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Quality assessment of 'Akamu' powder formulated using Cofermented maize (*Zea mays*) and African breadfruit (*Treculia africana*) powder

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Abstract

This study is aimed at preparing an improved fermented gruel locally known as 'akamu' using cofermented maize and African breadfruit powder in different ratios which include 50:50, 75:25 and 25:75, representing the percentage of maize to breadfruit, respectively. 100% maize-akamu powder is the control. Microbiological, physicochemical, proximate composition and functional properties of the powder was analyzed using Standard methods while sensory evaluation of pap prepared using the powder involved the use of 9 - point Hedonic scale. The total heterotrophic bacterial count (THBC) and total fungal count (TFC) of the samples was within the range 7.97 – 8.26 log_{10}CFU/ml and 6.30 – 7.57 log_{10}CFU/ml, respectively. The moisture, ash, protein, lipid, fibre and carbohydrate content of the samples were within the range 15.06±0.32 - 21.44 ±0.50%, 0.4±0.02 - 0.8±0.03%, 8.4±0.11 - 10.8±0.60%, 1.3±0.04 - 10.3±0.07%, 0.12±0.04 - 0.22±0.04% and 62.43±1.82 - 74.37±2.13%, respectively. The sensory attributes of the pap was disliked slightly or moderately by the panelists. Nevertheless, the inclusion of breadfruit flour during fermentation of maize for the production of akamu powder improved its nutritional quality and functional properties.

Keywords: Malnutrition; Micronutrients; Fermented foods; Legumes; Food fortification; Flour

1. Introduction

Malnutrition in children as a result of deficiency in protein and micronutrients especially in developing countries is a challenge facing many families and the authorities [1]. In these countries, affordable diet locally available for millions of children including weaning foods for infants are rich in carbohydrate, but poor in protein and other vital nutrients needed for growth and development of children. According to Ajanaku *et al*. [2], Nigeria account for 10% maternal mortality globally associated with malnutrition which also include children below five years old. In order to tackle the problem headlong, food fortification has always been a strategy adopted to supply micronutrients originally lacking in foods which could cause malnutrition in children who depend solely on them [3].

A fermented maize product popularly consumed in Nigeria by the Igbos is known as 'akamu' [4]. The product is similar with 'ogi' prepared using maize, millet or sorghum subjected to lactic acid fermentation [5, 6]. Akamu in the form of a wet cake is prepared as a porridge (pap) and consumed by adults as a breakfast meal. In Nigeria, many families prepare pap as a weaning food for infants [6]. Ogi contain proteins, vitamins and minerals in trace amount; carbohydrate in large quantity [7]. During fermentation of akamu which is usually carried out using traditional methods in various homes, a substantial quantity of protein and fibre are lost. Maize subjected to different processing methods lead to loss of micronutrients (K, Fe, Vitamin B complex, among others). Consequently, nutritional quality of akamu (fermented maize product) will be affected [8]. Many researchers have successfully prepared improved akamu by carrying out co-fermentation of maize and legumes such as soybeans, cowpea, among others rich in nutrients [9, 10].

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African breadfruit (*Treculia africana* Decne) tree is among the leguminous crops rich in protein found growing in rural areas where most inhabitants use mainly akamu as a weaning food without adding other food materials to improve its nutritional content [11]. It is naturally found growing in the tropical countries [12]. African breadfruit is a crop popularly consumed by Igbos and other tribes in Southern Nigeria [13, 14]. '*Ukwa*' is the name Igbos call African breadfruit [11]. The seeds of African breadfruit is usually cooked and eaten as porridge; fried or roasted and eaten as a snack [15]. Ojimelukwe and Ugwuona [16] also stated that seeds of African breadfruit is consumed after it has been mixed with cereals (rice, sorghum and maize) or tubers (yams and shredded cassava). It can as well be used to prepare some food products. Maduka *et al.* [17] used African breadfruit seeds instead of soybeans to prepare a tempeh-like product. When African breadfruit seeds are processed into flour, it is used as soup thickener, preparation of cookies, cakes and bread, among other food formulations. Despite its immense potentials, African breadfruit is still regarded as being underutilized [18, 19].

According to Bennett and Isaiah [19], the crude protein, ash, fibre, fat, carbohydrate and moisture content of *Treculia africana* is 4.98%, 1.46%, 12.40%, 5.01%, 1.08%, 75.07%, respectively. The seeds of *T. africana* also contain potassium (587 mg/100 gDM), calcium (165 mg/100 g/DM), magnesium (186 mg/100 gDM), zinc (8.50 mg/100 gDM), iron (1.66 mg/100 g DM), copper (3.67 mg/100 g/DM) [20]. Carotene, ascorbic acid, thiamine, riboflavin and phosphorus are also present in the seeds of African breadfruit [18]. According to Umezurike and Nwabueze [21], management of hyper-lipidemia, diabetes and obesity are health benefits derived from consumption of foods prepared using *Treculia africana* seeds.

Although Oyeyipo *et al*. [10] produced ogi/African breadfruit flour by co-fermenting maize (*Zea mays* L.) and African breadfruit (*Treculia africana*), the functional properties of the product was not reported by the researchers. Therefore, this study is aimed at carrying out microbiological, physicochemical, functional properties, proximate analysis and sensory evaluation of cofermented maize and African breadfruit which was used to prepare maize-breadfruit akamu powder.

2. Material and methods

2.1. Sample collection

Two kilograms (2 Kg) of white variety maize and 2 Kg dehulled African breadfruit seeds were purchased from Rumuokoro market, Rivers state using sterile nylon bags. The materials were transported to Microbiology Laboratory, University of Port Harcourt, Nigeria for preparation of akamu-breadfruit flour and laboratory analysis of the product.

