www.coast.oaustech.edu.ng
COAST
JOURNAL OF THE SCHOOL OF SCIENCE
Volume 3, Issue 2. November, 2021 ISSN: 2714-3716
Coast, J. Sch. Sci. 3 (2): 636 - 651

QUALITY CHARACTERISTICS OF MAIZE *OGI* FLOUR ENRICHED WITH OKRA SEED FLOURS, PROTEIN CONCENTRATE, PROTEIN ISOLATE AND HYDROLYSATES

[1,2] Famuwagun, A. A., [2] Nnamezie, A. A. and [2] Gbadamosi, S. O.

[1]Department of Food Science and Technology, Joseph Ayo Babalola University, Ikeji-Arakeji
[2]Department of Food Science & Technology, Obafemi Awolowo University, Ile-Ife, Nigeria
*Corresponding Author's Email: akinsolaalbert@gmail.com

Abstract
The need to improve the nutrient quality of local but widely accepted food informs the use of okra seed bye products to improve the quality characteristics of maize *ogi*. Whole flour was obtained from matured okra seed. The whole flour was subsequently defatted to produce defatted flour (DF) and concentrated to obtain protein concentrate. The protein isolate was obtained by combined processes of solubilization, precipitation and neutralization of defatted flour. The protein isolate was hydrolysed using pepsin, pancreatin and trypsin enzymes to obtain pepsin hydrolysate, pancreatin hydrolysate and trypsin hydrolysate respectively. Maize *ogi* was prepared using established procedures and the okra seeds bye products was added to the prepared *ogi* at 2.5, 5.0 and 10.0 % concentrations. The enriched samples were evaluated for proximate composition, physicochemical properties and pasting properties. The results showed increase in the protein and ash contents of the enriched samples as the concentrations of the okra seed bye products increased in the mixtures. The pasting properties of the enriched sampled were affected depending on the percentages of addition of the okra seed bye products to the maize *ogi*. The study concluded that okra seed protein flours and by extension, the protein bye products are potential candidates for fortifying starch-based foods.

Keywords: Okra seeds, Amino acids, proteases, hydrolysates, enriched maize *ogi*, pasting properties.

Introduction

Enrichment or fortification of traditional but commonly consumed food material has been on the increase in recent times, due to inadequate or complete lack of essential nutrients needed for proper growth of the body. The enrichment process may become necessary in view of the need to expand the consumption and usage of such local foods, which may have received less attention worldwide due to limited nutrient (Ajanaku *et al.*, 2017). *Ogi* is one of such food products consumed by adults and infants of many households in Nigeria as breakfast cereals and as weaning foods. The wide acceptance of *ogi* is not due to the nutritional profile, but its low cost, shelf stable properties and ease of preparation (Aremu *et al.*, 2011). *Ogi* is a fermented product of cereal grain crops such as maize, sorghum or millet. Maize represents about 90 % of cereals consumed in Nigeria. One of the most popular forms of consuming maize in Nigeria is by processing into *ogi,* especially the over-matured form of maize. *Ogi* is consumed in

various forms in Nigeria, such as *eko* (a hot liquid smooth gel), *eko agidi* (thick paste) to mention a few. In all of these, the major nutritional content is carbohydrate, being the dominant class of food in cereal grain (Olorode *et al.*, 2013). The presence of carbohydrate, as the major nutrient in *ogi* suggests its inability to support proper growth of the body. The inadequacy of major nutrients, such as protein and amino acids, despite the wide acceptability of *ogi*, has opened ways for improving the nutrient composition of the food commodity, using various plant materials (Akinrinola *et al.*, 2014). Several attempts have been made to improve the protein content of maize ogi, *viz-a viz* the amino acid content, using plant-based materials, such as pigeon pea (Okafor *et al.*, 2017), Ofal wheat (Ajanaku *et al.*, 2017), Bambara groundnut (Mbata *et al.*, 2009), pawpaw seeds (Ajanaku *et al.*, 2010), groundnut seeds (Ajanaku *et al.*, 2012), cowpea (Oyerekua, 2009) and kersting's groundnut flour (Aremu *et al.*, 2011).

