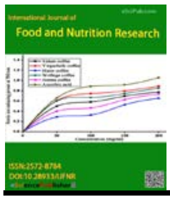
Research Article **IJFNR (2019) 3:29**



International Journal of Food and Nutrition Research
(ISSN:2572-8784)

Evaluation of Yield and Physicochemical Properties of Single Cereal Grain Akamu and Pre- and Post- Processed Multigrain Cereal Akamu Powders

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ABSTRACT

The yield and physicochemical properties of single grain and multigrain akamu powders were evaluated. Akamu, ogi or pap, powders were produced by soaking (fermenting) cereal grains (48-72 h), wet-milling, sieving, dewatering, drying (50oC) and pulverizing maize (MBA), pearl millet (PMBA) and sorghum (SBA). Multigrain akamu was produced by co-fermenting equal proportions of maize, pearl millet and sorghum (Blend1); and singly fermenting these cereals and blending the end products (Blend2). Yield, proximate and mineral compositions, functional and sensory properties of akamu were analyzed following established methods. The yield of MBA, PMBA, SBA, Blend1 and Blend2 were respectively 60%, 70%, 80%, 53.33% and 68.67%. Chemically, SBA had significantly ($p<0.05$) higher protein (10.17%), fiber (8.00%), iron, zinc, potassium and sodium contents than MBA and PMBA. The carbohydrate content of PMBA (69.27%) was higher ($p < 0.05$) than that of MBA (66.20%) and SBA (66.30%). PMBA had the lowest protein (7.55%) and MBA the lowest fiber (3.97%) content. The fat (6.27%) and ash (4.67%) of PMBA were significantly higher than that of SBA with 5.47% and 2.00%, respectively. Only the ash, carbohydrate, iron and sodium contents of multigrain akamu differed significantly ($p<0.05$) with Blend1 having higher carbohydrate and iron values but lower ash and sodium values. The water absorption capacity (WAC) of PMBA (1.87 g/g) was lower ($p<0.05$) than other single and multi grain samples. MBA had lowest emulsion activity (EA) (44.33%) but highest emulsion stability (ES) of 77.43% while SDA had the highest EA (50.00%). The ES of PMBA (55.17%) was significantly lower than that of MBA and SBA and the multigrain akamu samples. MBA and PMBA had significantly higher swelling capacity (SC) than SBA and the multigrain akamu. PBMA had lower least gelation concentration (LGC) (6%) than other single and multigrain samples which had 8%. The sensory properties of MBA were most preferred to other single and multi grain akamu samples.

Keywords:
Akamu, single grain, multi grain, yield, physicochemical properties

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How to cite this article:
Obiegbuna, J.E*., Nwankwo, J.A., Ozue, J.O. and Okolo A.C.Evaluation of Yield and Physicochemical Properties of Single Cereal Grain Akamu and Pre- and Post- Processed Multigrain Cereal Akamu Powders. International Journal of Food and Nutrition Research, 2019; 3:29.

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Introduction

Akamu is a name in Igbo speaking tribe of Southeastern Nigeria referring to pap, a lactic acid fermented gruel or porridge prepared from maize grain. In Yoruba and Hausa speaking tribes of Nigeria, it is called ogi and furali, respectively. It is a common food consumed by all irrespective of age, gender and socio-economic status. It is a complimentary food for weaning infants; food for convalescing adults due to ease of digestibility and convenience; breakfast cereal for healthy adults and children; and food for nursing mothers for stimulation of milk production.

The prevalent cereal for akamu production in Southeastern Nigeria is maize (*Zea may*). In the southwestern and Northern Nigeria, maize (*Oriza sativa*), sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum gluacum*) are common. The generic name for akamu from maize in the Southwestern Nigeria is ogi; whereas ogi from sorghum and millet are referred to as ogi-baba and ogi-gero, respectively [1]. Irrespective of the cereal source (maize, sorghum and millet), akamu is nutritionally deficient due to its low protein content and limiting amino acids notably lysine and methionine [2]. Osungbaro [3] reported nutrient losses occurring during the processing of cereals into akamu/ ogi. According to Omemuo *et al*. [4], the 'Guon' method of processing akamu (cooking grain for 10 min in boiling water and steeping for 12 – 48 h at ambient temperature of 30±2ºC) resulted to the loss of about 40% of total proteins but the digestibility of the protein is increased by 20%. About 50% of the micro and macro nutrients were also lost.