2.2. Preparation of maize-breadfruit akamu powder

The method described by Awoyale *et al.* [22] was adopted in preparing maize-breadfruit akamu powder with slight modification. The maize grains were sorted and washed while African breadfruit seeds were dehulled. Maize and African breadfruit seeds in the ratio 50:50, 75:25; 25:75 were formulated while 100% maize is the control. Figure 1 below shows the flow chart of preparation of maize-breadfruit akamu powder.

2.3. Serial dilution

Aseptically, ten-fold serial dilution of the sample from 10^{-1} to 10^{-5} were carried out. Exactly 1 ml of the sample was diluted with 9 ml of sterile diluent (peptone water broth). Subsequent dilutions were carried out by stepwise transfer of 1 ml solution into test tubes containing 9 ml of sterile diluent using a sterile pipette for each transfer.

2.4. Total heterotrophic bacterial count

The total heterotrophic bacterial count (THBC) in the samples were estimated using pour plate method. Exactly 0.1 ml of dilution 10^{-5} was inoculated onto Nutrient agar (NA) earlier autoclaved at 121°C for 15 minutes at 15 psi. The inoculums was spread immediately using a sterilized glass rod (flame sterilized using 70% ethanol). After spreading the sample on the agar, the glass rod was finally sterilized. The inoculated culture plates were incubated at 37 ℃ for 24 hours. After the incubation period, the number of colonies on the Petri dishes were counted manually. The colonial characteristics of the bacterial growth on the culture media was noted. The formula below was used to calculate the bacterial population in the sample.

$$\text{CFU/ml} = \text{no. of colonies} \frac{1}{dilution\ factor} \text{ x } \frac{1}{volume\ plated}$$

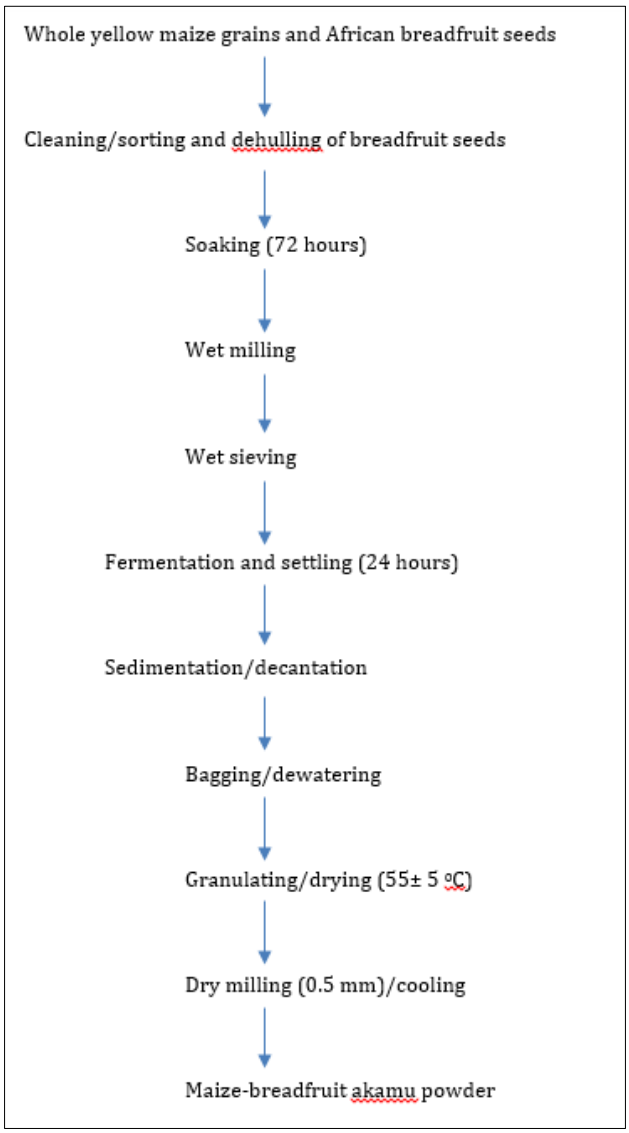


Figure 1 Flow chart for the production of maize-breadfruit akamu powder

2.5. Total fungal count

The total fungal count (TFC) in the samples were also estimated using pour plate method. Exactly 0.1 ml of dilution 10^{-5} was inoculated onto Potato dextrose agar (PDA) earlier autoclaved at 121°C for 15 minutes at 15 psi. A sterilized glass rod was used to spread the inoculum on the medium. Thereafter, the glass rod was finally sterilized and the inoculated plates were incubated at room temperature (28±2°C) for 7 days. The number of colonies on the culture plates were manually counted. The colonial characteristics of the fungal growth on the culture media was noted. The population of microorganisms was calculated using the formula below.

$$\text{CFU/ml} = \text{no. of colonies} \frac{1}{dilution\ factor} \text{ x } \frac{1}{volume\ plated}$$

2.6. Obtaining pure culture

The colonies on the culture plates were subcultured into freshly prepared NA and PDA plates to obtain pure and discrete colonies. Preservation of discrete colonies was done by transferring the isolates into slants and stored at 4 °C for further studies.

2.7. Morphological characteristics of bacterial isolates

The morphological characteristics such as colour, shape, transparency, size and edge of the bacterial colonies in the culture plates were noted.

2.8. Gram staining

Using a sterile wire loop, a colony of the isolate was picked and emulsified in normal saline placed on a clean slide to make a thin smear for Gram staining and allowed to air dry. The smear was heat fixed to prevent the washing off of the organism during Gram staining. The fixed smear was Gram stained for 60 seconds with crystal violet; the stain was washed off under a gentle running tap water. The stained smear was flooded with Lugol's iodine for 60 seconds. Then, the stain was washed off and was decolourized with 70% alcohol for 60 seconds and counter stained with Safranin for 30 seconds. The stain was washed off and the slide was placed in a rack and allowed to air dry. The slide was viewed under oil immersion using the x40 and x100 objective lens of the microscope.

