PROXIMATE, MINERALS, FUNCTIONAL AND ANTI-OXIDANT PROPERTIES OF CO-FERMENTED SORGHUM - PIGEON PEAS DRIED 'OGI' FLOUR AND GRUEL SENSORY ACCEPTABILITY

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ABSTRACT
This study aimed to reduce malnutrition in the tropics and a mixture of sorghum and pigeon peas at ratios: of 100:0, 90:10, 80:20, 70:30, and 60:40%) respectively were co-fermented to produce dried 'Ogi' flour. Proximate, minerals, functional and antioxidant properties of samples were evaluated and gruel sensory properties acceptability using a 9-point hedonic scale. Results showed moisture, protein, ash, fat, fibre and carbohydrates had varied values (13.071 -10.684%, 16.315 - 9.893, 4.039 - 2.012%, 0.874 – 1.601%, 0.533 – 1.327% and 70.551 to 68.751%) respectively. Moisture, ash; fibre and carbohydrates had the highest value at 10% level and protein and fat at 20% level. Calcium and potassium had increased values (0.015 - 0.181% and 0.026%- 0.098%), respectively but sodium decreased (0.163% - 0.021%). Water and oil absorption capacity increased (1.130 - 1.340 ml/g and 1.025 - 1.180 ml/g respectively, loosed and tapped bulk density decreased (0.581 - 0.434 g/ml and 0.778 - 0.716 g/ml), respectively, and swelling capacity increased with heating temperatures. TFC, TPC and FRAP increased, DPPH decreased and TAC had highest value at 30% level. Gruel at 30% level was rated highest. Therefore, these showed that the mixture and co-fermentation had produced a nutrient-dense 'ogi' capable of tackling malnutrition in the tropics.
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Keywords: Sorghum, Pigeon peas, Co-fermentation, 'Ogi", Quality

1.0 INTRODUCTION

"Ogi"is a popular weaning and breakfast meal in Nigeria and West Africa, and it is obtained from fermented cereals of maize (*Zea mays)* (Aremu, Osinfade, Basu & Ablaku. 2011) and Sorghum (*Sorghum bi-color vulgar*) (Afolayan, Afolayan & AbuahAn. 2010) or millet (*Eleusine coracana*) (Mal, Padulosi & Ravi. 2010). Traditional methods is often used to produce wet 'Ogi' by soaking grains in water for about 24-48 hours, wet milled, sieved and allowed to sediment and ferment for 24hrs before usage (Omemu & Faniran. 2011). However, during the 'Ogi' fermentation process microorganisms such as lactic acid bacteria and yeasts have been identified (Omemu & Faniran. 2011) which play important roles in aroma/flavor development, microbial stability reducing anti-nutritional factors, and increasing nutrient density (Makunba, Patrick, Oluwafemi, Adetola & Kayitesi. 2016). The traditional methods of processing 'Ogi' have been shown to lead to nutrient loss, 'Ogi' produced from sorghum has been shown to moderately contain high protein than maize (Ajanaku, Ajanaku, Edobor & Nwinyi. 2012). However, in the tropics sorghum is a household food commodity (processed into flour, fermented products and as animal feeds) and is highly drought and diseases resistant than maize, containing higher fibre, antioxidants, phenolic compounds, vitamins and minerals which have usefulness in humans physiology (Devi, Ujayabharathi, Santhyabama & Priyadarisimi. 2011).

However, since sorghum is deficient in lysine and tryptophan, but high in methionine and cysteine (Ajanaku et al., 2012), supplementation of sorghum 'Ogi' has been done by the addition of groundnut seed (Ajanaku et al., 2012), Soybean (Adeleke & Oyewole.2010), crayfish (Ajanaku, Ajani, Siyanbola, Akinsiku, Ajanaku & Oluwole. 2013) and pawpaw fruit (Ajanaku, Oguniran, Ajani, James & Nwinyi.2010) with improved nutritional and functional properties. Meanwhile, in the tropics, some legumes which have higher values of protein, energy, dietary fiber, minerals and healthy fats like pigeon peas and jack beans are highly underutilized and are almost going into extinction (Arawande & Borokini. 2010). Pigeon pea (*Cajanus cajan (L.) Huth*) is cultivated for its edible seeds and it is fast-growing, hardy, widely adaptable, and drought-resistant (Arawande & Borokinii. 2010). It is high in lysine content but low in methionine, high in flavonoids, total phenolic and high anti-oxidant properties (Rani, Poswal, Yadav & Deen. 2014) and its seed, roots and leave extracts have been used to treat kidney problems, diabetes, diarrhoea, hepatitis and anaemia (Pal, Sachan, Ghosh & Mishra. 2011). Though the addition of pigeon peas to cereals to produce various products has been done (Saxena, Kumar & Sultana. 2010; Makumba et al., 2016), information is scanty on co-fermentation of sorghum with pigeon peas at varied percentages to produce dried "Ogi" powder. Therefore, this study aimed to produce dried 'Ogi' as a weaning meal for infants and as a breakfast meal for adults to reduce malnutrition by co-fermentation of sorghum and pigeon peas grains and evaluate its properties