The improvement of the nutritional value of ogi by fortifying it with protein rich substrates/ sources [3] is not arguable at least for the increased protein content and the complimentary deficient essential amino acids mentioned earlier. Nursing mothers have observed that growth performance of infants fed akamu from equal ratios of maize, sorghum (dawa) and millet (jolo) were improved. Torneka *et al*. [5] have reported also that feeding trial revealed that growth performance of broiler birds fed feeds with higher replacement of up to 50% maize with pearl millet was significantly ($p < 0.01$) higher than one without millet. The feed intake was also more for birds fed with higher pearl millet though feed conversion ratio was higher ($p < 0.01$) without pearl millet. The feeding trials of broiler chicken fed with akamu from maize, millet and sorghum respectively containing 10.30, 12.12 and 11.7% protein; 0.24, 1.27 and 0.86% ash; 6.7, 8.31 and7.5% fat; and 70.42, 68.71, and 70.5% carbohydrate at 9.30, 9.00 and 9.62% moisture revealed that (over weeks) the body weight of chickens fed the maize, millet and sorghum akamu, respectively, increased from 43.31 – 397.4 g, 43.81 – 390.57 g, and 43.92 – 394.20 g; feed intake increased from 65.89 – 302.75 g, 63.62 – 307.81 g and 63.74 – 303.36 g; while feed efficiency decreased from 3.38 – 2.09 g, 3.26 – 2.20 g and 3.05 – 2.16 g [2].

The traditional practice in the multigrain akamu processing is to soak/ steep maize grain for 24 h prior to addition of equal measures of millet and sorghum to the process that usually last for 72 h. This work was aimed at producing multigrain akamu this usual way; and blending akamu produced singly from each of the grains. The objective is to evaluate the yield and the physicochemical properties of the akamu powder and its gruel.

Materials and Methods

Raw material acquisition

Maize, pearl millet, and sorghum used for akamu production were purchased from Eke-Awka Market in Awka South Local government Area of Anambra State, Nigeria.

Akamu Production

Single grain akamu were produced from each of the grains – maize, pearl millet and sorghum. One kilogram (I kg) each of maize, pearl millet and sorghum were soaked in twice the amount of water (w/ v). Whereas maize was steeped for

72 h, pearl millet and sorghum were steeped for 48 h prior to wet milling using attrition machine. Half a liter of water was added during milling to aid the milling. The slurry was sieved with another one liter of water added during the sieving to aid starch extraction and sieving through cheese or muslin cloth. The under-water was left (12 h) to sediment before the supernatant was decanted. The paste was scooped into a jute bag and manually dewatered by pressing. The resulting cake was broken into smaller sizes and dried in a laboratory air-oven (12 h) at 50ºC.

Pre-process cereal blended multigrain akamu was produced by steeping 1 kg of maize in 6 L of water for 24 h after which 1 kg each of pearl millet (jolo) and sorghum (dawa) were added and the fermentation allowed to proceed till the 72nd hour. The steeped grains were milled and processed into akamu as described above. For post-processed multigrain blended akamu, akamu were singly produced from equal amounts (500 g) of each of the cereal grains as described above and blended together.

Gruel preparation for sensory analysis

The cereal gruel/ porridge were prepared by reconstituting 20 g of akamu powder in 60 ml of water (32 ± 2ºC). Then 200 ml of boiling water (100ºC) was poured into the slurry to gelatinize it into a semi-solid gruel/ porridge.