2.9. Biochemical tests

The biochemical tests carried out on the bacterial isolates include motility, catalase, citrate, indole, oxidase, methyl red and triple sugar iron test.

2.10. Physicochemical tests

2.10.1. Titratable acidity

Titratable acidity was determined according to AOAC [23] method. Exactly 10 ml of the sample was diluted in 90 ml of sterile distilled water. The mixture was allowed to settle and from it, 20 ml was titrated against 0.1 ml of NaOH using phenolphthalein as indicator. Three (3) drops of the indicator was added. The appearance of prink red colour is an indication of end point. The titratable acidity was calculated using the formula below:

$$\% \text{ Acid} = [(\text{wt}/(\text{vol}))] = ([N*V1*Eq.wt]/[V2*10])]$$

Where:
N = Normality of titrant (NaoH) (mEq/ml)
V1 = Volume of titrant used (ml)
Eq. wt = Equivalent weight of predominant acid; in this case the predominant acid was lactic acid.
V2 = Volume of sample (ml)
1/10 = Factor relating milligram to gram (100/1000)

2.10.2. Determination of pH

The pH of the samples were determined according to the method of AOAC [24]. Ten grams (10 g) of sample was added to 50 ml of distilled water and stirred for 10 minutes. The pH was measured by dipping the electrode of the pH meter into the mixture. Triplicate measurement was done in all cases. The pH was calibrated using pH 4.0 and 9.0 buffers.

2.11. Determination of functional properties

2.11.1. Swelling index

The swelling index of each sample was determined using the method described by Suresh and Samsher [25]. A graduated cylinder of 100 ml was filled with the sample to the 10 ml mark. A total volume of 50 ml was made by adding distilled water. The top of the cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 minutes and left to stand for a further 8 minutes. The volume occupied by the sample was taken after 8 minutes as the swelling index.

2.11.2. Emulsion capacity

The procedure described by Uzoukwu *et al*. [26] was adopted. Two grams (2 g) of the sample was blended with 25 ml of distilled water at room temperature (28 ±2°C) for 30 seconds in a warring blender at 1,600 rpm. Thereafter, vegetable oil was added and blended for another 30 seconds. The mixture was transferred into a centrifuge tube and centrifuged at 1,600 rpm for 5 minutes. Thereafter, the mixture separated into layers - oil and water were on top and bottom layer, respectively. The distance of separation of the emulsion layer at the middle was measured with a ruler and recorded as the emulsion capacity of the sample.

$$\text{Emulsion Capacity} = \frac{X}{y} \text{ x } \frac{100}{1}$$

Where:
x = Height of emulsion layer
y = Height of whole mixture in centrifuge tube

2.11.3. Oil absorption capacity

As described by Uzoukwu *et al*. [26], the oil absorption capacity (OAC) of the samples were determined. One gram (1g) of sample was weighed into a centrifuge tube; 10 ml of oil was added and mixed thoroughly with a warring mixer for 30 seconds. The sample was allowed to stand for 30 minutes under room temperature (28±2 °C). Thereafter, the sample was centrifuged at 3,500 rpm for 30 minutes. The oil volume (supernatant) after centrifugation was decanted, measured and recorded as the oil absorption capacity. The formula below was used to calculate the OAC.

$$OAC = V_o - V_1$$

Where:
V_o = Initial volume of oil (10 ml)
V_1 = Volume of oil (Supernatant)

2.11.4. Water absorption capacity

The water absorption capacity (WAC) of the sample was determined using the procedure described by Uzoukwu *et al*. [26]. One gram (1g) of sample was weighed into a centrifuge tube; 10 ml of water was added and mixed thoroughly with a warring mixer for 30 seconds. The sample was allowed to stand for a period of 30 minutes at room temperature (28±2 °C). Afterwards, the sample was centrifuged at 3, 500 rpm for 30 minutes. The volume of supernatant (water) after centrifugation was decanted measured and recorded as the WAC. The formula below was used to calculate the WAC.

$$WAC = V_o - V_1$$

Where:
V_o = Initial volume of water (10 ml)
V_1 = Volume of water (supernatant)

2.11.5. Bulk density

The procedure described by Uzoukwu *et al*. [26] was adopted. A graduated cylinder of 10 ml capacity was weighed and recorded. The sample was gently placed in the cylinder to the 10 ml mark. The cylinder was gently tapped on the laboratory bench until there was no further reduction in the level of the sample. The bulk density was measured thus:

$$\text{Bulk density (g/ml)} = \frac{Weight\ of\ sample\ (g)}{Final\ volume\ of\ sample\ after\ tapping}$$

2.11.6. Gelation capacity

The test was performed using the procedure described by Sosulski [27]. Two grams (2 g) of the sample was weighed into a 20 ml test tube. Thereafter, 5 ml of distilled water was added and the mixture was heated for 1 hr in a boiling water bath. The temperature of the tube was cooled under tap water and kept for 2 hours at 10±2 °C. The gel capacity was determined as the concentration of the sample from an inverted tube that did not slip.

2.12. Proximate analysis

2.12.1. Crude fibre

The procedure described by Ilodibia *et al*. [28] was adopted. Exactly 0.5 g of sample was boiled in 150 ml of 1.25% H_2SO_4 solution for 30 minutes under reflux. The boiled sample was washed several times in hot water and the particles were trapped using a two-fold cloth. The same procedure was used for alkali digestion with NaOH. After boiling, it was transferred to a weighed crucible and dried in the oven at 105 °C to a constant weight. After drying, it was the transferred to a muffle furnace where it was burnt to ash. The percentage crude fibre was calculated thus:

$$\text{Crude fibre (\%)} = \frac{W2 - W3}{Weight\ of\ sample} \times 100$$

Where:
W_2 = weight of crucible + sample after washing, boiling and drying
W_3 = weight of crucible + ash