2.0 MATERIALS AND METHODS

2.1 Source of Materials and Preparation

Pigeon pea (*Cajanus cajan*) seeds and sorghum (*Sorghum bicolor vulgar*) were obtained from Sango market in Saki, Oyo State, Nigeria. The bench work was done at the Department of Food Science and Technology, The Oke-Ogun Polytechnic, Saki, Oyo State Nigeria. While all chemicals used for analysis were of analytical grade. Sorghum and Pigeon peas were manually sorted separately to remove all impurities like stones, sack wool, broken kernel weevil or mold growth and other foreign particles/seeds before usage.

Sample formulation for co-fermented 'Ogi'

Samples of the co-fermented 'Ogi' flour product were formulated by mixing sorghum grains with pigeon pea grains at varying ratios as presented in Table 1.

Table 1. Sample formulation of Sorghum and Pigeon peas Mixture

Sample	Sorghum Ratio	Pigeon Peas Ratio
100:0	100	0
90:10	90	10
80:20	80	20
70:30	70	30
60:40	60	40

Production of co-fermented Sorghum - pigeon pea dried 'Ogi' flour

Sorghum and pigeon peas grains blended at ratios in Table 1 were co-fermented to produce dried 'Ogi' flour as indicated in the Figure using a modified traditional fermentation method described by (Afolayan et al., 2010) . Samples were washed thoroughly in portable water and steeped in water at a grain: water ratio (1:2 (w/v) in properly labelled plastic buckets with lids for 48 hours. Soaking water was drained, grain wet-milled and then sieved using a muslin cloth to separate the pomace from the filtrate. The filtrates were allowed to settle and sour for another 48 hr. After fermentation, the water was drained and pressed and the cake was spread on an aluminium-wrapped flat plate and was dried in an air-drying oven set at 65^{o}C. The dried product was milled into fine powder using a laboratory Wiley disc mill and sieved using a 40 mm sieve to obtain 'Ogi' powder. The powder was packaged into plastic nylon (HDPE) and stored in the refrigerator until usage for analysis.

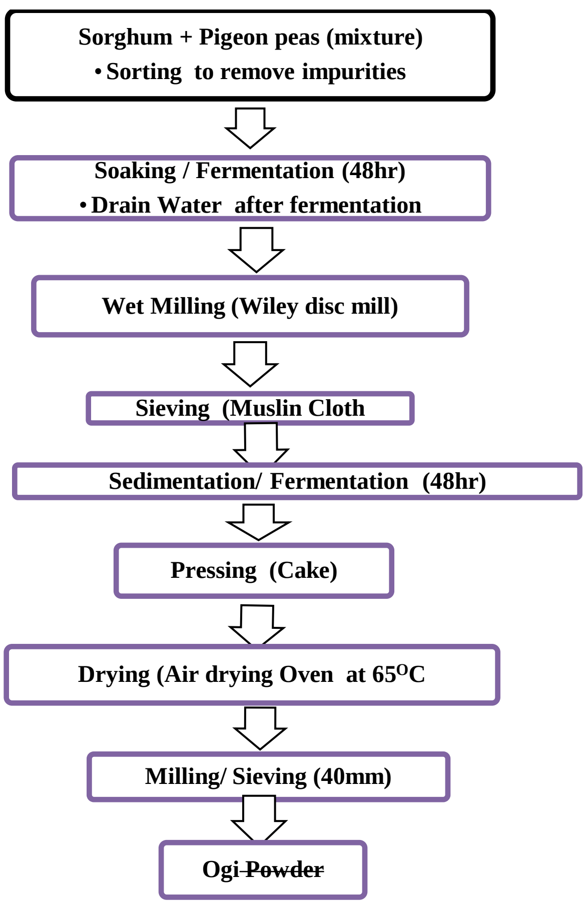

Figure 1. Production Process for Dried "Ogi" from Co-fermented Sorghum – Pigeon peas

Sample Analysis

Determination of Proximate Composition of dried 'Ogi' Flour

Proximate composition (moisture, ash, crude protein, crude fibres and carbohydrate) was determined in triplicates by using methods described by the Association of Official Analytical Chemists (A.O.A.C., 2005). Moisture was done by oven method, ash using a muffle furnace (Carbolite AAF110, United Kingdom), crude fat by

Soxhlet apparatus, crude protein by Kjeldahl apparatus, crude fibre by digestion methods and carbohydrate content by difference.

