) yam- fermented Bambara flour.

final viscosity for composite flours is similar to a report by Olapade *et al.* (2014), who reported a decrease in the final viscosity value of cassava-Bambara flour. In the same vein same reduction in peak and final viscosity was reported for croissant snacks when fermented Bambara flour was used to enrich wheat flour for the snacks production (Arise *et al.*, 2020). Reduction in peak viscosity could be due to the reduction in starch content, because wheat flour has more starch than Bambara groundnut flour. It could also be due to the interactions between the starch, fat, and protein contents of the blends. More so, peak viscosity has correlation with water binding ability of starch, which takes place at equilibrium point between swelling leading to an increase in viscosity, while reduction is caused by rupturing and realignment (Ocheme *et al.,* 2018). Trough viscosity is the maximum viscosity at the constant temperature of the RVU profile and the ability of the paste to withstand breakdown during cooling (Arise *et al.,* 2018a). There was a decrease in the trough from (3194 - 81.67 RVU) at each level of supplementation with Bambara groundnut. This is similar to a report by Arise *et al.* (2018a), who reported that the addition of Bambara groundnut lowers the trough of maize flours which implies that the blends may not find good applications in the food system, where high paste stability during cooking is required. The increase in inclusion of Bambara groundnut flour to cause a decrease in the trough viscosity implied that the blends might not maintain high paste stability during cooking (Adegunwa *et al.,* 2015). The breakdown, which is the difference in the peak viscosity and trough, is an indication of the rate of gelling stability, which is dependent on the nature of the product (Arise *et al.,* 2018).The breakdown value of the flour blends ranged from 7.33 RVU for sample E (80:20%) having the least value and sample F having the highest 136.50 RVU (75:25%). The result showed that the breakdown value do not follow a regular pattern. It is however noteworthy that sample F (75:25) had a higher value than the control. This is in agreement with the findings of Arise *et al.* (2018a), when maize was substituted with Bambara groundnut. The low breakdown viscosity of the flour blends indicates their ability to withstand breakdown during heating and shearing. High breakdown viscosity of flour may reduce its ability to withstand heating and shear stress during cooking (Ocheme *et al.,* 2018). The setback values of the flour blends ranged from 91.37 to 1980.00 RVU. Setback viscosity indicates gel stability and potential for retrogradation. This probably suggests that the dough would have higher resistance to retrogradation while the syneresis effect may be reduced (Akinwale *et al.,* 2017). The setback value does not follow a particular pattern. However, sample F (75:25) had highest setback value (1980.00 RVU) among the samples. This is similar to the findings of Arise *et al.* (2018a), who reported an irregular pattern in the setback value of *kokoro* made from maize-Bambara flour blends. Higher setback values means reduced dough digestibility (Akinwale *et al.,* 2017) while lower setback during the cooling of the paste indicates lower tendency for retrogradation (Arise *et al.,* 2020). The time it takes for peak viscosity to occur in minutes is referred to as peak time (Adebowale *et al.*, 2005). The peak time of the flour blends in this study ranged from 6.87 to 7.00 min. There was no significance difference ($p<0.05$) between the samples. The samples had similar peak time. Low peak time observed in the flour blends may be attributed to the reduced starch content as a result of Bambara groundnut flour substitution. It is indicative of its ability to cook fast, which is an added advantage (Ajatta *et al.*, 2016).

Table 2. Pasting properties of yam-bambara flour blends.

Samples	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final (RVU)	Setback (RVU)	Peak Time (min)	Pasting temp (˚C)
A	3301.50^{a} ±142.13	3194.50^{a} ±143.54	107.00^{a} ±1.41	4870.00^{a} ±125.87	1675.50^{b} ±17.68	6.94^{a} ±0.09	79.45^{e} ±0.57
B	2398.00^{b} ±80.61	2281.00^{b} ±50.90	117.00^{a} ±29.70	3671.50^{b} ±221.30	1390.50^{c} ±170.41	7.00^{a} ±0.00	82.33^{d} ±0.04
C	168.46^{d} ±10.91	157.38^{d} ±11.96	11.08^{b} ±1.06	248.75^{c} ±18.27	91.37^{d} ±6.30	6.87^{a} ±0.19	86.85^{a} ±0.49
D	164.84^{d} ±27.34	155.13^{d} ±24.33	9.71^{b} ±3.01	269.00^{c} ±46.42	113.88^{d} ±22.10	6.94^{a} ±0.09	85.60^{b} ±0.00
E	139.00^{d} ±35.00	81.67^{d} ±37.83	7.33^{b} ±2.12	244.92^{c} ±62.70	113.25^{d} ±29.81	7.00^{a} ±0.00	85.50^{b} ±0.07
F	1776.50^{c} ±51.62	1640.00^{c} ±26.87	136.50^{a} ±24.75	3620.00^{b} ±67.88	1980.00^{a} ±41.04	6.97^{a} ±0.05	84.35^{c} ±0.49
G	149.58^{d} ±13.7	141.25^{d} ±12.61	8.34^{b} ±1.18	320.25^{c} ±28.75	179.00^{d} ±16.15	7.00^{a} ±0.00	86.45^{a} ±0.00

Mean ± SD. Means with the same superscript within the same column are not significantly ($p<0.05$) different.
Keys: A= Control (100%) "poundo" yam ; B= (95:5%) yam- fermented Bambara flour; C = (90:10%) yam- fermented Bambara flour; D= (85:15%) yam-fermented Bambara flour; E= (80:20%) yam- fermented Bambara flour; F= (75:25%) yam-fermented Bambara flour; G= (70:30%) yam- fermented Bambara flour.

