

Correlation of Different Processing Techniques with Nutritional and Functional Properties of Soy-akamu Prepared with Yellow Maize, Sprouted and Un-sprouted Soybean

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ABSTRACT: *Akamu* or *ogi* is a commonly relished gruel when prepared with hot water by the sick, recovering patients and infants in Nigeria. It is nutritionally deficient due to inevitable processing losses which called for fortification with soybean (soy-akamu or soy-ogi). Soy-akamu was prepared from steeped yellow maize, sprouted and un-sprouted soybean cotyledons using different processing techniques. Proximate, micronutrients and functional properties were evaluated with standard analytical methods. The results showed that proximate composition of soy-akamu produced from dried steeped maize and sprouted soybean cotyledons had higher protein (63.20%), fibre (0.33%), ash (1.11%), energy (384.28 Kcal) and least moisture content (4.53%). The paste samples had respective proximate values of 0.77, 3.06%; 0.00, 0.00%; 0.71, 1.02%; 29.86, 33.03%; 143.50, 145.37 mg/100g, and 64 and 36-64-76%. Dried soy-akamu also had the highest calcium (41.18, iron (0.99), phosphorous (0.27), zinc (48.02), potassium (0.45), vitamin C (24.60) and least in magnesium (0.07 mg/100g) content. The paste samples had respective values of 40.13, 41.14; 0.86, 0.92; 0.39, 0.41; 0.39, 0.41; 20.46, 23.65 mg/100g with respective magnesium (0.10-0.12) and phosphorous (0.25, 2.21 mg/100g) contents. Different processing techniques had significant ($p < 0.05$) variations in proximate, micronutrient and functional properties of the soy-akamu. Drying technique could be adopted for the production of nutrient dense and shelf stable soy-akamu powder for children, adults and recuperating patients.

Keywords: *Processing techniques soy-akamu; sprouted soybean; yellow-maize*

INTRODUCTION

Akamu or *ogi* is a fermented cereal gruel made from either maize (*Zeamays*) or sorghum (*Sorghum vulgare*) also known as guinea corn or millet (*Pennisetum tyopideum*). When prepared with hot water, it is characterized by smooth textured gruel with slight sour taste and semi-liquid consistency (Ladunni *et al.*, 2013; Okwunodulu *et al.*, 2019). The gruel is a popular common staple food in Nigeria and most West African countries used it mainly as a special transitional infant food and also cherished by adults and recovering patients (Adelekan and Oyewole, 2010; Okwunodulu *et al.*, 2019). *Akamu* is nutrient deficient (Okwunodulu *et al.*, 2020a) and fortification or formulation with soybeans as soy-akamu had been generally adopted. Other methods of improvement have been recognized (Adelekan and Oyewole, 2010).

Akamu is popularly prepared traditionally by 72 h steeping of corn in tap water followed by wet milling and sieving to remove bran, hulls and germs (Okwunodulu *et al.*, 2019). The starchy sediment is dewatered to obtain semisolid *akamu* (Ijabadeniyi and Adebolu, 2005). This preparation technique involves inevitable protein, vitamins and mineral losses (WHO/FAO, 2006) that affect the nutritional quality and in turn affects growth (Akanbi *et al.*, 2003). Protein deficiency results in kwashiorkor among infants exclusively fed with *akamu* over time (Nnam, 2000). Several efforts have been made to modify the preparation technique to enhance the nutritive value, shelf life and possibly the therapeutic properties of *akamu* (Ogbonna *et al.*, 2013; Ogodu *et al.*, 2015). Formulation among others with animal or plant protein sources like soybean (Okwunodulu *et al.*, 2019; Okwunodulu *et al.*, 2020a) and orange-fleshed sweet potato

(OFSP) with African yam bean seed flours (Ukom *et al.*, 2019) had been recognized. Also, fortification with vitamins and minerals (Jude-Ojei *et al.*, 2017) and fermented cereal have been employed to preserve, impart aroma and had resulted in novelty foods products with improved nutrients for complimentary feeding (Ijabadeniyi, 2004; Omemu *et al.*, 2007). Formulation with sprouted soybean results in soy-akamu with improved nutrients due to restoration of inevitable nutrient lost during preparation to prevent hidden hunger.

Maize (*Zeamays*) is a widely consumed cereal grain with high carbohydrate content but lacks essential micronutrients such as B-carotene. New varieties of maize like yellow maize rich in B-carotene have been developed in Nigeria to alleviate the problem of vitamin A deficiency (Uchendu, 2013). Maize protein is deficient in lysine and tryptophan but has fair amounts of sulphur-containing amino acids (Bello-Perez *et al.*, 2003). Maize provides many of the B vitamins and essential minerals along with fiber, but lacks vitamin B₁₂, vitamin C and is poor sources of calcium, folate, tryptophan, a niacin precursor, and iron. Maize also contains about 72% starch, 10% protein, and 4% fat which supply an energy density of 365 Kcal/100g.

Soybean (*Glycine max*) contains high quantity of protein with amino acid composition comparable to animal proteins and therefore often used as replacement component of meat protein. Soybean contains considerable quantities of lysine, but limited in methionine and cystine (Hany, 2011). Absence of cholesterol, lactose and presence of essential amino acids makes soybean vital for infant growth and maintenance.

Soybean sprouting improves the nutritive value, reduces anti-nutrients and flatulence causing oligosaccharides (stachyose and raffinose), thereby increasing protein digestibility, bioavailability and sensory properties (Iwe, 2003). This study therefore aimed at exploring the effects of different processing techniques on the proximate and some micronutrient content of soy-akamu.

MATERIALS AND METHODS

Materials

Yellow maize and soybean used in this study were purchased from Orié Ugba market in Umuahia, Abia State, Nigeria.

Preparation of dried soy-akamu powder (DSAP) from steeped yellow maize and sprouted soybean flours

Yellow maize seeds (YMS) were sorted, washed, drained to remove dirt and steeped for 72 h with constant changing of water at every 24 h. The steeped YMS was drained, washed to remove any unwanted odour, oven-dried at 65 °C to constant weight, milled and sieved to obtain the flour. Soybean cotyledons were produced according to Okwunodulu *et al.*, (2017) by steeping (12 h) sorted soybeans, sprouted (72 h) on jute sac spread on the flour, hand dehulled to obtain soybean cotyledons. The cotyledons were oven-dried at 65 °C to constant weight, milled and sieved to obtain the powder. The DSAP was formulated by blending both powders according to proportion (70% maize: 30% soybean), packaged in air tight container and stored for analysis.