Okra (*Abelmoschus esculentus*) seed is a multipurpose oil seed that is commonly grown in sub-Saharan Africa, especially in Nigeria and an important vegetable crop for human nutrition. The proximate composition of okra seed showed that the matured seed of okra contained about 22 % protein, suggesting that okra seed can also be classified as protein seed (Gopalan *et al.,* 2007). When the seed coat is removed, the seed protein is increased to about 35 % (Adetuyi *et al.*, 2011). Despite the high protein content of okra seed, there is no known industrial application, probably due to inadequate research on the applicability of the seed flours and its bye-products. The lack of industrial application of the seeds usually leads to several post-harvest losses annually. The loss arises when the okra fruit is over-matured and no longer suitable for vegetable soup preparation. Some of the matured seeds are dried and re-planted while the rest are discarded (Nnamezie *et al.*, 2021). This type of post-harvest loss can be minimized or eradicated through commercialization of research outputs to diversify the use of okra and take it away from the ''plate only''. In doing this, the protein of the seed is one of the major nutrients that can be exploited and processed into high valued protein products (Famuwagun and Gbadamosi, 2016). The crude protein in the okra seed after removing the coat is about 35 %, this level of crude protein can be processed into purer protein forms such as protein concentrate and isolate. Production of protein concentrate and isolate involved the removal of fat from the seed flour, soluble carbohydrate (for concentrate) while protein isolate entails the removal of both soluble and insoluble carbohydrates and other minerals (Garba and Kaur, 2013). Concentrating and isolating the protein from okra seed would increase the protein content, amino acid level and also produce new class of food product from okra seed, which may attract industrial attention. Furthermore, in an attempt to improve the functionalities of the okra seed protein, in terms of free amino acid and antioxidant properties, the protein isolate is hydrolysed using proteolytic enzymes, such as pepsin, pancreatin, trypsin etc. The process of hydrolysis is one of the most economic ways to produce hydrolysates without compromising the compositions of the resulting peptides.

Attempts have also been made by various researchers to improve the nutritional content of maize *ogi* using okra seed, but this is limited to the use of okra seed whole and defatted flours (Otunola *et al.*, 2007; Akinrinola *et al.*, 2014; Aminigo and Akingbala, 2004). They observed tremendous improvement in the protein, ash and fibre

contents of the enriched maize *ogi* samples. However, there is paucity of information on the use of protein concentrate, isolate and the hydrolysate obtained from okra seed in improving the nutritional profiles and bioactivities of maize *ogi.* The application of okra proteins in improving the nutritional base of any food products depends greatly on the understanding of the basic nutritional level, the physicochemical as well as the pasting properties. This study therefore examined the effects of okra seed flours, protein concentrate, isolate and protein hydrolysates on the proximate composition, physicochemical properties and pasting characteristics of maize ogi. This is with a view to improve the nutritional profile of maize *ogi* while diversifying the utilization of okra seeds through protein products.

Materials and Methods

Materials

Mature Okra (*Abelmoschus esculentus* L. Moench) seed, were obtained from the Institute of Agricultural Research and Training, Ibadan and authenticated at the Department of Botany, O.A.U., Ile-Ife, Nigeria. All chemicals and reagents used were of analytical grade and obtained from Sigma-Aldrich chemical company, U.S.A and also from there accredited distributors in Nigeria.

Methods

Preparation of whole and defatted flours

The matured okra seeds were sorted, cleaned and washed with clean water. The cleaned seeds were dried with hot air oven (Uniscope Laboratory Oven, England) at 50 ± 2°C for 8 hr. The dried seeds were milled using laboratory blender (VLC sapphire grinder, IS-4930, England) at speed four (test sieve, ISO0330-1, Endecotts Ltd, London, England). The chaff removed and the sieved endosperm were packed as whole flour (WF). Portions of the whole flour were subjected to defatting process using n-hexane as the extracting solvent in a Soxhlet apparatus. After a 4-h defatting process, the hexane was separated using muslin cloth while the residual solvent in the flour were desolventized by drying in a fume hood to remove the residual solvent and the dried flour was finely ground in a grinder (VLC sapphire grinder, IS-4930, England) set at speed four to obtain homogenous defatted flour (DF). The defatted flour obtained was stored in an air-tight container and kept in a freezer until use.