Methods of Analysis

Estimation of the yields

The weights of cereal grains used singly or in combination were taken prior to akamu production. The weights of dried akamu produced were also taken after drying and pulverizing the akamu into powder. The yield was expressed as the percentage of the ratio of the weight of akamu produced to the weight of raw cereal used to produce the akamu.

Proximate analysis and energy estimation

Proximate compositions of akamu samples were determined using the standard procedures [6]. Triplicate samples were used for the determinations. Moisture content was determined using air-oven method in a hot-air circulating oven (Galenkamp, England). Ash was determined by incineration at 550ºC of known weights of the samples in a muffle furnace (Hotbox oven, Gallencamp, UK, size 3). Crude fat was determined using Soxhlet extraction by exhaustively extracting a known weight of sample in petroleum ether (boiling point, 40 to 60°C). Protein content was determined using micro-Kjeldahl method (N × 6.25). Crude fiber was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide. **C**arbohydrate content was estimated by difference, that is, addition of all the percentages of moisture, fat, crude protein, ash and crude fibre was subtracted from 100%.

$$\% \text{ carbohydrate} = 100-(\%\text{Moisture} + \%\text{Fat} + \%\text{Ash} + \% \text{ Crude fibre} + \%\text{Crude protein})$$

The energy value of the samples was estimated [in kcal/100g] using Atwater method, that is, by multiplying the percentages of crude protein, crude lipid and carbohydrate by 4.0, 9.0 and 4.0, respectively.

pH determination

Exactly 10% slurry of akamu in distilled water was made, stirred, allowed to stand for 15 minutes and then filtered. The pH of the filtrate was determined by placing the electrode of the pH meter already standardized with buffers 4 and 9 into the filtrate.

Mineral Analyses

The method described by Lawal *et al*. [7] was used for mineral analysis. Two grams (2 g) of sample was digested with concentrated nitric acid and hydrogen peroxide, filtered and the filtrate in a 5 mL volumetric flask was loaded to Atomic Absorption Spectrophotometer, (model 703 Perkin Elmes, Norwalk, CT, USA). Calcium

(Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), sodium (Na), potassium (K) were determined at wavelengths 317.9 nm, 285.2 nm, 259.9 nm, 324.7 nm, and 213.9 nm, respectively.

Sodium [Na] and Potassium [K] were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK), and NaCl and KCl were used as the standards.

Functional properties determinations

Bulk density was determined using a method described by Abbey and Ibeh [8]. Water and oil absorption capacities were determined using a method of Sosulski *et al*. [9]. Emulsion capacity and stability were determined by the method of Yasumatsu *et al*. [10]. Least gelation concentration was determined using the method of Coffman and Garcia [11]. Swelling capacity was determined using a method described by Okaka and Potter [12] with slight modification. Exactly 2 g of akamu powder was weighed into calibrated centrifuge tube. The volume it occupied was recorded as volume before soaking. Then, 10 ml of water was added and the tube tightly covered. The tube was inverted and shaken to mix the content which afterward was left for 30 min before centrifuging at 3000 rpm for 15 min. The volume of the sample occupied after centrifugation was taken and the swelling capacity (SC) calculated as:

$$SC = \frac{\text{volume before soaking – volume after soaking and centrifugation}}{\text{Weight of the sample}}$$

Sensory evaluation

This evaluation was carried out on the gruel using a twenty member panels drawn from the students and staff of Faculty of Agriculture of the Nnamdi Azikiwe University, Awka. The gruels were simultaneously served in white plastic plates of the same features to each panelist who assessed his/ her preference of the sensory properties of colour, flavor, aroma, mouthfeel and overall acceptability. Portable water was provided to the panelists to rinse mouth in-between taste to remove after taste. The evaluation was carried out on a 9-point Hedonic Scale with 1 representing extremely disliked, 5 – neither liked nor disliked and 9-extremely liked. The evaluation was carried out in the Food Processing Laboratory well illumination by sunray between 10.00 hours and 13.00 hours (Nigerian time)