Preparation of soy-akamu paste from steeped yellow maize and sprouted soybean cotyledons

Both steeped maize and soybean cotyledons were obtained as described before, blended (70:30) and wet milled together. Sprouting predigests the soybean for better bioavailability of the nutrients unlike un-sprouted. The paste obtained was sieved, allowed to sediment (24 h) and the supernatant water was decanted. The starch sediment was dewatered with double layered cloth to obtain the semi-solid soy-akamu paste. The paste was stored in the refrigerator for analyses.

Preparation of soy-akamu paste from steeped yellow maize and un-sprouted soybean cotyledons

The above process was repeated with steeped yellow maize and soybean cotyledons to produce soy-akamu using the same blending proportion (70:30) paste except that soybean used was not sprouted. The paste obtained was stored in refrigerator for analysis.

Proximate Composition

Moisture Content:

This was determined gravimetrically according to AOAC (2010) protocol. The samples (5 g) were each weighed separately into weighed dishes, oven dried (105 °C) to constant weight and final weights of the samples were taken. The moisture content (MC) was calculated by weight difference as expressed:

$$\%MC = \frac{W3 - W2}{W1} \times 100$$

Where: W1=weight of sample W2 =weight of empty can, W3=weight of dried sample + can.

Protein

The micro-kjeldahl method described by James (1995) was used. Two grams (2g) of each sample were separately digested by mixing with 10 ml of concentrated tetraoxosulphate (VI) acid in kjeldahl digestion flask and selenium catalyst added. The mixture was heated to digest, transferred into a 100 ml volumetric flask and made up with distilled water. Exactly 10 ml of the digest was mixed with equal volume of 45% sodium hydroxide (NaOH) solution and distilled in the kjeldahl apparatus. The distillate was collected into a 4% boric acid solution containing 3 drops of zuazaga indicator (mixture of methyl red and bromacresol green), to obtain a total of 50 ml distillate. The distillate was titrated again 0.02N tetraoxosulphate VI acid (H₂SO₄) solution to a deep red or pink end point. Total nitrogen was calculated and multiplied with the factor 6.25 to obtain the crude protein content.

$$\% \text{ Crude Protein} = \%N \times 6.25$$

$$\%N = \left\{ \frac{100 \times N \times Vf \times T}{W \times 1000 \times VA} \right\}$$

W= Weight of sample

N= Normality of the filtrate (H₂SO₄) = 0,02N

Vf= Total volume of the digest = 100 mL

VA = Titer volume

Fibre

Fibre content was determined according to Onwuka (2018) protocol. Two grams (2g) of each sample were separately defatted with petroleum ether and boiled under reflux for 30 min with 200 ml of a solution (1.25g of H₂SO₄ per 100 ml). The solution was filtered through linen or several layers of cheese cloth on a fluted funnel and washed with boiling water until it is no longer acidic. The residue was transfer to a beaker and boil for 30 min with 200 ml of a solution containing 1.25g of carbonate free NaOH per 100ml. The final residue was filtered through a thin but close pad and weighed. The weighed sample was incinerated, cooled and weighed. The fibre content was calculated thus:

$$\text{Crude fiber (\%)} = \frac{\text{Loss in weight after incineration}}{\text{Weight before incineration}} \times 100$$

Ash

The ash content of the sample was determined by gravimetric method described by (AOAC, 2010). The incinerated samples were each weighed into already cleaned and weighed crucibles and dry ashed for 6 h in the muffle furnace into greyish coloured ash. The weight of the dry as was taken and the percent ash content of each sample was calculated as:

$$\% \text{ Ash} = \frac{W3 - W2}{W1} \times \frac{100}{1}$$

Where: W1 = weight of sampel

W2 = Weight of empty crucible

W3 = Weight of crucible + ash

Carbohydrate

The carbohydrate content of the sample was determined by the arithmetic difference method of James (1995) as shown:

$$\% \text{ CHO} = 100 - \% (a + b + c + d + e)$$

Where:

a = protein content; b = fat content; c = ash content

d = crude fibre content; e = moisture content

Energy Values

Energy values of the samples were determined by calculating and summing the energy contents of all their individual energy substrates (Mullan, 2006). Only 97% of carbohydrate energy (Kcal/100g), 95% of fat energy (37 Kcal/100g), 92% of protein energy (17 Kcal/100g) and 1.35 Kcal of fibre energy values were calculated and summed up.

Mineral Composition

Calcium

Calcium content of the samples extract was determined using Versanate EDTA complexometric titration of Carpenter and Hendricks (2003). Twenty milliliter (20ml) of each sample was dispersed into two different conical flasks and pinch doses of the masking agents (potassium cyanide, potassium ferrocyanide, hydroxylamine hydrochloride) were added into them. Calcium was determinate by adjusting the pH to 12 with 10% NaOH solution and then titrated with 0.02N EDTA using seleochrome dark blue (calcon) as an indicator in place of Eric Rome black. A reagent blank was titrated to serve as control. The experiment was repeated two more times. Calcium content of the samples was calculated separately using the formula.

$$\% \text{ Calcium} = \frac{100}{W} \times EW \times N \times \frac{Vf}{Va} \times T - B$$

Where:

W= weight of sample analyzed

EW= equivalent weight

N= normality of EDTA

Vf= total volume of extract

Va= volume of extract titrated

T= titre value of the sample

B= titre value of blank.

Pottassium

Flame photometry method described by Carpenter and Hendricks, (2003) was used to determine the concentrations of potassium in the samples. According to manufacturer’s instruction, Digital Flame Photometer ME- 881 used was switched on for 10 min thereafter, gas and air inlet were opened. The equipment was ignited and the flame adjusted to a non-luminous flame (blue). Appropriate potassium filter was chosen and its standard solutions was prepared and diluted to concentrations of 2,4,6,8 and 10 ppm separately. The 10 ppm concentration was first aspirated and its emission intensity adjusted to a hundred units. Similarly, the rest were aspirated starting with the least concentration (2 ppm). Standard solutions of potassium was caused to spread over the non-luminous butane gas flame and their emission intensities recorded. The emission intensities of the standards were plotted against their concentrations to obtain a standard curve (calibration graph) for each element. The optical density emissions recorded from each of the samples were matched with the curve to obtain by extrapolation the quantity of potassium ion in each sample. The experiment was repeated two more times and their mean concentrations were used for potassium calculation as shown:

$$K(\text{mg}/100\text{g}) \text{ or } Na(\text{mg}/100\text{g}) = \frac{100}{W} \times \frac{I}{1000} \times X \times \frac{Vf}{Va} \times D$$

Where:

W= weight of sample used,

X= concentration (in ppm) from curve

Vf= total volume of the extract (digest) flamed

D= dilution factor where applicable.