Amino acid profile of yam and Bambara yam enriched flour

Nutritional quality of protein depends on its essential amino acid (EAA). The amino acid composition of two most preferred samples as showed by organoleptic test and the control sample is shown in Table 3. The result revealed that there was an increase in almost all of the amino acid composition in both samples D-85/FB-15 (85 % yam flour and 15 % Bambara) and E- 80/FB-20 (80 % yam flour and 20 % Bambara) than control (100 % Yam flour). The increase in the amino acid profile of wheat Bambara flour blends is due to the high quality of protein present in Bambara flour, since legumes are protein-rich crops and have higher amino-acid composition than cereals. The high lysine content of the Bambara groundnut protein is a very important nutritional attribute that makes the legume a good supplementary protein to cereals with known deficiency in lysine (Adebowale *et al.,* 2011, Arise e*t al.,* 2016, Arise *et al.,* 2020). In addition, the higher hydrophobic amino acids could be an added advantage as this yam- Bambara dough sample could be eaten as a functional food.

Proximate composition of poundo yam and Bambara enriched poundo yam

Moisture, protein and carbohydrate are the major components of yam dough and yam Bambara dough (Table 4). The results revealed that there was an increase in moisture content from 68.63 %-74.82 % and protein content from 6.55 % - 16.24 % with increase in Bambara flour substitution. The fat, ash and fiber content were not significantly different from the control. However, there is a decrease in carbohydrate content from 20.27 - 3.30 %. These results are similar to the findings of Oluwamukomi *et al.* (2005) when defatted soy bean flour was added to yam flour for poundo yam production. The increase in protein content is expected since Bambara groundnut is a good source of protein. Also, fermentation has been reported to lead to an increase in protein (Arise *et al.,* 2020). The low carbohydrate is also expected since carbohydrate is calculated by difference and since the protein content increased the carbohydrate content would decrease. The high moisture content could be due to the water that was added to the yam flour during production

Table 3. Amino acid (g/100 g protein) composition of yam and Bambara- enriched yam flour

Amino acid (g/100 g protein)	Control	D (85:15)	E (80:20)
Essential amino acids (EAA)			
Leucine	12.02	12.35	12.67
Lysine	3.65	3.71	4.03
Isoleucine	4.03	4.52	4.81
Histidine	3.96	4.03	4.38
Tryptophan	0.63	0.71	0.81
Valine	4.91	4.80	5.20
Methionine	1.17	1.20	1.44
Phenylalanine	4.52	4.71	4.52
Threonine	3.08	3.41	3.50
Total EAA	37.97(g/100 g protein)	39.44 (g/100 g protein)	41.36 (g/100 g protein)
Nonessential amino acids (NEA)			
Tyrosine	3.44	5.68	5.60
Cysteine	1.39	1.57	1.82
Alanine	5.65	5.61	6.14
Glutamic acid	15.22	15.29	15.67
Glycine	3.56	3.52	3.82
Arginine	5.00	5.16	5.59
Aspartic acid	7.51	7.72	8.00
Serine	4.27	4.46	4.81
Proline	4.36	4.47	4.77
Total NEA	50.40 (g/100 g protein)	53.48 (g/100 g protein)	56.22 (g/100g protein)
Hydrophobic amino acids	36.66	37.66	39.55
Hydrophilic amino acids	15.74	18.64	19.55
Basic amino acids	12.61	12.9	14
Acidic amino acids	22.73	23.01	23.67

Hydrophobic amino acids=Methionine +Alanine +Valine +Leucine + Isoluecine + Proline + Phenylalanine. Hydrophilic amino acids = Glycine + Tyrosine + Serine + Threonine + cysteine. Basic amino acids = Lysine + Histidine + Arginine.
Acidic amino acids = Glutamic acid + Aspartic acid.

Table 4. Proximate composition of yam-Bambara poundo yam.