Determination of minerals of dried 'Ogi' Flour

The method of Mbaeyi and Onweluzo, (2010) was used to determine Ca, K and Na. Nitric acid was used to digest the sample to free the minerals from the ash. Standard serial concentrations of pure forms of the minerals were prepared to standardize the Atomic Absorption Spectroscopy (AAS, model DW-AA320N) before reading the concentration of minerals. A serial dilution that was used was 0.5, 1.0, 2.0, 4.0, and 8.0 mg made from 100 mg/100 ml standard flask.

Determination of Functional Properties of Dried 'Ogi' Flour

The co-fermented 'Ogi" flour samples' functional properties (Water holding capacity (WHC), Oil holding capacity (OHC), Loosed and Tapped bulk density and swelling power/capacity (SC) at varied temperatures were determined using the method described by Adebowale and Maliki (2011)

Determination of Total Phenolic Content (TPC) of dried 'Ogi' Flour

The Folin C (Folin and Ciocalteu) colourimetric method (Pedro, Ranto & Rosso. 2016) was used to determine the total phenolic content of 'Ogi'. The assay involved the addition of Folin Ciocalteu reagent (2.5 mL) and 7% (w/v) of sodium carbonate (2 mL) to 0.5 mL of the 'Ogi'. The mixture was allowed to react for 1.5 h before reading the absorbance at 765 nm on a spectrophotometer. Gallic acid was used as standard and the TPC was estimated from the standard curve obtained.

Determination of Total Flavonoid Content (TFC) of 'Ogi' flour

The total flavonoid content of 'Ogi' flour samples was evaluated using Saikia, Dutta, Saikia & Mahanta. (2012) method. The 'Ogi (0.25 mL) was diluted with 1.25 mL distilled water followed by the addition of $NaNO_3$ solution (75 μL). The resulting mixture was incubated for 6 min before the inclusion of 10% $AlCl_3$ (150 μL) followed by 5 min of incubation. Thereafter, 1 M Sodium hydroxide (0.5 mL) was added to the mixtures and made up to 3 mL before reading at 510 nm on the spectrophotometer. Quercetin was used to construct the calibration curve which estimated the TFC concentration in mg/100g.

Determination of Total Antioxidant Content (TAC) of 'Ogi" flour

The phosphomolybdum assay was reported by Dutta, Gope, Banik, Rahman, Makhnoon, Siddiquee & Kabir. (2013) was used to determine the total antioxidant capacity of 'Ogi' samples. The mixture of sulphuric acid (3.3 mL), Sodium phosphate (335 mg) and ammonium molybdate was dissolved in 100 mL of distilled water to produce the phosphomolybdenum reagent. Boiling of the mixture 0.1 mL of 'Ogi' and the phosphomolybdenum reagent at 95 °C for 90 minutes was done. The absorbance of the resulting mixture was read at 695 nm. A standard curve was constructed from the absorbance readings of different concentrations of gallic acid. The total antioxidant capacity was estimated in mg/g from the standard curve.

Determination of 1,1diphenyl-2-Picrylhydrazyl (DPPH) of 'Ogi' flour Samples

The radical scavenging potential of 'Ogi' flour was determined by the DPPH radical scavenging assay using the method described by Cheng, Moord & Yu (2006). About 0.004% DPPH solution was prepared. "Ogi" dilution (0.1 mL) was mixed with DPPH reagent (p.3 mL) and kept in the dark for 30 min the resulting mixture was taken at 516 nm. The DPPH reagent without the sample extract was used as a control. The percentage inhibition of the extract was calculated using Equation 1.

$Percentage\ inhibition = [\frac{(Ac-Ae\ )}{Ac} x\ 100)$ Where Ac= Absorbance of control; Ae= Absorbance of extract.

Determination of Ferric Reducing Antioxidant Power (FRAP)

The ferric reducing antioxidant power for "Ogi' sample was determined using modified method described by Sukrasno, Tuty & Fidrianny, (2017). The FRAP reagent was prepared by the mixture of Acetate buffer, 2, 4, 6-Tris (2-pyridyl)-s-triazine (TPTZ) and $FeCl_3.6H_2O$ in the ratio 10:1:1, respectively. Distilled water (0.7 mL) was used to dilute 0.3 mL of "Ogi" dilution, followed by the addition of FRAP reagent (2.85 mL). The reacting mixture was kept for 20 minutes at 50^OC. The equivalent concentration! (EG) as the concentration of A_O with a reducing effect equivalent to 1mmol/L Fe (II), was used to compare A_O efficiency before reading its absorbance at 700 nm. The ascorbic acid concentration in the (range 0.003 – 0.53 mg/L of Asc (R2 = 0.9882) was used to prepare the standard curve using a correlation coefficient of 0.9993 for the estimation of the antioxidant power of 'Ogi' flour samples.

FRAP value = $\left[\frac{AI-AO}{Ac-Ao)}\right)] \, x\ 2.$

Where Ac is the absorbance of the positive control; AI is the absorbance of the sample and Ao is the absorbance of the blank.