Zinc

Zinc content was determined using atomic absorption spectrophotometer (Buck scientific 205 atomic absorption spectrophotometer) method of. AOAC (2010), Sample digest from both ashes were aspirated into the atomic absorption spectrophotometer at different wave lengths during which they were converted into a free atom vapour. A monochromatic zinc source was directed through the flame and the amount of radiation of a specific energy absorbed by the solution was recorded. A calibration graph was prepared and used to determine the amount of zinc in each sample. Zinc content of the sample was calculated as shown:

$$Zn(\text{mg}/100\text{g}) = \frac{100}{W} \times \frac{X}{100} \times D$$

Where:

W= Weight of the sample analyzed

X= Equivalent concentration (ppm) derived from the standard curve

D= Dilution factor.

Phosphorous

Phosphorous in the sample digest was determined by the vanadomohybdate (yellow) spectrometry method of James (1995). Jenway electronic spectrophotometer was used at a wavelength of 420 nm for the absorbance of the samples and blank at zero. Percent phosphorous content (g) for the samples were calculated:

$$\frac{g}{100g} = \frac{100}{W} \times \frac{Au}{Ax} \times \frac{Vf}{Va}$$

Where:

W= weight of sample analyzed

Au= absorbance of test sample

As= absorbance of standard solution

Vf= total volume of filtrate

Va= Volume of filtrate analyzed.

Iron

Method of Onwuka (2018) was adopted. One gram (1g) of the sample was digested in a digestion flask with 20ml of acid mixture of 650ml concentrated HNO₃ and 20ml H₂SO₄, and 90ml PAC. The mixture was heated until a clear digest was obtained and then diluted with distilled water to 500ml. An aliquot of 20ml was subjected to AAS analysis at 248.3nm [30]. A stock solution containing 1000mg/ml of Fe³⁺ ion was prepared by dissolving 1.0g of pure iron wire in 100ml concentrated HNO₃, boiled in water bath and diluted to 1000ml with distilled water. Standard solutions with concentrations 0.0, 0.5, 1.0, 2.0 and 4.0 ppm were prepared and used to plot a calibration graph with which to extrapolate for iron content of the samples.

Magnesium

Magnesium contents of the sample extracts were determined using Versanate EDTA complexiometric titration described by Onwuka (2018). A 20 ml of each extract was dispersed into two different conical flasks and pinch doses of the masking agents (potassium cyanide, potassium ferocyanide, hydroxylamine hydrochloride) where added into them

separately. The pH of the solution was adjusted to 10 with 20 ml of ammonia buffer, a pinch of the indicator Eric Rome black was added and the mixture was shaken very well and titrated against 0.02N EDTA solution, until the color changed from mauve to a permanent deep blue color. Magnesium content was determined as shown:

$$\% \text{ Magnesium} = \frac{100}{W} \times EW \times N \times \frac{V_f}{V_a} \times T - B$$

Where:

W = weight of sample analyzed

EW = equivalent weight

N = normality of EDTA

V_f = total volume of extract

V_a = volume of extract titrated

T = titre value of the sample

B = titre value of blank.

Vitamin

The method used was described by Okwu and Josiah (2006). Ten grams (10 g) of each sample was extracted with 50 ml EDTA/ TCA extracting solution for 1 h and filtered through Whatman filter paper into a 50 ml volumetric flask and made up to the mark with the extracting solution. 20 ml of the extract was pipette into a 250 ml conical flask, 10 ml of 30% KI and 50 ml of distilled water were added. This is followed by 2 ml of 1% starch indicator and titrated against 0.0 ml CuSO₄ solution to a dark endpoint. The vitamin C content of the samples was calculated as shown:

$$\text{Vitamin C (mg/100g)} = 0,88 \times \frac{100}{10} \times \frac{V_f}{20} \times \frac{T}{1}$$

Where:

v_f = Volume of extract

T = Sample titre – blank titre.

Functional Properties

Water absorption capacity and water holding capacity

The method described by Onwuka (2005) was used. One gram (1.g) of each sample was weighed into a graduated 15 ml centrifuge tube and 10 ml distilled water was added. The mixture was mixed thoroughly and allowed to stand for 30 min at room temperature and centrifuged at 2000-5000rpm for 30 min. The volume of free water (supernatant) was determined read directly from the graduated centrifuge tube while the increase in weight of the flour gave the water holding capacity (WHC). Water absorption capacity was calculated thus:

$$\text{Water absorption capacity} = (V_1 - V_2) \text{ m/g}$$

Where;

V₁ = initial volume of water before centrifugation

V₂ = final volume of water after centrifugation

Bulk Density

This was determined using the method advanced by Owuka (2018). Ten grams (10 g) of the sample was measured into 100 ml graduated measuring cylinder. The bottom of the cylinder was tapped repeatedly on a pad placed on a laboratory bench. Tapping was done until no further diminution or reduction in volume was noticed. The bulk density was calculated as the ratio of the weight of the sample to its volume as shown:

$$\text{Bulk density} = w/v \text{ (g/dm}^3\text{)}$$

Where: W = weight of sample in grams

V = volume of sample (dm³)

Swelling power index

The sample swelling power was determined according to the methods as described by (Onwuka, 2018). Two grams (2 g) of each sample was suspended in 10 ml of water and incubated in a thermostatically controlled water bath at 95°C in a 15 ml tarred screw cap tube. The suspension was stirred intermittently over 30 min to keep the flour granules suspended. The tubes were rapidly cooled to 20°C. The cooled paste was centrifuged to separate the jelly and the supernatant. The jelly was weighed after decanting the supernatant.

Gelatinization Temperature and time

The method described by (Onwuka, 2018) was adopted. 10% suspension of the flour sample was prepared in a test tube and heated in a boiling water bath with constant stirring. Temperature of the sample was recorded with a thermometer 30 sec after gelatinization was visually noticed as the gelatinization temperature while the time involved was recorded as the gelatinization time.

Viscosity

According to Onwuka (2005), 10% flour was suspended in distilled water and mechanically stirred for 2 h at room temperature. The viscosity was measured using Oswald type of viscometer and the readings were taken.

Statistical analysis

Data obtained were subjected to ANOVA using Statistical Package for Social Sciences (SPSS) Version 16.0. Duncan Multiple Range Test was used to separate the means at a 95% confidence level (p<0.05).