2.12.2. Moisture content

The moisture content of the sample was determined using the gravimetric method described by AOAC [29]. The weight of the sample (0.5 g) was measured into a previously weighed moisture can. The sample inside the can was placed inside an oven at 105℃ and dried for 3 h. Thereafter, it was cooled inside a dessicator and weighed. The sample was returned to the oven for further drying, cooling and weighing. This was done at hourly interval until a constant weight of the sample was obtained. The percentage moisture was expressed as thus:

$$\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

Where:
W_1 = weight of empty moisture can
W_2 = weight of empty can+ sample before drying
W_3 = weight of can + sample dried to constant weight

2.12.3. Total ash

The procedure described by Ilodibia *et al*. [28] was adopted. The weight of empty crucible was taken as W_1. Exactly 0.5 g of sample was measured into a porcelain crucible. The crucible was placed inside a muffle furnace and burnt to ash at 550 ℃. After ashing of sample inside the crucible was completed, it was allowed to cool in a dessicator and weighed as W_2. The total ash content of the sample was calculated using the formula below:

$$\text{Ash (\%)} = \frac{W1 - W2}{Weight\ of\ sample} \times 100$$

Where:
W_1 = weight (g) of empty crucible
W_2 = weight of crucible + ash

2.12.4. Crude fat

Five grams (5 g) of dried sample was placed inside a clean and dry thimble. The thimble was covered with cotton wool at the top and bottom. Then, it was placed in an extraction chamber. The process of extraction lasted for 4 h according to AOAC [23] Official method. The crude fat was calculated using the formula below:

$$\text{Weight of fat (WF)} = W_a - W_b$$

Where:
W_a = weight of extraction flask after extraction
W_b = weight of extraction flask before extraction

2.12.5. Crude protein

The determination of protein content of the samples was carried out using AOAC [23] method. One gram (1g) sample was measured into a digestion flask and 6 ml mixture of acid (concentrated H_2SO_4 and orthophosphuric acid) was added followed by 3 g of catalyst mixture (K_2SO_4 and selenium). The mixture was exposed to about 370 ℃ to allow digestion take place. Distillation was achieved by adding 25 ml of 40% NaOH and 25 ml of boric acid with 10 drops of indicator solution. The distillate was titrated with standardized 0.1N sulphuric acid to a reddish colour. The crude protein was estimated using the formula below:

$$\text{Total nitrogen} = \frac{(V2 - V1)\ x\ N\ x\ 14.007}{W} \times 100$$

Where:

V_2 = volume in ml of standard H_2SO_4 used in the titration for the test material
V_1 = volume in ml of standard H_2SO_4 used in the titration for the blank determination
N = Normality of standard H_2SO_4
W = weight in gram of the test material

Note: Crude protein percentage per weight = total nitrogen = 6.25

2.12.6. Lipid

Lipid extraction from the sample was carried out using the soxhlet extraction method. Two grams (2 g) of the sample was placed in a filter paper. The filter paper containing the sample was placed in a pre-weighed dried distillation flask. Acetone was used as a solvent and was introduced into the distillation flask through the condenser and attached to the soxhlet extractor. The set up was held in place with a retort and clamp. An outlet of cold water was allowed to flow into the condenser and the heated solvent was refluxed as a result. Refluxing continued which resulted in lipid extraction. On completion, the set up was disconnected and the solvent was allowed to evaporate to concentrate the lipid. The flask was dried using air oven to a constant weight which becomes the weight of the lipid.

2.12.7. Total carbohydrate

Total carbohydrate content of the samples was carried out using AOAC [23] method. It involved subtracting the values obtained with regards to lipid, crude protein, crude fat, crude fibre, fat and moisture content of each sample from 100.

Total carbohydrate (%) = 100 – (% moisture + % protein + % fat + % Ash + % fibre)

2.13. Sensory evaluation

Preparation of ogi for sensory evaluation was done using the procedure described by Abioye and Aka [30]. The sensory characteristics of the product was evaluated by 10 panelists. Using 9 point Hedonic scale, the sensory attributes of the samples evaluated include taste, aroma, colour, appearance, mouth feel and general acceptability. According to the 9 point Hedonic scale, the score 9 means extremely like and 1 extremely dislike panel.

2.14. Statistical analysis

Data obtained from the study was analyzed using Two-way Analysis of variance (ANOVA) and significance was accepted at ($p<0.05$). The means were separated using Duncan's multiple range test. The performance of statistical analyses were carried out using SPSS (version 20.0) software.

3. Results

Presented in Table 1 is the total heterotrophic bacterial count (THBC) in maize-breadfruit akamu and maize-akamu powder mixed in different proportions. The values were within the range 7.97 – 8.26 log_{10}CFU/ml. The result of Gram staining and biochemical tests of bacterial isolates from maize akamu and breadfruit-maize akamu powder in different proportions is presented in Table 2. The bacterial isolates encountered in the samples were *Corynebacterium* sp., *Lactobacillus* sp., *Staphylococcus* sp., *Bacillus* sp., *Pseudomonas* sp., *Leuconostoc* sp. and *Escherichia coli.*

Table 1 Total heterotrophic bacterial count of maize-breadfruit akamu powder

Sample	Mean colonies (log_{10}CFU/ml)
AW	7.97
BX	8.13
CY	8.26
DZ	8.06

Key: AW represent 100% maize akamu powder; BX represent 50% breadfruit + 50% maize akamu powder; CY represent 75% breadfruit + 25% maize akamu powder; DZ represent 25% breadfruit + 75% maize akamu powder

Table 3 shows the total fungal count (TFC) in maize-breadfruit akamu and maize-akamu powder mixed in different proportions. The result shows that TFC of the samples were within the range 6.30 - 7.57 log_{10}CFU/ml. Presented in

Table 4 is the cultural and microscopic characteristics of fungi isolated from maize-akamu and maize-breadfruit akamu powder. The fungi isolates identified were *Rhizopus* sp., *Mucor* sp., *Aspergillus caulidatum, Candida nigosa* and *C. krusei.*