Sensory Evaluation

Panels of 20 members consisting of students in the Oke-Ogun Polytechnic, Saki who are used to consuming "ogi" porridge were selected. Samples of 'Ogi' porridge (Akamu) were prepared by mixing 100 g powder 'Ogi' into a slurry by diluting it with 50 mL water in a transparent 1000 mL plastic bowl and 400 mL of boiled water at 100 °C was added to gelatinize the sample with continuous stirring and was further boiled for 5 min and allowed to cool to 50-60 °C. The temperature of the gruel was maintained by pouring samples into a well-labelled vacuum flask before serving. Samples were served randomly in coded (3-digit numbers?) transparent plastic with a disposable cup, spoon and water to rinse the mouth. A 9-point hedonic scale was used for the difference test (multiple comparison tests). Where 9 rates "like extremely" and 1 rate "dislike extremely.

Statistical Analysis

All data obtained were subjected to statistical analysis using one-way analysis of variance (ANOVA). Mean separation was done by Duncan's multiple range tests to determine significant differences between the mean (p<005), i.e. at a 5% level of significance. The statistical package for the Social Sciences (SPSS) 20.0 for Windows (SPSS Inc., Chicago, IL, USA) was used

3.0 RESULTS AND DISCUSSION

Proximate composition of co-fermented dried 'Ogi' flour

Table 4 shows the proximate composition of the dried 'Ogi' flour. Moisture content had the highest value at a 10% level (13.071%). Lower moisture content of the flour could assist in maintaining stability during storage and less than 14% has been recommended (Hanee, 2013). Protein had the highest value at 20% level (16.415%). Protein varied values could be attributed to the addition of pigeon peas which has higher protein content than sorghum

(Aminar, Vajiha & Usha. 2015). Protein plays an important role in structure, function and regulation of the body's tissues and organs and about 0.75g per kg of body weight per day for average woman and 45 or 55 g for men (Guoyao, 2016). Ash had highest value at 10% level (4.04%). Ash content has been used to determine mineral content of foods. Fat had highest value at 20% level (1.60%). Fat contribute to energy level in dieting but saturated fats from animal origin causing cholesterol has been implicated in various heart related diseases while vegetative fat from grains contains less saturated fats and are considered to be hearts friendly (Mesina, 2014). Fiber had highest value at 10% level (1.33%). Fiber from grains has been shown could assist in regular bowel movement, weight management, gut health, cholesterol reduction, reduce diabetes risk and cardiovascular diseases (Duyff, 2017) of which 25 to 30 grams per day with 6-8 grams per day coming from the soluble fiber is recommended (Fuller, Bedk, Saiman & Topsell. 2016). Carbohydrate highest value at 30% level (73.16%). Carbohydrates are needed for energy but high carbohydrates consumption have been implicated in cases of malnutrition's and diabetes and legumes (high protein and fiber) has been used as supplement.

. **Table 2. Proximate Composition of co-fermented dried 'Ogi' flour (%)**

Sample Ratio	Moisture	Protein	Ash	Fat	Fiber	Carbohydrate
100:0	11.351±0.342^{c}	13.788±0.044^{c}	2.780±0.030^{c}	0.988±0.012^{d}	0.681±0.030^{bc}	70.414±0.339^{c}
90:10	13.071±0.392^{a}	9.893±0.088^{e}	4.039±0.017^{a}	1.158±0.053^{b}	1.327±0.098^{a}	70.515±0.170^{b}
80:20	10.690±0.297^{e}	16.315±0.044^{a}	2.012±0.089^{e}	1.601±0.185^{a}	0.533±0.012^{c}	68.751±0.033^{cd}
70:30	10.684±0.290^{d}	11.644±0.0875^{d}	2.842±0.083^{b}	1.005±0.010^{c}	0.660±0.004^{bc}	73.160±0.0308^{a}
60:40	11.995±0.379^{b}	15.408±0.000^{b}	2.234±0.096^{d}	0.874±0.060^{e}	0.719±0.004^{b}	68.771±0.286^{cd}

The mean values on same column with different superscripts are significantly different (*p* < 005) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Mineral composition (Ca, P and Na) of Sorghum-Pigeon peas 'Ogi' Flour

Table 3 showed composition of Ca, P and Na evaluated. Calcium values increased with increased addition of pigeon pea with highest value at 40% level (0.031%). Calcium is needed for bones developments which are required by growing children and the elderly to prevent arthritis and recommended mg/day differ with age and is between 210 to 1,300 mg (ABS, 2011). Potassium also increased with highest value at 20% level (0.098%). Potassium has been shown could assist in lowering blood pressure, and recommended daily intake for adult is (3.7 to 5.1 mmol/L) (Ayat, Hger, Ibrahim & Omer. 2018). While sodium decreased with highest value at the control level (0.163%). High consumption of sodium salts have been implicated in increasing blood pressure and the recommended daily intake for adult is (136 to 144 mmol/L) (Ayat et al., 2018). High potassium and lower sodium content is expected to give balance electrolyte.