RESULT AND DISCUSSION

Proximate composition

There was significant (P< 0.05) moisture content (MC) variations (4.53% to 64.76%) among the entire samples which confirmed significant (p<0.05) correlation of processing techniques with MC (Table 1). Sample B (sprouted soy-*akamu* paste) had the highest value (64.76%) while sample A (dried sprouted soy-*akamu* paste) had the least (4.53%). Water imbibition during steeping and drying may have made the difference. This implied that sample A will swell better than the rest samples. The MC values obtained in this study were higher than 13.03-13.77% reported by Okwunodulu *et al.* (2020a) for maize-soy *akamu* except sample A (dried sprouted soy-*akamu*) which could be attributed to drying. The variation could be assigned to the maize variety, protein and carbohydrate content as well as amylose and amylopectin proportion.

The crude protein (CP) of soy-*akamu* samples also exhibited significant (p<0.05) CP variations (0.77-63.20%) with sample A (dried sprouted soy-*akamu* powder) having the highest value (63.20%) while C (un-sprouted soy-*akamu* paste) had the least (0.77%). Drying may have increased the CP by proportion as the MC decreased. Also sprouting may have increased the CP as well. The aim of soy fortification is justified more in the drying technique than the rest with more loss of CP. Only sample A (dried sprouted soy-*akamu* powder) had higher CP than 9.97-10.87% reported by Ijabadeniyi and Adebolu (2005) from *ogi* produced from three varieties of

maize and 16.33-38.40 by Okwunodulu *et al.*, (2020a). Processing techniques most especially drying and soybean sprouting may be the major sources of the variations. Similar higher CP (17.20-39.94%) was reported by Okwunodulu *et al.* (2019) for *akamu* powder from sorghum and sprouted

soybean which is also higher than 3.06% for *akamu* paste in this study. As protein is responsible for growth and wellbeing, sample A could be better for infants, elderly people and recovery patients.

Table 1. Effects of processing techniques on proximate composition of the soy-*akamu* samples (%)

SAMPLE	MC	CP	CF	ASH	CHO	EV (Kcal/100g)
A	4.53 ^c ±0.04	63.20 ^a ±0.04	0.22 ^a ±0.01	1.11 ^a ±0.01	86.40 ^a ±0.02	384.28 ^a ±0.16
B	64.76 ^a ±0.06	3.06 ^b ±0.02	0.00 ^b ±0.00	1.02 ^b ±0.02	29.86 ^c ±0.01	143.50 ^c ±0.21
C	64.36 ^b ±0.04	0.77 ^c ±0.03	0.00 ^b ±0.00	0.71 ^c ±0.01	33.03 ^b ±0.01	145.37 ^b ±0.18

Values are means of triplicate determination ±SD. Means with the same superscripts within the column are no significantly different (P> 0.05). A = dried sprouted soy-*akamu* powder, B= sprouted soy-*akamu* paste, C= un-sprouted soy-ogi paste. MC= moisture content, CP= crude protein, CF= fibre content, CHO= carbohydrate content and EV= energy value.

Processing techniques employed also produced significant (p<0.05) higher crude fibre (CF) of 0.22% in sample A (dried sprouted soy-*akamu* powder) than the rest samples that recorded no fibre contents. The absence of fibre in samples B (sprouted soy-*akamu* paste) and C (un-sprouted soy-*akamu* paste) could be attributed to sieving that must have removed all the fibre unlike sample A that was not sieved. Low fibre content of sample A (dried sprouted soy-*akamu* powder) could be due to oiling of soybean with 0.5% of sodium bicarbonate that must have tenderized and liquefied some of them. Also, soybean dehulling is another factor as the hulls are the sources of fibre. However, the fibre content was lower than 2.00% reported by Ijabadeniyi and Adebolu (2005) and 0.28-4.11% by Okwunodulu *et al.*, (2020a). Same processing technique adopted in this study which may likely vary from theirs may be responsible for the variations as it varies with locations. Sample A could be suitable for infants because of low fibre content.

The ash content of the entire samples also varied significantly (p<0.05) from 0.71-1.11% with processing techniques. Sample A (dried sprouted soy-*akamu* powder) had the highest value (1.11%) while C (un-sprouted soy-*akamu* paste) had the least (0.71%). The discrepancy could be attributed to drying and sprouting that may have improved ash content. General low ash content of the entire samples could be due to leaching of minerals into the steeping water (Ijeh *et al.*, 2010; Okafor *et al.*, 2016), sieving, decanting and dewatering processes. The ash contents obtained in this study were lower than 1.61-3.07% reported by Beruk *et al.* (2015) from maize-soybean complementary food and within 0.72-4.94% from Okwunodulu *et al.* (2020a). Processing technique employed may be the sources of variations. Ash is an index of mineral content which therefore projected sample A better than the rest samples.

The carbohydrate contents of the entire samples varied (29.86-86.40%) significantly (p<0.05) with processing techniques. The variation could stem from inevitable processing losses associated with each unit operation like steeping, drying and wet-sieving which sieved off some the coarsely milled maize endosperm thereby reducing the carbohydrate content. Also, some finely milled maize endosperm were loss during decanting and dewatering as

some sieved through the muslin cloth used when pressed. This is evident in the milky exudates obtained during the press-dewatering process. Also, increased paste MC may have proportionally decreased the carbohydrate content. Higher carbohydrate value (86.40%) of sample A (dried sprouted soy-*akamu* paste) than the least value (29.86%) of sample B (sprouted soy-*akamu* paste) could be associated to drying without wet-sieving, decanting and dewatering losses. Boiling of soybean with sodium bicarbonate may have hydrolyzed more of the little carbohydrate content which is also lost during sieving, decanting and dewatering. Only the carbohydrate value of sample A obtained in this study was higher than 73.32-74.10% reported by Beruk *et al.* (2015) while the entire values were within 28.23-80.76% reported by Okwunodulu *et al.*, (2020a) for soy-maize *akamu*. Soybean and maize varieties, processing techniques as well as the blending ratios must have been the sources of variations. While sample A is good for baby feeding, samples Band C are good for weight management.