Results and Discussion

Yield of Akamu

The percentage yield of akamu is presented in Table 1 below. The result revealed that pearl millet based akamu (PMBA) gave the highest yield of 80%. This was followed by sorghum based akamu (SBA) (70%) whereas the least yield was observed in maize based akamu (MBA) which gave 60%. This could be a function of size of cereal grain. The grain size of maize was largest with average weight of 250 – 300 mg, followed by sorghum grain with weight range of 20 – 30 mg and pearl millet with least average weight of 8.9 mg [13, 14]. Hence it could be assumed that the larger the size of cereal grain, the lower the yield. Xie and Liang [15] observed in a study on hybride sorghum grain that starch in grain decreased about 4% as kernel weight increased. Gomez *et al*. [16] gave the milling yield of sorghum with kernel weight greater than 2 g as 75% while that of pearl millet of kernel weight greater than 1.1 g was given as 80%. Anatomical fractional composition of the cereal grain may also play a role in the yield of akamu.

Preprocess combination of cereals for akamu production yielded only 53.33% akamu while the post-process combination in multi-cereal grain akamu yielded about the same quantity (68.67%) as the SBA (70%) single grain akamu. This could be attributed to milling efficiency. The differences in grain size of the mixed cereal grain could cause some smaller grains of millet and probably sorghum to escape proper grinding.

Table 1: Percentage yield of akamu

Samples	Quantity of cereals (kg) used			Total weight (kg) of cereal(s) processed	Total weight (kg) of akamu produced	% yield
	Maize	Pearl millet	Sorghum			
MBA	1	0	0	1	0.6	60
PMBA	0	1	0	1	0.8	80
SBA	0	0	1	1	0.7	70
Blend 1	0.5	0.5	0.5	1.5	0.8	53.33
Blend 2	0.5	0.5	0.5	1.5	1.03	68.67

MBA – maize based akamu; PMBA – pearl millet based akamu; SBA – sorghum based akamu; Blend 1 – pre-cereal processed blended akamu; Blend 2 – post-cereal processed blended akamu

Proximate composition and energy content of akamu

The proximate composition and energy value of single grain and multigrain akamu are presented in Table 2. There were significant ($p < 0.05$) difference in the composition of akamu. The result revealed significant ($p < 0.05$) differences in protein and fiber contents of the single grain akamus (MBA, PMBA and SBA). Whereas SBA had highest protein (10.17%) and fiber (8.00%) contents, the PMBA had the lowest protein (7.55%) and MBA the lowest fiber (3.97%) content. The fat (6.27%) and ash (4.67%) of PMBA were significantly higher than those of SBA which were respectively 5.47% and 2.00%. Also, the carbohydrate content of PMBA (69.27%) was significantly higher ($p < 0.05$) than that of MBA (66.20%) and SBA (66.30%). The proximate compositions of single grain akamus were suggestive of the respective nutrient contributions to the multigrain akamu (Blend1 and Blend2). The indication was that SBA significantly ($p < 0.05$) contributed more protein and fiber while PMBA contributed higher amounts of fat, ash and carbohydrate. The proximate composition of akamu may be a function of the cereal grain content, size, soaking/ fermentation time and other physical characteristics of the grain such as pericarp/ bran thickness and hardness and size of germ. Maize with larger grain size is likely to have lower surface area than sorghum and millet with smaller grain sizes. Sorghum has thicker and harder pericarp impermeable to moisture, which could lead to less leaching of nutrients. Maize with lighter pericarp was soaked in water for a longer period (72 h) rather than 48 h for sorghum and millet and could lead to loss of more nutrients through leaching. At the same moisture level (12%), Akanbi *et al*. [2] observed 9.2, 10.4 and 11.8% protein, 4.6, 3.1 and 4.8% fat, 1.2, 1.6 and 2.2% ash, 2.8, 2.0 and 2.3% fiber, and 73.0, 70.0 and 67.0% carbohydrate for maize, sorghum and millet grains, respectively. Also for ogi (akamu) from maize, millet and sorghum with moisture range of 9.00 – 9.62%, Akanbi *et al*. [2] reported 10.30, 12.12 and 11.70% protein; 0.24, 1.27 and 0.86% ash; 6.70, 8.31 and 7.50% fat; and 70.42, 68.71 and 70.50% carbohydrate, respectively, indicating higher protein and lower ash, comparable fat for maize akamu but higher fat for millet and sorghum akamu, and comparable carbohydrate, if fiber is part of the reported carbohydrate, than observed in this work.