Table 2 Gram reaction and biochemical reaction of bacterial isolates from maize akamu and breadfruit-maize akamu powder

Sample code	Gram reaction	Catalase	Oxidase	Indole	MR	Citrate	Motility	TSI			H_2S	Urease	Probable organism
								Slant	Butt	Gas			
A1	+	+	-	-	-	+	-	A	B	-	-	+	*Staphylococcus* sp.
A 2	+	+	-	-	+	+	-	A	A	+	+	-	*Lactobacillus* sp.
A3	+	+	-	-	-	+	-	A	A	+	+	+	*Corynebacterium* sp.
A4	+	-	+	-	+	+	+	A	A	-	-	-	*Clostridium* sp.
B1	-	-	+	+	-	+	+	B	A	-	+	-	*Escherichia coli*
B2	-	+	+	-	-	+	-	A	B	+	+	+	*Pseudomonas* sp.
B3	+	+	-	-	+	+	-	A	B	-	-	-	*Leuconstoc* sp.
B4	+	+	-	-	-	+	-	A	A	+	+	+	*Corynebacterium* sp.
B5	+	+	-	-	+	+	-	A	A	+	+	-	*Lactobacillus* sp.
C1	+	+	-	-	-	+	-	A	B	-	-	+	*Staphylococcus* sp.
C2	+	+	-	-	+	+	-	A	A	+	+	-	*Lactobacillus* sp.
C3	+	+	-	-	+	+	+	B	A	+	+	+	*Bacillus* sp.
C4	+	+	-	-	+	+	-	A	B	-	-	-	*Leuconstoc* sp.
C5	+	+	-	-	+	+	-	A	A	+	+	+	*Lactobacillus* sp.
D1	-	+	+	-	-	+	-	A	B	+	+	+	*Pseudomonas* sp.
D2	+	+	-	-	+	+	-	A	A	+	+	+	*Lactobacillus* sp.
D3	+	+	-	-	+	+	-	A	B	-	-	-	*Leuconostoc* sp.

Key: MR – Methyl red; TSI – Triple sugar iron; A – Acid; B – Base; + represent positive result; - represent negative result

Table 3 Total fungal count of maize-akamu and maize-breadfruit akamu powder

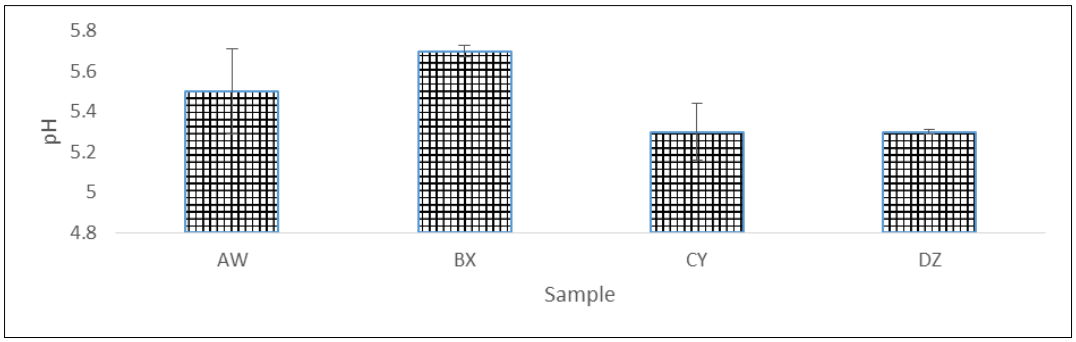
Sample	Mean colonies (log_{10}CFU/ml)
AW	7.57
BX	7.45
CY	6.90
DZ	6.30

Key: AW represent 100% maize akamu powder; BX represent 50% breadfruit + 50% maize akamu powder; CY represent 75% breadfruit + 25% maize akamu powder; DZ represent 25% breadfruit + 75% maize akamu powder

Table 4 Cultural and microscopic characteristics of fungi isolated from maize-akamu and maize- breadfruit akamu powder

Samples	Colonial morphology	Microscopic appearance	Organism
AW	Black surface with velvet whitish surrounding; the reverse is creamy and crack colony	Non-septate, non-branched sporangio-spores, no stolon and rhizoids	*Mucor* sp.
	Surface is light yellowish brown, reverse side is yellowish brown.	Hyphae is septate, the condiospores is smooth and short. Conidia is rough and elongated	*Aspergillus caulidatum*
	White mycelia appear cottony	Non-septate hypha with a large diameter	*Rhizopus* sp.
BX	Surface is light yellowish brown, reverse side is yellowish brown	Hyphae is septate, the condiospores is smooth and short. Conidia is rough and elongated	*Aspergillus caulidatum*
	Black surface with velvet whitish surrounding; the reverse is creamy and crack colony	Non-septate, non-branched sporangio-spores, no stolon and rhizoids	*Mucor* sp.
	White to cream, dry fairly rough colonies	Oval to cylindrical budding mother and daughter cells	*Candida nigosa*
	White mycelia appear cottony	Non-septate hypha with a large diameter	*Rhizopus* sp.
CY	White mycelia appear cottony	Non-septate hypha with a large diameter	*Rhizopus* sp.
	Dry rough creamy colony	Round to oval hypha with candidia	*Candida krusei*
DZ	White to cream, dry fairly rough colonies	Oval to cylindrical budding mother and daughter cells	*Candida nigosa*
	Surface is light yellowish brown, reverse side is yellowish brown.	Hyphae is septate, the condiospores is smooth and short. Conidia is rough and elongated	*Aspergillus caulidatum*
	Dry rough creamy colony.	Round to oval hypha with candidia	*Candida krusei*
	Black surface with velvet whitish surrounding, the reverse is creamy and crack colony.	Non-septate, non-branched sporangio-spores, no stolon and rhizoids	*Mucor* sp.