The energy values (143.50-384.28 Kcal) of the entire samples also varied significantly (p<0.05) with processing techniques. Sample A (dried sprouted soy-*akamu* powder) had the highest value may be because of drying and its higher contents of energy substrates than the rest samples. Removal of MC by drying which proportionally increased the major energy substrates (protein and carbohydrate) of the dried soy-*akamu*, must have caused the energy increase. Sample C (un-sprouted soy-*akamu* paste) had the least value. Only the energy value of sample A (dried sprouted soy-*akamu* powder) with 284.28 Kcal is higher than 300.97-369.62 Kcal/100g reported by Okwunodulu *et al.* (2020a), but lower than 386.75 to 394.83 kcal/100g reported by Beruk *et al.* (2015) for maize-soybean complementary food. Maize variety and processing technique may be responsible. The higher energy content of sample A points to its adequacy for infant feeding as they are more active and require more energy.

Micronutrient Composition

As presented in Table 2, calcium results revealed no significant ($p>0.05$) calcium difference between samples A (dried sprouted soy-*akamu* powder) and C (un-sprouted soy-*akamu* paste) with respective values of 41.8 and 41.14 mg/100g. This implied that their processing techniques had no significant ($p>0.05$) impart on calcium. Sample B (sprouted soy-*akamu* paste) with calcium value of 40.13 mg/199g is significantly ($p<0.05$) lower than them. This

variation could be attributed to more loss of leached calcium during steeping, decanting and dewatering processes in sample B (sprouted soy-*akamu* paste) than C (un-sprouted soy-*akamu* paste) unlike in A (dried sprouted soy-*akamu* paste). However, the entire results are lower than 44.16 to 90.28 mg/100g reported by Elizabeth (2015) on fortified ogi. Calcium which is good for strong bones and teeth projected sample A slightly better than the rest samples.

Table 2. Effects of processing techniques on micronutrient compositions of the soy-*akamu* samples (mg/100g)

Samples	CALCIUM	IRON	P	Mg	ZINC	K	Vitamin C
A	41.18 ^a ±0.04	0.99 ^a ±0.01	0.27 ^{ba} ±0.01	0.071 ^a ±0.01	48.02 ^a ±0.0	0.45 ^a ±0.01	24.60 ^a ±0.03
B	40.13 ^b ±0.04	0.86 ^b ±0.23	0.25 ^b ±0.01	0.12 ^a ±0.03	0.41 ^b ±0.01	0.41 ^{ab} ±0.01	23.46 ^b ±0.01
C	41.14 ^a ±0.01	0.92 ^{ab} ±0.03	2.21 ^a ±0.01	0.10 ^a ±0.01	0.39 ^b ±0.01	0.39 ^b ±0.01	20.65 ^c ±0.02

Values are means of triplicate determination± SD. Means with same super-scripts within in the column are no significant different ($p>0.05$). A = dried sprouted soy-*akamu* powder, B= sprouted soy-*akamu* paste, C= un-sprouted soy-*akamu* paste., P= phosphorus, Mg= magnesium, K= potassium

Processing techniques also differed significantly ($p<0.05$) the iron content of the entire samples. Sample A (dried sprouted soy-*akamu* powder) had the highest value (0.99 mg/100g) and B (sprouted soy-*akamu* paste) the least (0.86 mg/100g). Leached of iron during sieving, decanting and dewatering may be the major sources of variations. Iron loss may have been more in sample B than C probably due to sprouting that released more iron. The iron results are lower than 18.85 to 23.76 mg/100g reported by Elizabeth (2015) which may stem from the processing technique adopted and maize variety used. Also, ashing temperature may contribute as iron if sensitive to that.

The different processing techniques employed in this study varied significantly ($p<0.05$) the potassium content of the soy-*akamu*. Sample A (dried sprouted soy-*akamu* powder) had the highest value (0.45 mg/100g) while C (un-sprouted soy-*akamu* paste) had the least. Leaching losses, sprouting and drying process may be responsible for the difference.

Sample C (un-sprouted soy-*akamu* paste) had significant ($p<0.05$) higher phosphorous content (2.21 mg/100g) than the rest samples (0.27 and 0.25 mg/100g) which had no variation between them. This also validated variation due to processing technique. This may therefore mean that sprouting and drying are associated with phosphorous improvement despite hydrolyses of anti-nutrients that bounds minerals by sprouting.

The vitamin C content of the soy-*akamu* products also varied significantly ($p<0.05$) with processing techniques. This could be attributed to sprouting and inevitable vitamin C loss due to its heat-labile and water-soluble nature. The variations may depend majorly on sprouting among others which increases nutrient content than heat exposure of the samples as sample A (dried sprouted soy-*akamu* powder) which had extra heat treatment (65 °C) during the drying process still had the highest vitamin C content (24.60 mg/100g). While sample C (un-sprouted soy-*akamu* paste) with only boiling heat treatment (100 °C for 20 min} had the least (20.65 mg/100g) vitamin C content. Besides, more vitamin C may have been lost during sieving, decanting and dewatering in other processes than in the dried process.

The different processing techniques employed produced soy-*akamu* with significant ($p<0.05$) magnesium variations. Sample B (sprouted soy-*akamu* paste) had higher value (0.12 mg/100g) while A (dried sprouted soy-*akamu* powder) had the least (0.07 mg/100g). Drying may have affected magnesium improvement.

Functional properties of dried soy-*akamu* flour (DSAF)

Water absorption capacity (WAC) is the ability of the (DSAF) to bind or associate with water which is summarized as the amount of water absorbed per gram depending on particle sizes (Boye et al., 2011) and initial moisture content of the flour. The WAC correlates inversely with MC (Hoover, 2001). The results presented in Table 3 showed that WAC of 0.97 g/g obtained in this study was lower than 1.16 g/g reported for wheat-cassava composite flour by Okwunodulu et al. (2022) which suggests higher carbohydrates in the composite flour than in the dried akamu flour. Steeping of maize and sprouting of soybean with low carbohydrate content compared to cassava with higher carbohydrate content may attest to that (Okwunodulu et al., 2022). With lower WAC of the DSAF, only small amount of free water may be absorbed to make the gruel consistent with moderate viscosity and lesser bulk density (BD) which is ideal for infants' feeding. Conversely,

The zinc content of the soy-*akamu* was significantly ($p<0.05$) improved (48.02 mg/100g) in sample A (dried sprouted soy-*akamu* powder) more than the rest samples which had insignificant ($p>0.05$) values (0.41 and 0.39 mg/100g). The increment may have been due to no leaching losses while drying improved the zinc content due to moisture reduction. Therefore, drying of soy-*akamu* improves zinc content.

higher WAC implies watery gruel which may be better in solubility and digestibility, but not ideal for infant feeding due to nutrient dilution. The variation in WAC may affect

acceptability but could be improved by altering the proportion of sprouted soybean in the formulation though it will affect the protein content of DSAF.