Table 2: Proximate composition, calorific and pH values of single and multigrain akamu

Parameters (%)	Akamu samples				
	MBA	**PMBA**	**SBA**	**Blend 1**	**Blend 2**
Moisture	11.0^{a}±0.00	6.13^{d}±0.15	8.03^{c}±0.06	11.33^{a}±0.06	9.27^{b}±0.38
Protein	8.73^{b}±0.03 (9.81)	7.55^{c}±0.31 (8.04)	10.17^{a}±0.06 (11.06)	8.44^{b}±0.21 (9.52)	8.56^{b}±0.29 (9.43)
Fat	6.13^{ab}±0.15 (6.89)	6.27^{a}±0.46 (6.68)	5.47^{bc}±0.42 (5.95)	5.33^{c}±0.58 (6.01)	5.53^{bc}±0.31 (6.10)
Ash	4.00^{a}±0.00 (4.49)	4.67^{a}±0.58 (4.97)	2.00^{b}±0.00 (2.17)	2.67^{b}±1.15 (3.01)	4.27^{a}±0.25 (4.71)
Fiber	3.97^{c}±0.06 (4.46)	6.10^{b}±0.10 (6.50)	8.00^{a}±0.00 (8.70)	6.03^{b}±0.06 (6.80)	6.03^{b}±0.06 (6.65)
Carbohydrate	66.20^{c}±0.10 (74.38)	69.27^{b}±0.47 75.79)	66.30^{c}±0.49 (72.09)	71.20^{a}±0.62 (74.66)	66.67^{c}±0.29 (73.48)
Energy (Kcal)	354.89^{b}	363.31^{a}	355.11^{b}	366.53^{a}	350.69^{c}
pH	5.83^{b}±0.06	6.27^{a}±0.23	6.30^{a}±0.10	5.53^{c}±0.15	6.36^{a}±0.12

Values in parenthesis are in free moisture basis. Values are means of triplicate determinations. Means on the same row with different superscripts are different ($p < 0.05$). MBA – maize based akamu; PMBA – pearl millet based akamu; SBA – sorghum based akamu; Blend 1 – pre-processed cereal blended akamu; Blend 2 – post-processed cereal blended akamu

Comparison of the pre-processed cereal grain blended akamu (Blend1) and post-processed blended akamu (Blend2) revealed that only ash and carbohydrate contents were significantly ($p < 0.05$) affected by the stage of blending of grains/ akamu during multigrain akamu production. Higher ash (4.27%) was obtained by post-process akamu blending (Blend2) whereas higher carbohydrate was observed in pre-process grain blended akamu (Blend1). The ash content of Blend2 multigrain akamu differed significantly ($p < 0.05$) with that of SBA single grain ash content while Blend1 carbohydrate content was significantly ($p < 0.05$) different from that of all the single grain akamu.

Consideration of the calorific content revealed that PMBA had significantly ($p < 0.05$) higher energy than MBA and SBA. The Blend1 calorific content was also significantly ($p < 0.05$) higher than the Blend2 content. This could be attributed to higher carbohydrate content as the differences in fat and protein contents of the multigrain akamu (Blend1 and Blend2) were insignificant ($p > 0.05$).