Table 3. Mineral Composition of Co-fermented Sorghum-Pigeon peas 'Ogi' Flour

Sample Ratio	Calcium (%)	Potassium (%)	Sodium (g/kg)
100:0	0.015±0.005^{c}	0.040±0.001^{c}	0.163±0.003^{b}
90:10	0.021±0.001^{b}	0.026±0.001^{d}	0.149±0.001^{c}
80:20	0.026±0.001^{b}	0.098±0.003^{a}	0.021±0.005^{cd}
70:30	0.019±0.000^{c}	0.037±0.002^{c}	0.161±0.001^{bc}
60:40	0.031±0.001^{a}	0.044±0.005^{b}	0.184±0.004^{a}

The mean values on same column with different superscripts are significantly different (*p* < 005) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Functional Properties of Sorghum- Pigeon peas 'Ogi' Flour

Results in Table 4 showed the functional properties of the "Ogi" samples. Water Absorption capacity (WAC) and oil absorption capacity (OAC) increased with increased pigeon peas addition with WAC had highest value at 40% level (1.340 ml/g) and OAC highest value at 40% level (1.180 ml/g). Water and oil absorption capacity measure total amount of water and oil that can be absorbed per gram of protein based on the direct interaction of protein molecule with water and other solutes and pigeon peas has been shown to have 2.60ml and 1.66ml WAC and OAC respectively (Anmar et al., 2015). Loosed and tapped bulk densities decreased as the substitution increased and LBD had highest value at control level (0.581g/ml). While TBD had highest value at 20% level (0.778g/ml). Diets that have low bulk densities enables ease of swallowing during consumption and promotes easy digeststbility of the food (Tiencheu, Achidi, Fossi, Tenyang, Ngongang & Womeni. 2016) The density or heaviness of the processed products dictate the characteristic of its container in terms of strength of packaging materials, material handling and application in the food industry (Falade & Okafor, 2015).

Table 4. Functional Properties of Sorghum- Pigeon peas 'Ogi' Flour.

Sample Ratio	WAC (ml/g)	OAC (ml/g)	LBD (g/ml)	TBD (g/ml)
100:0	1.250±0.000^{b}	1.025±0.045^{d}	0.581±0.001^{a}	0.755±0.000^{b}
90:10	1.130±0.010^{b}	1.154±0.024^{b}	0.528±0.002^{b}	0.729±0.003^{c}
80:20	1.3370±0.010^{b}	1.149±0.045^{c}	0.525±0.005^{b}	0.778±0.002^{a}
70:30	1.297±0.0130^{b}	1.082±0.007^{cd}	0.434±0.014^{c}	0.716±0.005^{cd}

60:40	1.340±0.0200[a]	1.180±0.010[a]	0.551±0.001[b]	0.742±0.003[bc]

The mean values on same column with different superscripts are significantly different (*p* < 005) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)
WAC, Water Absorption Capacity; OAC, Oil Absorption Capacity; LBD, Loosed Bulk Density; TBD, Tapped Bulk Density

Swelling Power / capacity of Sorghum - Pigeon peas 'Ogi' Flour at Different Temperature

The swelling power of the sample flours as influenced by heating temperatures is indicated in Table 5. Swelling capacity increased with increased tiger nut addition and as the temperature of heating increased. At 50 ^{O}C the highest value was at the 40% level (1.340g/g). At 60 ^{O}C highest value was at the control level (1.253g/g), 70ºC at the 30% level (1.773g/g); 80 ^{O}C at the 10% level (3.616g/g) and 90 ^{O}C at 30% level (4.760g/g). Swelling capacity measure the ability of the flour to imbibe water when heated in aqueous suspensions and this study's results agreed with Shiqi, Mario & Benjamin. (2019) that power increases when the temperature increases. Swelling power is a measure of hydration capacity and when flour is heated to above the gelatinization range in excess water, hydrogen bonds stabilizing the structure of the double helices in crystallites are disrupted and are embraced with water, thus leading to flour swelling and increased overall volume (Shiqi et al., 2019)

Table 5. Swelling Capacity (g/g) of Sorghum- Pigeon peas 'Ogi' Flour at Different Temperatures in Degree Celsius

Sample Ratio	50	60	70	80	90
100:0	1.125±0.005[c]	1.253±0.015[b]	1.570±0.010[bc]	3.075±0.065[c]	3.490±0.040[c]
90:10	1.070±0.020[d]	1.140±0.030[d]	1.622±0.002[b]	3.616±0.026[a]	4.380±0.120[e]
80:20	1.317±0.003[a]	1.272±0.032[a]	1.552±0.023[c]	2.657±0.038[e]	4.448±0.003[d]
70:30	1.180±0.010[b]	1.270±0.010[a]	1.773±0.018[a]	3.317±0.017[b]	4.760±0.060[a]
60: 40	1.340±0.020[a]	1.230±0.010[c]	1.720±0.020[ab]	2.900±0.015[d]	4.587±0.023[b]