Table 3. Effect of processing techniques on the functional properties of dried soy-*akamu* from steeped maize and sprouted soybean

Samples	WAC (%)	BD (g/ml)	WHC (g/g)	SI (g/g)	G-temp (°C)	G-time (s)	Viscosity (mpa.s)
A	0.97±0.0	0.65±0.00	0.98±0.00	8.22±0.03	65.23±0.04	5.11±0.01	148.19±0.01

Values are means of triplicate determinations ± S.D. Means with the same superscripts within each column are not significantly different ($p > 0.05$). A = dried sprouted soy-*akamu* powder. WAC= Water absorption capacity, WHC= Waterholding capacity, SI= Swelling power index, G.temp= Gelation temperature,

Density is mass per unit volume of any substance which reveals the porosity, and weight and in turn decides the type of packaging materials for packaging the food material in question (Onimawo and Akurbor, 2005). It is a physical attribute of the DSAF that depends on the intensity of attractive inter-particle forces, particle sizes as well as the number of contact points (Oluwaseun *et al.*, 2015). It therefore, determines also the mixing quality (Achinewhugar *et al.*, 1998). The BD value (0.65 g/ml) obtained in this study is higher than 0.63 g/ml and 0.53-0.61 g/ml reported respectively for orange flesh sweet potato flour (OFSPF) and wheat-cassava composite flour respectively by Okwunodulu *et al.* (2021) and Okwunodulu *et al.* (2022). This could be attributed to variation in their amylose and amylopectin ratios, and carbohydrate content as BD is a function of carbohydrate content (Okwunodulu *et al.*, 2022). The DSAF therefore may have contained more carbohydrates and amylopectin than them and may likely make a better complementary food formulation (Ugwu and Ukpabi, 2002). Hydrolysis of soybean macromolecules during sprouting that result in smaller particle sizes with larger surface areas may have contributed too (Oluwaseun *et al.*, 2015). The DSAF may be less porous, bulkier, and with reduced transportation and packaging cost than them.

Water absorption capacity (WAC) is an index of association of the DSAF with water which can be referred to as the amount of water absorbed per gram of the flour depending on its particle sizes (Boye *et al.*, 2011). It decreases with an increase in initial moisture content (Hoover, 2001). The WHC of 0.98 g/g obtained for the DSAF is lower than 1.13-1.38 g/g and 2.79 g/g obtained respectively for wheat-cassava composite flour and OFSPF by Okwunodulu *et al.* (2022) and Okwunodulu *et al.* (2021). The value is also lower than 5.00-10.00 g/g reported for millet-wheat composite flour by Adegunwa *et al.* (2014). The variation could be due to their particle sizes, amylose: amylopectin ratio and molecular structure (Adegunwa *et al.*, 2014). Lower WAC of the DSAF could be attributed to the destruction of the macromolecular matrix of the flour that entraps large amounts of water during processing (Chen and Lin, 2002). Therefore, the low WHC of DSAF which implied finer particle sizes may enhance gruel consistency and stability as it will take relatively longer time for the flour to

bind the available water. Therefore the DSAF will be good for infants, the elderly, and recovery patients.

Swelling index (SI) is an indication of how much water the DSAF will absorb based on the carbohydrate content (Echendu *et al.*, 2004; Okwunodulu *et al.*, 2022). The SI increases with the temperature and carbohydrate increase (Okwunodulu *et al.*, 2022). The swelling pattern of the flour reveals the level of crystalline packing of their starch granules (McWatters *et al.*, 2003) and the extent of the association forces within the granules. The 8.22% SI of the DSAF obtained in this study is higher than 3.76 and 0.96-1.09% respectively for OFSPF and wheat-cassava composite flour reported by Okwunodulu *et al.* (2021) and Okwunodulu *et al.* (2022). Probably, the DSAF may have been drier with more amylopectin and lower amylose than them. High amylopectin is primarily responsible for starch granules swelling with better digestibility. Also, low amylose content is associated with high swelling power due to low reinforcement in the internal network by amylose molecules (Fagbemi, 1999). Other sources of variations could be due to the degree of interaction with water and their conformational characteristics (McWatters *et al.*, 2003). Higher DSAF SI value suggests higher carbohydrate content, lower moisture, more packing of starch granules with high association force within the flour particles. Therefore, DSAF may bind most of the available free water thereby increasing the viscosity and bulk density. The DSAF gruel may be suitable for infant, elderly, sick and recovering patients.

The gelatinization temperature (GT) is the temperature at which the DSAF particles will gelatinize or cook to form gruel depending majorly on the type, particle size, protein and the proportion of amylose and amylopectin content. The GT of 65.23 °C obtained in this study for DSAF is higher than 57-59 °C for soy-sorghum *akamu* powder by Okwunodulu *et al.* (2020a), 61 °C for Cerelac and 62-64 °C for complementary blend of soybean, breadfruit and plantain flours reported by Okwunodulu *et al.* (2020b). Conversely, 100% maize flour had higher GT (71 °C) than 65.23 °C for DSAF. The variations could be traced to maize variety, particle size of the starch, starch content, protein content, sprouting, steeping time and the proportion of amylose and amylopectin content of the starch. Sprouting and steeping increase protein and decreases

carbohydrate which is the primary determinant of GT. The blending ratio is another factor which could explain the reason why 100 °C corn flour had higher GT (71 °C) than the composite flours. This implied that DSAF will gelatinize at higher temperature and therefore will require higher energy to cook than them except 100% maize flour. Maize flour will have a better gelling property than all due to higher carbohydrate content.

Gelatinization time (GT) is the time taken to cook the DSAF in the presence of water and heat. It increases with increase in protein content, particle sizes, amylopectin while increase in amylose content decreases it. The GT of DSAF (5.11 s) is higher than 0.45 s reported for 100% maize flour and 0.40-0.52 s for soy-maize *akamu* flour by Okwunodulu *et al.* (2020a). It is also higher than 0.35 s for 100% sorghum, but lower than 36-57 s for soy-*akamu* flour from sprouted soybean and sorghum flours reported by Okwunodulu *et al.* (2019). Higher GT in this study could be traced to higher protein content due to inclusion of higher proportion of sprouted soybean in the blend, relatively larger starch granule sizes and the maize varieties used. Similar increase in GT by protein had been reported (Okwunodulu *et al.*, (2019 and 2020a). Protein had been reported to embed the starch granules within its stiff matrix and gradually reduces their access to water and may increase the cooking time (Aprianita *et al.*, 2009). High GT may suggest higher amylopectin with low amylose content which may result in high viscosity gruel when gelatinized with hot water. Same reasons may explain the higher GT of soy-sorghum *akamu* (36-57 s) than 5.11 s obtained in this study. Lower GT implies high solubility level and will predispose the blends for better complementary food formulation and foods for elderly and recovering patients.