The pH values of akamu samples ranged from 5.53 to 6.36 (Table 2). The MBA had the lowest pH value (5.83) among the single grain akamu. This is likely due to longer fermentation period of 72 h as against 48 h for PMBA and SBA. However, pre-process combination of cereals during multi-grain akamu (Blend1) production achieved significantly ($p <0.05$) lower pH of 5.53. The post processed multigrain akamu had higher pH (6.36) comparable to that of PMBA and SBA. It worthy to observe that in Blend1 akamu production, maize was ferment for 24 h prior to the addition of sorghum and pearl millet leading to the later cereals encountering greater number of microorganisms for their fermentation.

Selected mineral contents of akamu

Table 3 shows some selected mineral element of akamu. Only calcium and magnesium were the elements that were insignificantly ($p > 0.05$) different among the akamu samples. Iron, zinc, potassium and sodium contents of SBA were significantly ($p < 0.05$) higher than those of MBA and PMBA which in themselves did not differ significantly ($p > 0.05$). This may be indicating that SBA delivers more mineral in the diet than MBA and PMBA. Wide variations exist in reports of various researchers on the mineral contents of akamu/ ogi. Except for zinc, other minerals analyzed for SBA were by far lower than the values reported by Abioye [17] for sorghum akamu/ ogi. In all, Ojo and Enujiugha [18] reported higher of these minerals for maize akamu than observed in this work while Eke-Ejiofor and Beleya [19] reported lower Mg (0.03 mg/100 g) and K (0.02 mg/100 g) but higher Na (11.41 mg/ 100 g) and Fe (10.43 mg 100 g). Akanbi *et al*.[2] (2010) did not determine K and Na but reported higher Fe, Ca, Mg, and Zn for maize, millet and sorghum ogi than observed in this work (Table 3). Only the iron and sodium contents of Blend1 and Blend2 differed significantly ($p < 0.05$) and so may have been affected by stage of blending.

Table 3: Mineral compositions of akamu

Parameters (mg/100g)	Akamu samples					
	MBA	**PMBA**	**SBA**	**Blend 1**	**Blend 2**	**LSD**
Iron	2.23^{b}	2.48^{b}	4.05^{a}	4.61^{a}	2.94^{b}	0.78
Zinc	0.99^{bc}	0.79^{c}	1.47^{a}	1.41^{ab}	1.15^{abc}	0.43
Calcium	26.52^{a}	26.27^{a}	26.67^{a}	27.42^{a}	26.75^{a}	0.86
Potassium	1.39^{b}	0.32^{c}	3.31^{a}	4.32^{a}	4.12^{a}	1.02
Sodium	1.29^{c}	1.23^{c}	3.21^{b}	3.17^{b}	4.33^{a}	0.88
Magnesium	17.35^{a}	17.41^{a}	17.68^{a}	17.74^{a}	17.42^{a}	1.14

Values are means of triplicate determinations. Means on the same row with different superscripts are different ($p < 0.05$). MBA – maize based akamu; PMBA – pearl millet based akamu; SBA – sorghum based akamu; Blend 1 – pre-processed cereal blended akamu; Blend 2 – post-processed cereal blended akamu

Table 4: Functional properties of akamu samples

Parameters	Akamu samples				
	MBA	**PMBA**	**SBA**	**Blend 1**	**Blend 2**
BD(g/cm^3)	0.757^{a}±0.02	0.717^{a}±0.03	0.723^{a}±0.02	0.760^{a}±0.02	0.757^{a}±0.03
WAC (g/g)	2.30^{a}±0.10	1.87^{b}±0.06	2.37^{a}±0.12	2.18^{a}±0.15	2.20^{a}±0.10
OAC (g/g)	2.20^{a}±0.10	2.30^{a}±0.10	2.37^{a}±0.12	2.30^{a}±0.20	2.43^{a}±0.06
EA (%)	44.33^{c}±0.2	47.30^{b}±0.26	50.00^{a}±2.00	51.63^{a}±0.32	47.93^{b}±2.18
ES (%)	77.43^{a}±0.4	55.17^{c}±0.76	76.23^{a}±0.75	69.50^{b}±0.50	76.43^{a}±1.21
SC (ml/g)	1.27^{a}±0.03	1.23^{a}±0.09	0.86^{b}±0.04	0.73^{b}±0.03	0.64^{b}±0.01
LGC (%)	8.0	8.0	6.0	8.0	8.0