The mean values on same column with different superscripts are significantly different (*p* < 005) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Anti-Oxidant Profile of Sorghum-Pigeon peas 'Ogi' Flour

Table 6 showed the anti-oxidant properties of 'Ogi' samples. Flavonoids had highest value at 10% level. (0.733mg Quercetin/g). While phenolic had highest value at 10% level (0.247 mgGAE/100g). The increased in flavonoids and phenolic substances are both contributed by sorghum (Mal et al, 2010) and pigeon peas with high potential to reduce some nutritional problem related to immunity and metabolic disorder. FRAP had highest value at 10% level (1.530mg/g) and TAC had highest value at 30% level (1.843 mg GAE/g). While, DPPH values were not significantly different (p<0.05), but had highest value at 10% level (16.328 %). High anti-oxidant and free radical scavenging in the samples measured by FRAP, TAC and DPPH are significantly important in dieting and studies on pigeon peas (Rani et al., 2014) and sorghum (Heba, Eman, Abdul, Kaleemullah, Rafiq & Mahmoud. 2022) had shown the high anti-oxidant properties capable of assisting in the treatment of some diseases such as diabetes, fever, dysentery, hepatitis, inflammation, sickle cell anemia, etc. Therefore, results had shown an increase in anti-oxidant properties, thus making it a functional foods good for infants and adults. .

Table 6. Anti-Oxidant Profile of Sorghum-Pigeon peas 'Ogi' Flour

Sample Ratio	TFC (mg Quercetin/g)	TPC (mg GAE/100g)	FRAP (mg/g)	(TAC) (mg GAE/g)	(DPPH) (%)
100:0	0.463±0.007[d]	0.180±0.002[cd]	0.196±0.004[de]	1.161±0.005[c]	16.322±0.071[a]
90:10	0.733±0.007[a]	0.247±0.000[a]	1.530±0.009[a]	1.568±0.008[b]	16.328±0.173[a]
80:20	0.373±0.007[e]	0.194±0.004[c]	0.357±0.271[c]	0.889±0.006[e]	16.255±0.123[b]
70:30	0.663±0.013[b]	0.207±0.005[b]	0.305±0.005[d]	1.843±0.030[a]	16.119±0.071[c]
60:40	0.530±0.020[c]	0.170±0.005[d]	1.038±0.009[b]	0.961±0.15[d]	15.181±0.071[d]

The mean values on same column with different superscripts are significantly different (*p* < 005) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)
TFC, Total Flavonoid Content; TPC, Total Phenolic Content; FRAP, Ferric Reducing Antioxidant Power; TAC, Total Antioxidant Content; DPPH, 1,1diphenyl-2-Picrylhydrazyl

Sensory Properties of Sorghum-Pigeon peas 'Ogi' Gruel

Table 7 above shows the sensory scores by the panellist on 'Ogi'gruel samples. The highest value for gruel ranking in terms of appearance was at 40% level (7.73), mouth feels at 30% level (7.93), Color at control level (7.50), taste at 40% level (7.87) aroma at 40% level (7.53) and general acceptability at 30% level (7.97) The increased value in mouth feel, taste, aroma and general acceptability of the rest samples might have been contributed by the addition of pigeon peas which is high in protein content and when heated impacted these acceptable characteristics and low acceptability of appearance and colour might be as a result of brown colourations of pigeon peas .

Table 7. Sensory Properties of Co-fermented Sorghum- Pigeon peas 'Ogi' Gruel

Sample Ratio	Appearance	Mouth feel	Colour	Taste	Aroma	General Acceptability
100:0	7.36±0.233^{c}	7.64±0.240^{c}	7.50±0.205^{c}	7.69±0.266^{c}	7.00±0.228^{c}	7.50±0.206^{c}
90:10	7.00±0.185^{c}	7.47±0.180^{c}	7.033±0.189^{c}	7.70±0.226^{c}	7.00±0.198^{c}	7.43±0.184^{c}
80:20	7.53±0.190^{c}	7.83±0.210^{c}	7.27±0.172^{c}	7.63±0.206^{c}	7.20±0.188^{c}	7.70±0.145^{c}
70:30	7.47±0.190^{c}	7.93±0.210^{c}	7.43±0.202^{c}	7.73±0.203^{c}	7.23±0.196^{c}	7.97±0.169^{c}
60:40	7.73±0.200^{c}	7.70±0.2042^{c}	7.47±0.184^{c}	7.87±0.202^{c}	7.53±0.202^{c}	7.67±0.194^{c}