Viscosity is an aspect of rheology that deals with the study of deformation and flow of matter when force is applied (Rao, 2003). It is resistant to shear forces during shearing (Badejo *et al.*, 2017) depending on the fluid particles (Rubalya and Neelamaagan, 2008). Viscosity is expressed as stress per unit force applied and an indication of the ability to form a viscous gel after cooling. It increases with carbohydrate content. The viscosity of DSAF (148.19 mPas) obtained in this study is higher than 117.02 mPas for 100% sorghum flour and 84.09-109.04 mPas for soy-sorghum *akamu* powder reported by Okwunodulu *et al.* (2019). Similarly, the value is higher than 91.25 mPas for 100% maize flour and 83.26-90.50 mPas for maize soy-*akamu* reported also by Okwunodulu *et al.* (2020a). The variation could stem from the source and amount of carbohydrates, proportion of amylopectin and amylose, water absorption capacity and swelling index of the starch granules of the flour. Higher viscosity value may imply that DSAF had higher carbohydrate content may be due to the blending proportion. The proportion of sprouted soybean flour in the blend will significantly affect the viscosity as sprouting thins down the carbohydrate content. A similar decreasing viscosity trend by sprouting had been reported for sorghum-soy *akamu* (Okwunodulu *et al.*, 2019).

acceptability but could be improved by altering the proportion of sprouted soybean in the formulation though it will affect the protein content of DSAF.

CONCLUSION

Different processing techniques employed varied significantly the nutritional components of soy-*akamu* produced. Among all the processing techniques, the production of soy-*akamu* flour from dried steeped maize and sprouted soybean is the best followed by wet-milling of steeped maize with sprouted soybean and sieving in terms of nutrient retention. The drying technique had nutrient superiority in protein, fiber, ash, carbohydrate, energy, calcium, iron, zinc, potassium, vitamin C and comparable functional properties than the rest. Soy-*akamu* flour will be more shelf stable, convenient to handle and readily available than soy-*akamu* pastes that requires refrigeration. Though production of soy-*akamu* powder may not be easy at household level due oven and energy involved, it should be encouraged as against the paste (nutrient deficient) to avoid hidden hunger or mal-nourishment.

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REFERENCE

- Achinewhugar, SC., Barber, LI. and Ijeoma, IO. 1998. Physicochemical properties and reification of selected cassava cutovers in River state. *Plant Food for Human Nutrition*. 52: 133-140.
- Adegunwa, M/O., Ganiyu, AA., Bakare, HA., and Adeboreale, AA. 2014. Quality evaluation of composite millet-wheat chin-chin. *Agricultural and Biology Journal of North America*. ISSN. 2151-7517.
- Adelekan, AO. and Oyewole, OB. 2010. Production of ogi from germinated sorghum supplemented with soybeans. *African Journal of Biotechnology*. 9:7114-7121.
- Akanbi, CT., Ade-omowaye, BIO. OJo, A. and Adeyemi, IA. 2003. Effect of processing factors on rheological properties of ogi. *International Journal Food Property*. 6:405-418.
- Aprianita, A., Purwandari, U., Watson, B. and Vasiljevic, T. 2009. Physicochemical properties of flours and starches from selected commercial tubers. *Australia International Food Research Journal*. 16: 507-20.
- Association of Official Analytical Chemists (A.O.A.C) 2010. 'Official methods of analysis.' 8th edition Gaithersburg, United State of America. 3: (1).
- Badejo, AA., Osunlakin, AA., Pamakinwa, AP., Idowu, AO. and Fagbemi, TM. 2017. Analysis of dietary fiber content, antioxidant composition, functional and pasting properties of plantain and Moringa oleifera composite flour blends. *Cogent. Food and Agriculture*. 3: 1-10.
- Beruk, BD., Kebede, A. and Esayas, K. 2015. Effect of blending ratio and processing techniques on physicochemical composition, functional properties and sensory acceptability of maize-soybean based supplementary food. *International Journal of Food Science and Nutrition Engineering*. 5(3): 121-129.
- Boye, JI. and Zubair, F. 2011. "Water holding capacity." In: *Pulse Foods* <http://www.sciencedirect.com/topic/agricultural-and-biological-sciences/water-binding/pdf>