Values are means of triplicate determinations. Values with the same superscript within a row are not significantly different (p<0.05). MBA – maize based akamu; PMBA – pearl millet based akamu; SBA – sorghum based akamu; Blend 1 - pre-processed cereal blended akamu; Blend 2 – post-processed cereal blended akamu; BD – bulk density; WAC – water absorption capacity; OAC – oil absorption capacity; EA – emulsion activity; ES – emulsion stability; SC – swelling capacity; LGC – least gelation concentration.

Functional properties of akamu

The functional properties of akamu were presented in Table 4. The differences in the bulk density (BD) and oil absorption capacity (OAC) of the akamu samples were insignificant ($p > 0.05$). The water absorption capacity (WAC) of PMBA (1.87 g/g) was significantly ($p < 0.05$) lower than that of other samples (single and multi grain) which in themselves were not significantly ($p > 0.05$) different. The WAC value of PMBA is comparable to 1.69 ml/g reported for pearl millet flour [20]. WAC is a function of availability of polar binding sites.

The lower BD of PMBA is an indication of greater particle size and consequently smaller surface area than other akamu samples, hence lesser water binding site. The lower BD of PMBA, though insignificantly ($p > 0.05$) different from other akamu samples; and lower ($p < 0.05$) protein content (Table 2) which is also a factor in provision of water binding sites could likely be the cause of lower WAC of PMBA. Protein level influences WAC as high protein level might lead to high hydrogen bonding and high electrostatic repulsion; both conditions facilitating binding and entrapment of water [21]. According to Abdalla *et al*. [22] and Hansen [23], WAC is important in foods system because it is related to other functional properties such as solubility, emulsification, wettability, cohesion and adhesion, dispersibility, viscosity and gelation.

Emulsion activity and stability

Significant difference in emulsion activity (EA) of akamu was observed. Whereas the MBA had the lowest value (44.33%), SDA had the highest value (50.00%). The EA value of Blend1 and Blend2 differed significantly ($p < 0.05$) indicating that the blending stage in multigrain akamu production had effect on the EA. The EA of PMBA significantly compared with Blend2 whereas EA value of SDA compared significantly with that of Blend1. EA reflects the ability of the proteins to aid formation and stabilization of newly created emulsion [24] and may be related to solubility of protein [25]. According to Kaushel *et al*. [26], hydrophobicity of protein has been attributed to their emulsifying properties which are influenced by many factors among which are solubility, pH and concentration [26]. The highest EA of SBA may among other factors be related to higher protein content (Table 2).

Though MBA had the lowest EA, it had the highest emulsion stability (ES) of 77.43%. The ES of PMBA (55.17%) was significantly lower than that of MBA and SBA which in themselves were not significantly ($p > 0.05$) different. The ES of PMBA was significantly lower than that of the multigrain akamu (B1 and B2). The Blend2 akamu with significantly ($p < 0.05$) lower EA (47.93%) than Blend1 (51.63%) had significantly ($p < 0.05$) higher ES (76.43%) than Blend1 (69.50%). The ES seemed to follow the pattern of the amount of protein in the samples as samples with higher protein content had higher ES and sample with the lowest protein content has the lowest ES. The capacity of protein to enhance the formation and stabilization of emulsion is important for many applications in food products [26].

Swelling capacity

The difference in swelling capacity (SC) of MBA and PMBA was not significant ($p > 0.05$) but was significantly higher than the values for SBA and the multigrain akamu (Blend1 and Blend2). SC is a function of the volume increase of product when having interaction with water [27]. It is an indication of the extent of associative forces within flour granules [28, 29]; and also related to the water absorption index (WAI) of starch based flour during heating [26, 28, 30,31]; and depends on the particle size, variety and type of processing or unit operation [26, 30].