AW represent 100% maize akamu powder; BX represent 50% breadfruit + 50% maize akamu powder; CY represent 75% breadfruit + 25% maize akamu powder; DZ represent 25% breadfruit + 75% maize akamu powder

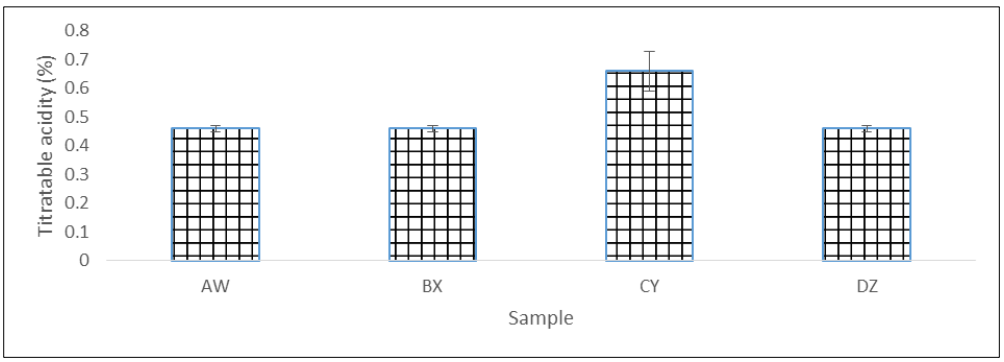


AW represent 100% maize-akamu powder; BX represent 50% breadfruit + 50% maize-akamu powder; CY represent 75% breadfruit + 25% maize-akamu powder; DZ represent 25% breadfruit + 75% maize-akamu powder

Figure 2 pH of maize-akamu and breadfruit-maize akamu powder in different proportions

Presented in Figure 2 is the pH of maize-akamu and breadfruit-maize akamu powder in different proportions. The lowest pH 5.3 was encountered in sample CY and DZ which comprise of breadfruit-maize akamu powder in the ratio 75: 25 and 25: 75, respectively. Breadfruit-maize akamu powder in the ratio 50: 50 had the highest pH 5.7.

Figure 3 shows the titratable acidity (TTA) of maize-akamu and breadfruit-maize akamu powder in different proportions. The results shows that maize-akamu powder and breadfruit-maize akamu in the ratio 50: 50 had the lowest TA (0.46%) whereas the highest TTA (0.66%) involved breadfruit-maize akamu in the ratio 75: 25.



AW represent 100% maize-akamu powder; BX represent 50% breadfruit + 50% maize-akamu powder; CY represent 75% breadfruit + 25% maize-akamu powder; DZ represent 25% breadfruit + 75% maize-akamu powder

Figure 3 Titratable acidity of maize-akamu and breadfruit-maize akamu powder in different proportions

Presented in Table 5 is the proximate composition of maize-akamu and breadfruit-maize akamu powder in different proportions. The moisture, ash, protein, lipid, fibre and carbohydrate content of the samples were within the range 15.06±0.32 - 21.44 ±0.50%, 0.4±0.02 - 0.8±0.03%, 8.4±0.11 - 10.8±0.60%, 1.3±0.04 - 10.3±0.07%, 0.12±0.04 - 0.22±0.04% and 62.43±1.82 - 74.37±2.13%, respectively. For each of the parameters, there is significant difference ($p>0.05$) in the values obtained among the samples.

Table 4 shows the functional properties of maize-akamu and breadfruit-maize akamu powder in different proportions. Bulk density (0.50±0.02 - 0.72±0.03 g/ml), water absorption capacity (93±1.73 - 155±3.61 ml/g), swelling index (10±2.00 - 17±3.61 ml), oil absorption capacity (112±2.00 - 184±1.97 ml) and emulsion capacity (35.5±0.67 - 42.9±0.40) were reported in the samples. There is significant difference ($p>0.05$) in the values obtained among the samples for each of the proximate parameters.

Table 5 Proximate composition of maize-akamu and breadfruit-maize akamu powder in different proportions

Sample	Moisture (%)	Ash (%)	Protein (%)	Lipid (%)	Fibre (%)	Carbohydrate (%)
AW (100%)	15.29±0.43^{a}	0.4±0.02^{a}	8.4±0.11^{a}	1.4±0.04^{a}	0.14±0.02^{a}	74.37±2.13^{c}
BX (50: 50)	21.44±0.50^{b}	0.8±0.03^{c}	9.7±0.07^{b}	1.3±0.04^{a}	0.17±0.03^{ab}	66.59±1.22^{b}
CY (75: 25%)	15.06±0.32^{a}	0.8±0.02^{c}	10.0±0.04^{b}	3.5±0.09^{b}	0.12±0.04^{a}	70.51±1.81^{b}
DZ (25: 75%)	15.65±0.68^{a}	0.6±0.04^{b}	10.8±0.60^{c}	10.3±0.07^{c}	0.22±0.04^{b}	62.43±1.82^{a}

AW represent 100% maize-akamu powder; BX represent 50% breadfruit + 50% maize-akamu powder; CY represent 75% breadfruit + 25% maize-akamu powder; DZ represent 25% breadfruit + 75% maize-akamu powder. Values show means of triplicate analysis ±SD. Values with different superscript down the column are significantly different (P = 0.05).