The mean values on the same column with different superscripts are significantly different (p < 005) of significance. Where sample ratios are Sorghum: Pigeon peas (co-fermented)

4.0 CONCLUSION

These results showed that the addition of pigeon pea to sorghum and co-fermentation had effects on proximate composition comparing the samples with the control sample with moisture, ash, fibre and carbohydrates having the highest value at 10% level and protein and fat at 20% level. Minerals of calcium and potassium increased but sodium decreased but had the highest value at 40% level Also, water, and oil absorption capacity increased, loosed and tapped bulk densities decreased and swelling capacity increased with increased heating temperature. High antioxidant activities were exhibited by the samples, showing pro-health benefits to both infants and adults while gruel samples had the highest acceptability rating at 30% level,. Therefore, the addition of pigeon peas to sorghum and co-fermentation produced a highly nutritious dense and functional food adequate to tackle malnutrition and increase the utilization of sorghum and pigeon peas in the tropics.

References

Adebowale, O. J. & Maliki K. (2011). Effect of fermentation period on the chemical composition and functional properties of pigeon pea seed flour, *International Research Journal* 18:1329-1333.

Australian Bureau of Statistics, (2011). Australian Health Survey: Usual Nutrient Intakes: In National Nutrition and Physical Activities Survey of 2011-12. Retrieved from tttp://www.abs.gov.au/statistics/health/health_Conditional.risk/Australian-health-survey-usual-nutient-intakes latest-release.

Adeleke, A. O., & Oyewole, O. B. (2010). Production of ogi from germinated sorghum supplemented with soybeans. *Africa Journal of Biotechnology*,9 (42), 7114-7121.

Afolayan M.O, Afolayan M & AbuahAn, J.N. (2010). Investigation into Sorghum-Based Ogi (Ogi-Baba) Storage Characteristics. *Advanced Journal Food Science Technology,* 2(1), 72-78.

Ajanaku, K. O., Ogunniran, K. O., Ajani, O. O., James, O. O., & Nwinyi, O. C. (2010). Improvement of nutritive value of sorghum ogi fortified with Pawpaw (Carica papaya L.). *Fruit Vegetable Cereal Science Biotechnology,* 4 (1), 98-101.

Ajanaku, K. O., Ajanaku, C. O., Edobor, O., & Nwinyi, O. C. (2012). Nutritive value of sorghum-Ogi fortified with groundnut seeds. *American Journal of Food Technology*, 7(2), 82-88

Ajanaku, K. O., Ajani, O., Siyanbola, T. O., Akinsiku, A. A, Ajanaku, C. O., & Oluwole, O. (2013). Dietary fortification of sorghum-ogi using crayfish (Paranephrops planifrons) as supplements in infancy. *Food Science and Quality Management*, 15, 1-9

Anmar, N. H., Vajiha, B. A., & Usha., A. (2015). In vitro Evaluation, Functional properties of protein from pigeon peas (Cjanus cajan) and its application in food. *Asian Journal of Microbial Biotech, Environmental Science,* Vol 17 No (1). 181-187.

Arawande, J. O., & Borokini, F. B. (2010). Comparative study on chemical composition and functional properties of three Nigerian legumes (Jack beans, pigeon pea and cowpea) *Journal of Emerging Trends in Engineering Applied Sciences*, 1 89-95

Aremu, M. O., Osinfade, B. G., Basu, S. K., & Ablaku, B. E. (2011). Development and nutritional quality evaluation of kersting's groundnut-ogi for African weaning diet. *American Journal of Food Technology* 6 (12), 1021-1033.

AOAC, (2005). Official Methods of Analysis 17th Edn Association of Official Analytical Chemists. Washington D. C., USA.

Ayat A. H., Hger, O., Ibrahim, A. A., Omer, M. (2018). Reference values for Serum Electrolytes (Na+, K+, Ca++) in Khartoum state. *Saudi Journal. of Medicine and Pharmacology Science,* 4 (7) 753-757.

Cheng, Z., Moor, J., & Yu, L. (2006). High-throughput relative DPPH radical scavenging capacity assay. *Journal of Agricultural and Food Chemistry*, 54(20), 7429-7436.

Devi, P.B., Vijayabharathi, R.S., Sathyabama, N.G., Priyadarisini, V.B. (2011). Health benefits of Sorghum and finger millet (Eleusine coracana L.) polyphenols and dietary fiber: A review. *Journal Food Science Technology,* .1 (3),4-9.

Dutta, A., Gope, P., Banik, S., Rahman, M., Makhnoon, S., Siddiquee, M. & Kabir, Y. (2013). "Physicochemical, cooking and antioxidant properties of nine aromatic rice cultivars of Bangladesh," *Acta Alimentaria,* 42, 552-564

Duyff, R.L (2017). Carbs, Sugars, Starches and Fiber In: Academy of Nutrition and Diettetics Complete food and Nutritional Guide 5th Ed New York, N.Y. Houghton Miffin Harcourt.