- Carpenter, CE and Hendricks, DG. 2003. "Mineral analysis." 3rd. ed. 198–20. Springer, LLC, New York, NY.
- Chen, LA. and Lin, CS. 2002. Sensory characteristics of sorghum composite bread. *International Journal of Food Science and Technology*. 35: 465–471.
- Echendu, CA., Onimawo, IA. and Somtochi, A, 2004. Production and evaluation of doughnuts and biscuits from maize–pigeon pea flour blends. *Nigerian Food Journal*. 22: 147–153.
- Elizabeth, OF. 2015. The chemical and sensory properties of sieved and unsieved fortified ogi. *Nature and Science*. 13(1): 49-53.
- Fagbemi, EN. 1999. Effects of blanching and ripening on the functional properties of plantain (Mosaab) flour. *Plant Food for Human Nutrition*. 54(3): 261-69.
- Hany, AE. 2011. Soybean and nutrition. *Janeza Trdine: Rijeka, Croatia*. 9: 51000.
- Hoover, R. 2001. Composition, molecular structure, and physicochemical properties of tuber and root starches: A review. *Carbohydrate Polymer*. 45: 253-267.
- Ijabadeniyi, AO. 2004. Microorganisms associated with ogi, traditionally produced from three varieties of maize supplemented with soybeans. *Journal of Food Science and Technology*. 17: 139-148.
- Ijabadeniyi, AO. and Adebolu, TT. 2005. The effect of process method on the nutritional properties of ogi produced from three maize varieties. *Journal of Food, Agriculture and Environment*. 3(1): 108-109.
- Ijeh, II, Chukwunonso, ECC., Ejike, O., Nkwonta, MB. and Njoku, C, 2010. Effect of traditional processing techniques on the nutritional and phytochemical composition of African breadfruit (*Treculia africana*) seed. *Journal Applied Science and Environment*. 14(4): 169-173.
- Iwe, MO. 2003. "Chemistry, nutrition, processing and utilization." Chapter In: "The Science and Technology of Soy bean". 1st edition. Rojoint communication services, Enugu, Nigeria.
- James, SC. 1995. 'Analytical chemistry of food'. Chapman and Hill printers, London. pp 25.
- Jude-Ojei, BS., Lola, A., Ajayi, O. and Iemobayo, S. 2017. Functional and pasting properties of maize "ogi" supplemented with fermented moringa seeds. *Journal of Food Processing and Technology*. 8: 5.
- Ladunni E; Aworh, O. C; Oyeyinka S. A and Oyeyinka A. T (2013). Effects of drying method on selected properties of ogi (gruel prepared from sorghum (*sorghum valgare*) millet (*pennisetum glaucum*) and maize (*zea mays*). *Journal of food processing and technology*. ISSN: 2157-7110.
- McWatters, KH, Ouedraogo, JB, Resurrection, AVA., Hung, Y. and Philips, RD. 2003. Physical and sugar content of cookies containing mixtures of wheat, Forio (*Digitaria exilis*) and Cowpea (*Vigna unguiculata*) flours. *International Journal of Food Science and Technology*. 38: 403–410.
- Mullan, WMA. 2006. Labeling determination of the energy content of food (On-line). <http://www.dairyscience.info/packing-/119-labelling-determination-of-the-energy-content-of-food-html>.
- Nnam, NM. 2000. Chemical evaluation of multimixes formulated from some local staples use as complementary food in Nigeria. *Plant Food for Human Nutrition*. 55:255-263.
- Ogbonna, CN., Nozaki, K. and Yajima, H. 2013. Antimicrobial activity of *Xylopiya aethiopica*, *Aframomum melegueta* and *Piper guinenses* ethanolic extracts and the potential of using *Xylopiya aethiopica* to preserve fresh orange juice. *African Journal of Biotechnology*. 12: 6.
- Ogodo, AC., Ugbogu, O. and Ekeleme, U. 2015. Bacteriological quality of commercially prepared fermented ogi (Akamu) sold in some parts of South Eastern Nigeria *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*: 9: 6.
- Okafor, CS., Okwudiri, MA. and Ekwulundu, G. 2016. Determination of aluminium contents of distilled water, water heated in aluminium foil only, and food products (moi-moi) cooked in aluminium foil, plantain leaves and transparent water proof. *Journal of Biological and Chemical Research*. 33(1): 314-317.
- Okwu, DE. and Josiah, C. 2006. Evaluation of chemical composition of two Nigerian medicinal plants. *African Journal of Biotechnology*. 5(4): 357-361.
- Okwunodulu, IN., Iwe, MO., Akobundu, ENT. 2017. Storage stability of un-stabilized predigested soy milk fortified with micronutrients. a response surface approach. *Nigerian Food Journals*. 35(1): 82-94.
- Okwunodulu, IN., Eze, NL, Ndife, J. and Ukom, NA. 2019. Quality characteristics of soy-akamu powder formulated from sorghum and sprouted soybean flour blends for complementary feeding. *World Journal of Food Science and Technology*. 3(4): 48-57.
- Okwunodulu, IN., Eze, N., Okakpu, KG. and Okakpu, CJ. 2020a. Quality parameters of soy-maize akamu paste from maize and sprouted soybean blends and sensory attributes of their gruel for complementary feeding. *Sumerianz Journal of Nutrition and Food Science*. 1 (1): 33-40.
- Okwunodulu, IN., Obasi, IU. Ndife, J. and Iguh, NB. 2020b. Formulation and evaluation of complementary food from sprouted soybean, breadfruit and plantain flour blends compared with Cerelac, a commercial counterpart. *Direct. Research Journal of Agriculture and Food Science*. 8: ISSN 2354-4147.
- Okwunodulu, IN., Onwuzurike, UA., Ochiogu, OA. and Uzochukwu, UC. 2021. Evaluation of stabilized soymilk prepared from sprouted soybean with orange flesh sweet potato starch for ambient storage. *Turkish Journal of Agriculture-Food Science and Technology*. 9(4): 655-664, DOI: <https://doi.org/10.24925/turjaf.v9i4.655-664.3826>.
- Okwunodulu, IN., Iloka, UJ., Okakpu, KG. and Okakpu, CJ. 2022. Proximate composition and consumers' subjective knowledge of deep fat fried chin-chin and functional properties of the wheat-cassava composite flour used. *Turkish Journal of Agriculture- Food Science and Technology*. 10(2): 228-234, 2022 DOI: <https://doi.org/10.24925/turjaf.v10i2.228-234.4595>.
- Oluwaseun, PB., Mofoluwaso, BF., Dolapo, AO. and Egunoluwa, GA. 2015. Nutritional composition of fufu analog flour produced from cassava root (*Manihot exculenta*) and cocoyam (*Colocasia esculenta*) tubers. *Food Science and Nutrition*. 3(6): 597-603.
- Onimawo, AI and Akubor, PI. 2005. "Functional properties of food". In: *Food chemistry. Integrated approach with biochemical background*. Ambik Press Limited, Benin City, Nigeria. pp 208-221.
- Onwuka, GI. 2018. "Food analysis and instrumentation theory and practice." 2nd ed. Naphthali, Prints. Pp 104-12.
- Omemu, AM., Oyewole, OB. and Bankola, MO. 2007. Significant of yeasts in the fermentation of maize for ogi production. *Food Microbiology*. 24: 571-576.
- Rao, MA. 2003. Shear rheology of liquid foods: A study of rheological and oxidative stability of rice bran and corn oil using FTIR Spectra.

- Encyclopedia of Agriculture, Food and Biological Engineering Abstract. 4, (1): 77-86.
- Rubalya, VS. and Neelamegam, P. 2008. A study of rheological and oxidative stability of rice bran and corn oil using FTIR Spectra. *Journal of Pure and Applied Physics* 4, (1): 77-86.
- Uchendu, FN. 2013. The role of bio-fortification in the reduction of micronutrients food insecurity in developing countries African *Journal of Biotechnology*. 12 (37): 5559-5566.
- Ukom, AN., Adiegwu, .EC., Ojmelukwe, PC. and Okwunodulu, IN. 2019. Quality and sensory acceptability of yellow maize ogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours for infants. *Scientific African*. 6 e00194.
- Ugwu, E. and Ukpabi UJ. 2002. Potential of soy cassava flour processing to sustain increasing cassava production in Nigeria. *Outlook to Agriculture*. 31(2): 129 - 133.
- World Health Organization and Food and Agriculture Organization of the United Nations (WHO/FAO). 2006. *Guidelines on Food Fortification with Micronutrients*.