Gelation concentration

The least gelation concentration (LGC) of SBA (6%) was lower than other single grain and multigrain akamu which value was 8%. The LGC indicates the gelation capacity; and the lower the LGC, the better the gelling ability of protein [24]. Though, gelation is not only based on protein quantity but appears to be related to the type of protein as well as the non-protein components [24], higher protein content of SBA may have likely contributed to its lower LGC.

Sensory Properties of akamu

Table 5 revealed that the sensory properties of MBA were most preferred to other akamu samples (single or multi grain). The MBA sensory properties did not differ significantly ($p > 0.05$) from those of SBA in colour, flavor, mouthfeel and overall acceptability. PMBA was, however, significantly less preferred than SBA in colour, flavor, aroma and overall acceptability. James *et al*. [32] observed flavor, colour, and overall acceptability scores of millet ogi (akamu) as 8.59, 8.73 and 8.36, respectively, which is higher than 7.50, 7.50 and 7.70 observed by Ojo and Enujiugha [18] in maize ogi. This may be indicating a higher preference of millet ogi to maize ogi which is contrary to the observation in this work. This could be probably caused by the consumption pattern, culture/ custom and feeding behaviour/ characteristic of people. In the Eastern part of Nigeria where this work was carried out, maize akamu is popular unlike the Western and Northern part of Nigeria where millet and sorghum are also well known/ consumed. It is likely that the grey colour of PMBA, which was unappealing, might have influenced scores on other sensory parameters since the colour was not masked. PMBA influenced the preference for the sensory parameters of flavor, mouthfeel, aroma and overall acceptability of multigrain akamu as the values did not significantly ($p > 0.05$) differ.

Table 5: Mean sensory scores of akamu gruels from maize, pearl millet, sorghum and their blends

Parameters	Akamu samples				
	MBA	PMBA	SBA	Blend 1	Blend 2
Flavor	7.73^{a}±1.16	6.33^{c}±0.90	7.13^{ab}±1.13	6.60^{bc}±0.99	6.33^{c}±0.62
Colour	7.80^{a}±0.68	5.53^{c}±0.99	7.27^{a}±0.96	6.47^{b}±1.30	6.27^{b}±1.03
Mouthfeel	7.47^{a}±1.30	6.80^{ab}±0.94	6.80^{ab}±0.84	6.93^{ab}±1.22	6.33^{b}±1.35
Aroma	7.07^{a}±1.62	6.13^{b}±1.06	6.53^{b}±0.99	6.27^{b}±0.88	6.27^{ab}±0.88
Overall acceptability	7.78^{a}±0.92	6.13^{b}±0.99	7.53^{a}±0.83	6.73^{b}±0.79	6.53^{b}±0.90

Values with the same superscript along the row are not significantly different (p>0.05). MBA – maize based akamu; PMBA – pearl millet based akamu; SBA – sorghum based akamu; Blend 1 - pre-processed cereal blended akamu; Blend 2 – post-processed cereal blended akamu

Conclusion

Sorghum gave the highest yield of single grain akamu. The lowest yield was obtained with maize grain. Pre-process combination of cereals (co-fermentation) gave lower yield than post-process combination of akamu in multigrain akamu. The sorghum based akamu had the highest protein, fibre, iron, zinc, potassium and sodium contents. Maize and pearl millet based akamu had higher ash and fat than sorghum based akamu. Stage of blending (pre- and post-) only affected the ash and carbohydrate contents and consequently energy content of multigrain akamu with pre-process blending having less ash and more carbohydrate and energy contents. Sorghum based akamu had highest water absorption capacity, emulsion activity but lower least gelation concentration. Only emulsion properties of multigrain akamu were affected by stage of blending. Maize akamu was preferred in all sensory parameters and most accepted while pearl millet akamu was least preferred among the single grain akamu. Blending decreased the sensory acceptability of maize akamu.

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