Table 6 Functional properties of maize-akamu and breadfruit-maize akamu powder in different proportions

Sample	BK (g/ml)	WAC (ml/g)	SI (ml)	OAC (ml)	EC (%)
AW (100%)	0.50±0.02^{a}	143±2.65^{c}	11±2.65^{a}	133±6.24^{b}	35.5±0.67^{a}
BX (50: 50)	0.53±0.03^{a}	93±1.73^{a}	13±2.65^{ab}	112±2.00^{a}	40.2±0.77^{b}
CY (75: 25%)	0.62±0.03^{b}	125±7.94^{b}	10±2.00^{a}	134±4.36^{b}	40.6±0.78^{b}
DZ (25: 75%)	0.72±0.03^{c}	155±3.61^{d}	17±3.61^{b}	184±9.17^{c}	42.9±0.40^{c}

Key: BK- Bulk density; WAC - Water absorption capacity; SI –Swelling index; OAC - Oil absorption capacity; EC - Emulsion capacity**;** AW represent 100% maize-akamu powder; BX represent 50% breadfruit + 50% maize-akamu powder; CY represent 75% breadfruit + 25% maize-akamu powder; DZ represent 25% breadfruit + 75% maize-akamu powder. Values show means of triplicate analysis ±SD. Values with different superscript down the column are significantly different (P = 0.05).

Table 7 Sensory result of maize-akamu and breadfruit-maize akamu powder in different proportions

Sample	Taste	Aroma	Mouth feel	Appearance	Colour	Overall acceptability
AW	3.9 ± 0.57^{a}	4.5 ± 0.85^{b}	3.8 ± 0.79^{a}	4.4 ± 0.52^{a}	3.9 ± 0.57^{a}	3.9 ± 0.74^{ab}
BX	4.8 ± 0.79^{b}	3.2 ± 0.42^{a}	3.7 ± 0.82^{a}	3.9 ± 0.74^{a}	4.2 ± 0.63^{a}	3.6 ± 0.70^{a}
CY	3.8 ± 0.63^{a}	4.1 ± 0.74^{b}	4.3 ± 0.48^{a}	4.0 ± 0.67^{a}	4.1 ± 0.57^{a}	3.9 ± 0.74^{ab}
DZ	4.0 ± 0.82^{a}	4.2 ± 0.79^{b}	3.9 ± 0.74^{a}	4.3 ± 0.67^{a}	4.1 ± 0.88^{a}	4.3 ± 0.48^{b}

AW represent 100% maize-akamu powder; BX represent 50% breadfruit + 50% maize-akamu powder; CY represent 75% breadfruit + 25% maize-akamu powder; DZ represent 25% breadfruit + 75% maize-akamu powder. Values show means of sensory score for each attribute reported by ten panelists ±SD. 9-Like extremely, 8-Like very much, 7-Like moderately, 6-Like slightly, 5-Neither liked or disliked, 4-Disliked slightly, 3-Disliked moderately, 2-Disliked very much, Disliked extremely. Values with different superscript down the column are significantly different (P = 0.05).

Table 7 shows the result of sensory evaluation of maize-akamu and breadfruit-maize akamu powder in different proportions. The panelists reported that no significant difference (p>0.05) exist in the appearance, colour, and mouth feel of all the samples. On the contrary, there was significant difference in taste, aroma and overall acceptability among the samples. The overall sensory report revealed that the most preferred sample was coded DZ (25% breadfruit + 75% maize-akamu powder).

4. Discussion

The total heterotrophic bacterial count (THBC) and total fungal count (TFC) of maize-akamu and breadfruit-maize akamu powder mixed in different proportions were within the range 7.97 - 8.26 $\log_{10}$CFU/ml and 6.30 - 7.57 $\log_{10}$CFU/ml, respectively. In a related study, Oyeyipo *et al.* [10] reported that THBC of maize and breadfruit-ogi during primary and secondary fermentation is within the range 9.28 - 9.63 $\log_{10}$CFU/ml and 6.23 - 6.58 $\log_{10}$CFU/ml, respectively. They also reported that total fungal count (TFC) of the samples were within the range 1.23 - 2.18 and 1.78 - 2.53 $\log_{10}$CFU/ml. The dominance of bacterial population in the samples compared with fungi is in agreement with the report of Ahaotu *et al.* [31].

The bacterial isolates encountered in powdered maize-akamu and powdered maize-akamu fortified with breadfruit powder in different proportions include *Corynebacterium* sp., *Lactobacillus* sp., *Staphylococcus* sp., *Bacillus* sp., *Pseudomonas* sp., *Leuconostoc* sp. and *Escherichia coli.* Some of these bacterial isolates were reported by Oyeyipo *et al.* [10] and Ahaotu *et al*. [31] from related studies. Unhygienic conditions during preparation of akamu commonly carried out using traditional processing methods is one of the possible sources of undesirable bacterial species found in the product [32]. *Rhizopus* sp., *Mucor* sp., *Aspergillus caulidatum, Candida nigosa* and *Candida krusei* were the fungal isolates encountered in the samples. According to Nwokoro and Chukwu [5], these molds are associated with fermentation of maize involved in the production of ogi.

The results obtained in this study show that pH of maize-akamu powder fortified with different proportions of African breadfruit within the range 5.3 - 5.7 was lower than the value reported in 100% maize-akamu powder (pH 5.5) with the exception of the sample which comprise of 50% maize-akamu and 50% breadfruit powder. Oyeyipo *et al.* [10] attributed the reduction in pH to availability of more nutrients for microorganisms to breakdown as a result of adding breadfruit

powder to maize-akamu powder. The presence of lactic acid bacteria (LAB) in the product could also contribute to low pH values reported. According to Adebolu *et al.* [33], the relationship between pH and titratable acidity (TTA) is such that reduction in pH due to the presence of organic acids, e. g lactic acid, resulted in the increase of TTA. The TTA of 75% breadfruit + 25% maize akamu powder was 0.66% while the value reported for other samples was 0.46%.