Samples	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
A	$68.63^{a} \pm 0.01$	$1.06^{a} \pm 0.20$	$1.49^{a} \pm 0.04$	$6.55^{a} \pm 0.01$	$2.00^{a} \pm 0.20$	$20.27^{g} \pm 0.40$
B	$71.22^{b} \pm 0.02$	$1.12^{a} \pm 0.03$	$1.63^{a} \pm 0.50$	$10.03^{b} \pm 0.03$	$2.01^{a} \pm 0.02$	$13.99^{f} \pm 0.20$
C	$71.63^{b} \pm 0.05$	$1.13^{a} \pm 0.40$	$1.66^{a} \pm 0.10$	$12.26^{c} \pm 0.10$	$2.05^{a} \pm 0.10$	$11.27^{e} \pm 0.40$
D	$72.63^{c} \pm 0.03$	$1.15^{a} \pm 0.02$	$1.74^{a} \pm 0.01$	$13.27^{d} \pm 0.04$	$2.10^{a} \pm 0.01$	$9.11^{d} \pm 0.03$
E	$73.71^{c} \pm 0.10$	$1.24^{a} \pm 0.06$	$1.75^{a} \pm 0.02$	$14.26^{e} \pm 0.30$	$2.11^{a} \pm 0.40$	$6.93^{c} \pm 0.20$
F	$74.81^{d} \pm 0.05$	$1.32^{a} \pm 0.30$	$1.76^{a} \pm 0.30$	$15.26^{f} \pm 0.01$	$2.13^{a} \pm 0.02$	$4.72^{b} \pm 0.08$
G	$74.82^{d} \pm 0.10$	$1.55^{a} \pm 0.10$	$1.87^{a} \pm 0.40$	$16.24^{g} \pm 0.10$	$2.22^{a} \pm 0.10$	$3.30^{a} \pm 0.01$

Mean ± SD. Means with the same superscript within the same column are not significantly ($p<0.05$) different.
Keys: A= Control (100%) "poundo" yam ; B= (95:5%) yam- fermented Bambara flour; C = (90:10%) yam- fermented Bambara flour; D= (85:15%) yam-fermented Bambara flour; E= (80:20%) yam- fermented Bambara flour; F= (75:25%) yam-fermented Bambara flour; G= (70:30%) yam- fermented Bambara flour.

Sensory qualities of poundo yam and Bambara enriched poundo yam

The sensory evaluation revealed that all the samples with fermented Bambara groundnut inclusion were generally accepted (Table 5). Interestingly, the overall acceptability revealed that samples with fermented Bambara groundnut (85% wheat: 15% fermented Bambara) was more acceptable than the control (D: 100% Yam flour). The addition of fermented Bambara groundnut makes the poundo yam to be more appealing to behold. This result is in line with the report of other researchers. Bambara groundnut addition to maize pudding, maize snacks and croissants has been reported to increase the acceptability of the product by the consumer (Arise *et al.,* 2018a, Arise *et al.,* 2019, Arise *et al.,* 2020).

CONCLUSION

The study showed that the poundo yam of acceptable quality and higher nutritional value could be produced from flour blends of yam and fermented Bambara groundnut flour. The inclusion of fermented Bambara groundnut in production of poundo yam will help in combating the protein- energy malnutrition and this will also enhance the utilization of the underutilized Bambara groundnut. The preparation with 85 % yam: 15 % fermented Bambara could be recommended as a viable and fortified formulation for poundo yam production.

STATEMENT FOR CONFLICTS OF INTEREST

The authors had none to declare. The study proposal was presented within the Departmental Research and Ethical committee and was approved by the Ethical committee of the Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria.

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Table 5. Sensory qualities of Yam and Bambara –yam enriched Poundo yam

Samples	Appearance	Texture	Taste	Aroma	Overall Acceptability
A	$7.20^{c} \pm 0.63$	$7.90^{b} \pm 1.05$	$7.40^{a} \pm 0.42$	$7.00^{b} \pm 0.57$	$7.45^{ab} \pm 0.31$
B	$7.20^{c} \pm 0.47$	$7.40^{b} \pm 0.97$	$6.90^{ab} \pm 0.57$	$7.05^{b} \pm 0.42$	$7.13^{abc} \pm 0.47$
C	$7.30^{c} \pm 0.94$	$7.30^{b} \pm 0.82$	$6.40^{b} \pm 0.84$	$7.20^{b} \pm 0.88$	$7.05^{b} \pm 0.48$
D	$7.40^{c} \pm 0.67$	$7.80^{b} \pm 0.63$	$7.50^{a} \pm 0.53$	$7.80^{a} \pm 0.42$	$7.60^{a} \pm 0.53$
E	$6.70^{b} \pm 0.48$	$6.90^{a} \pm 0.88$	$5.00^{c} \pm 1.05$	$5.80^{c} \pm 0.90$	$6.10^{c} \pm 0.74$
F	$6.30^{b} \pm 0.95$	$6.60^{cd} \pm 0.70$	$3.90^{d} \pm 0.88$	$4.90^{d} \pm 0.74$	$5.30^{d} \pm 0.48$
G	$5.90^{a} \pm 0.88$	$6.20^{d} \pm 0.63$	$2.40^{e} \pm 1.34$	$4.60^{d} \pm 1.51$	$5.10^{d} \pm 0.57$

Mean ± SD. Means with the same superscript within the same column are not significantly ($p<0.05$) different.
Keys: A= Control (100%) "poundo" yam ; B= (95:5%) yam- fermented Bambara flour; C = (90:10%) yam- fermented Bambara flour; D= (85:15%) yam-fermented Bambara flour; E= (80:20%) yam- fermented Bambara flour; F= (75:25%) yam-ferment`ed Bambara flour; G= (70:30%) yam- fermented Bambara flour.

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