Falade K.O & Okafor C.A.C. (2015. Physical, Functional and Pasting properties of flour from Corms of two Cocoyam (Colocasia exculent and Xanthosoma sagittifolium) cultivars. *Journal of Food Science and Technology*, 52(6) 3440 – 3448.

Fuller, S., Bedk, E., Saiman, H., & Topsell, L. (2016). New Horizon for the Study of Dietary Fiber and Health: A review. *Plant Foods Human Nutrtioni.* 71 (1): 1-12.

Guovao, Wu. (2016). Dietary Protein Intake & Human Health. *Food Function* 7(3), 1251-65.

Heba I. Mohamed, Eman Mfawzi, Abdul Basit, Kaleemullah Raviq Losne & Mahmud R. Sofy. (2022). Sorghum Nutritional Factors, Bioactive compounds, Phamaceutical and Application in food systems: A Review. *Phyton – International Journal of Experimental Botany* 91(7) 1-23.

Khady, B., Emmanuel, T., Jacqueline, D., Ndiaga, C., & Philippe, T. (2010). Comparative study of phenolic compounds, the antioxidant power of various Senegalese sorghum varieties anda amylolytic enzymes of their malt. *Biotechnology, Agron. Soc. About*. 14(1):131-139.

Makumba, C.T., Patrick, B.N., Oluwafemi, A.A., Adetola, O.O & Kayitesi, E. (2016). The Role of Compositing Cereals with Legumes to Alleviate Protein Energy Malnutrition in Africa. *International Journal Food Science Technology,* 51(3): 543-554.

Mal, B., Padulosi, S., Ravi, S.B. (2010). Minor millets in South Asia: learning's from IFAD-NUS Project in India and Nepal. Maccarese, Rome, Italy: *Bioversity Intl and Chennai, India: M.S. Swaminathan Research Foundation.* 1–185

Mbaeyi, I. E., & Onweluzo, J. C. (2010). Effect of sprouting and pre-gelatinization on the physicochemical properties of sorghum – pigeon pea composite blend used for the production of breakfast cereal. *Journal of Tropical Agriculture, Food, Environment and Extension, 9(3): 184-192*

Messina, V. (2014). Ntritional and Health benefits of dried beans. *The American Journal of Clinical Nutrition,* 100(1), 437S -442S

Omemu, A. M., & Faniran, O. W. (2011). Assessment of the antimicrobial activity of lactic acid bacteria isolated from two fermented maize products- ogi and kunnu zaki. *Malaysian Journal of Microbiology* 7(3), 124, 124 – 128.

Pal, D., Sachan, N., Ghosh, A. & Mishra, P.. (2011). Biological activities and medicinal properties of Cajanus cajan (L) Millsp," *Journal of Advanced Pharmaceutical Technology & Research*, 2(4). 207– 214

Pedro, A.C., Granto, D., Rosso, N.D. (2016). Extraction of anthocyanins and polyphenols from black Rice Oryza sativa) by modeling and assessing their reversibility and stability. *Food Chemistry* 191, 12-20.

Rani, S, Poswal, G., Yadav, R. &. Deen, M. K. (2014). "Screening of Pigeon pea (Cajanus cajan L.) Seeds for study of their flavonoids, total phenolic content and antioxidant properties," *International Journal of Pharmaceutical Sciences Review and Research*, 28, 90–94.

Shiqi Huan, Mario M. Martinez.,& Benjamin M. Bohrer. (2019).The compositional and Functional Attributes of Commercial Flours from Tropical Fruits (Breadfruit and Banana). *Foods* 8(11), 586.

Saikia, S., Dutta, H. Saikia, D., & Mahanta, C. L. (2012). "Quality characterization and estimation of phytochemicals content and antioxidant capacity of aromatic pigmented and non-pigmented rice varieties," *Food Research International,* 46,334-340..

Saxena, K.B., Kumar, R. V., & Sultana, R. (2010). "Quality nutrition through pigeon pea-a review," *Health,* 2(11),1335–1344.

Sukrasno, S.,Tuty, S., & Fidrianny, I. (2017). Antioxidant evaluation and phytochemical content of various rice bran extracts of three varieties rice from Semarang, Central Java, Indonesia, *Asian Journal of Pharmaceutical and Clinical Research*. 10, 377-382.

Tiencheu B , Achidi, A.U, Fossi T, Tenyang N, Ngongang E F.T, & Womeni H.M. (2016). Formulation and Nutritional Evaluation of Instant Weaning Foods Processed from Maize (Zea mays), Pawpaw (Carica papaya), Red Bean (Phaseoulus vulgaris) and Mackerel fish Scomber Sconmbrus). *American Journal of Food Science and Technology,* 4 (5) 149-159.