The ash and protein content of all the samples was within the range 0.4±0.02 - 0.8±0.03 and 8.4±0.11 - 10.8±0.60%, respectively. It was observed that ash and protein content of maize-akamu powder increased with the addition of breadfruit powder. A similar result was observed with regards to moisture (15.06±0.32 - 21.44±0.50%), lipid (1.3±0.04 - 10.3±0.07%) and fibre (0.12±0.04 - 0.22±0.04%) content of the samples with few exceptions. Notably, the carbohydrate content of maize-akamu powder (74.37±2.13%) was higher than the values reported in breadfruit-maize-akamu powder which was within the range 62.43±1.82 - 70.51±1.81%. This could be attributed to the fact that maize-akamu is richer in carbohydrate content than African breadfruit. Aminigo and Akingbala [34] reported that carbohydrate content of raw maize and maize-ogi obtained from the market is 81.6 and 91.3%, respectively. In a separate study, Bennett and Isaiah [19] reported that carbohydrate content of *Treculia africana* seeds is 1.08%. Therefore, a combination of breadfruit powder and maize-akamu powder could have contributed in reducing the carbohydrate content of the final product. The protein and carbohydrate content of maize-akamu is in agreement with research findings by Abioye and Aka [30]. Similarly, the ash and crude fibre of maize-akamu flour reported by Inyang and Effiong [35] is in agreement with our results.

The bulk density of 100% maize-akamu (0.50 g/ml) increased with the addition of breadfruit flour. Our results showed that bulk density of the samples was within the range 0.53 - 0.72 g/ml. A study carried out by Bolaji *et al*. [36] reported that bulk density of ogi prepared using different varieties of maize, subjected to different drying temperature and soaking time is within the range 0.625 - 0.678 g/ml. Going by the results obtained in this study, the addition of breadfruit powder to maize-akamu had little effect on its bulk density. According to Adisa and Enujiugha [32], it is necessary for ogi to have a high bulk density in order to reduce the thickness of paste and make it suitable for children to consume. Furthermore, a weaning food ought to be a high energy density food which has a low water absorption capacity and bulk density [37a].

According to Inyang and Effiong [35], the consistency of food sample is largely influenced by water absorption capacity (WAC) and swelling capacities (SC). A measure of the ability of starch to take in water and swell is referred as swelling capacity. The swelling index of flour sample is an indication of the extent at which associative forces operate within the granules [37a]. The result obtained from this study showed that addition of African breadfruit to maize-akamu influenced its swelling index (SI) which increased in value. This could be attributed to higher amount of protein content in breadfruit-maize akamu compared with maize-akamu [37b]. The SI of 100% maize-akamu was 11 ±2.65 ml while the values reported in maize-akamu powder fortified with breadfruit powder was within the range 10±2.00 - 17±3.61 ml.

The water absorption capacity (WAC) of maize-akamu fortified with different proportions of African breadfruit was within the range 93±1.73 - 155±3.61 ml/g. Meanwhile, the result reported in 100% maize-akamu powder was 143±2.65 ml/g. It is suggested that flour samples that have low WAC contain more nutrients compared with the samples that have high WAC. The result obtained from this study showed that WAC of maize-akamu decreased when 50 % breadfruit flour was incorporated into it. As a result of low WAC, the gruel prepared using maize-akamu powder fortified with African breadfruit in the ratio 50: 50 could become thinner compared with others; possess a high calorific density per unit volume and suitable to be used as a weaning food [37a]. A successful incorporation of protein into aqueous food formulations is indicated by water absorption capacity of the improved food product [32].

Our results showed that oil absorption capacity of maize-akamu fortified with different proportions of African breadfruit including 100% maize-akamu powder was within the range 112±2.00 - 184±1.97 ml. Baadifu *et al.* [39] reported that oil absorption capacity (OAC) of African breadfruit seed subjected to varying parboiling time is within the range 99.0 ±0.30 - 134.0 ± 0.01% whereas Jude-Ojei *et al.* [37b] reported that OAC of maize-ogi powder is 185.00%. Since the flavour of food characterized by mouth feel is influenced by fat content, the parameter referred as oil absorption capacity (OAC) is taken into consideration in product development. Through capillary attraction, protein content in the 100% maize-akamu powder and maize-akamu cofermented with African breadfruit in different proportions binds to fat and influences the OAC by exposing as many non-polar amino acids as possible to fat. Due to hydrophobicity, the flour sample will absorb increased quantity of oil.

The emulsion capacity (EC) of maize-akamu fortified with different proportions of African breadfruit including 100% maize-akamu powder was within the range 35.5±0.67 - 42.9±0.40. The result shows that EC of maize-akamu powder

increased with the addition of breadfruit powder. Jude-Ojei *et al*. [37b] reported that EC of maize-ogi is 21.76% which increased with the addition of moringa flour. It is in agreement with the findings from this study.

The sensory report revealed that mouthfeel, appearance and colour of the samples were not significantly different. The implication is that addition of breadfruit powder had a minimal effect on these sensory attributes of maize-akamu powder. On the contrary, the sensory score for overall acceptability, taste and aroma of the samples were significantly different with few exceptions. It is surprising that the sensory panelists disliked slightly or disliked moderately the sensory attributes of the samples. In a related study involving cofermentation of breadfruit and maize for the production of improved pap, Oyeyipo *et al*. [10] reported higher sensory scores compared with the result obtained in this study. The rating of the sensory panelists include: like very much, like moderately and like slightly.

5. Conclusion

Cofermented breadfruit and maize-akamu powder prepared in different proportions including the control (maize-ogi powder) were contaminated with microorganisms. The bacteria identified in the samples include *Corynebacterium* sp., *Lactobacillus* sp., *Staphylococcus* sp., *Bacillus* sp., *Pseudomonas* sp., *Leuconostoc* sp. and *Escherichia coli* while the fungi were *Rhizopus* sp., *Mucor* sp., *Aspergillus caulidatum, Candida nigosa* and *C. krusei.* The protein, lipid and ash content of maize-ogi powder increased as the proportion of breadfruit powder added to it increased. On the contrary, the carbohydrate content of maize-akamu powder reduced as the proportion of breadfruit included in the powder increased. The functional properties of maize-akamu powder was influenced by the inclusion of breadfruit powder. In terms of sensory attributes, pap prepared using 25% breadfruit + 75% maize-akamu powder was the most preferred product.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that no competing interests exist.

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