Preparation of protein concentrate and protein isolate

The protein concentrate was prepared following the method described by Gbadamosi *et al.* (2012) with little modification. Two hundred grams of the defatted flour was dispersed in 2-L distilled water to give flour to water ratio of 1:10. The dispersion was then gently stirred on a magnetic stirrer for 10 min to form a suspension, after which the pH of the resultant slurry was adjusted with 1.0 M HCl to the point at which the protein was least soluble (pH 4; a value obtained from preliminary solubility results of the defatted flour during preliminary investigation) to precipitate the proteins.

The precipitation process was allowed to proceed with gentle stirring for 4-h at constant pH. Soluble carbohydrates (oligosaccharides) and minerals was removed by centrifugation at a speed of 3,500 × g for 30 min using a centrifuge (Bosch, TDL-5, United Kingdom). The precipitate (concentrate) was afterward washed twice with distilled water and the pH was adjusted with 1.0 M NaOH to 7.0 and then centrifuged at 3,500 × g for 10 min. The resultant precipitate (concentrate) was collected and dried in an oven at 45 °C for 8 h (Uniscope SM9053 Laboratory Oven,

Singerfriend, England) and packaged as protein concentrate.

Okra seed protein isolate (PI) was prepared by a method described by Gbadamosi *et al.* (2012) One hundred grams of the okra seed defatted flour was dispersed in 1 L of distilled water to give final flour to liquid ratio of 1:10. The suspension was gently stirred on a magnetic stirrer for 10 min. The pH of the resultant slurry was adjusted by drop-wise addition of 1M HCl with constant stirring until the pH was adjusted to the point at which the protein was most soluble (pH 10.0) and the extraction was allowed to proceed with gentle stirring for 4 h keeping the pH constant to solubilize the proteins. The mixture was centrifuged (Harrier 15/80 MSE) at 3500 × g for 10 min to remove the non-soluble materials (residue). The proteins were precipitated from the supernatant by adjusting the pH to the point at which is protein is least soluble (pH 4.0) and the soluble proteins was recovered by centrifugation (3500 × g for 10 min). After separation of proteins by centrifugation, the precipitate was washed twice with distilled water to remove the excess salt formed during the pH adjustment. The precipitated protein was re-suspended in distilled water and the pH was adjusted to 7.0 with 1 M NaOH prior to freeze-drying. The freeze-dried protein was stored in air-tight plastic container at room temperature for further use.

Preparation of protein hydrolysate

Okra seed protein hydrolysate was prepared using different enzymes (pepsin, pancreatin and trypsin with different optimum reaction conditions) in different containers using the method of Omoni and Aluko (2006). A 5% okra seed protein isolate's slurry was adjusted to pH 2.0 and incubated at 37 ºC followed by addition of pepsin (4% w/w, on the basis of protein content of okra seed protein isolate), another slurry was adjusted to pH 7.5 and incubated at 40 °C followed by the addition of pancreatin (4% w/w, on the basis of protein content of okra seed protein isolate) and lastly, another protein slurry in water was adjusted to pH 7.5 in another container and incubated at 45 °C followed by the addition of trypsin enzyme (4% w/w, on the basis of protein content of okra seed protein isolate). The digestion was carried out for 4 h and the pH was maintained by adding 1 M NaOH or HCl when necessary. The digestion was terminated by adjusting the pH to 4.0 and the mixture was placed in boiling water for 30 min to inactivate the enzymes which ensure complete denaturation of enzyme protein and coagulation of undigested proteins. The mixture was allowed to cool to room temperature and later centrifuged (3,500 × g for 30 min). The resulting supernatants were freeze-dried to produce the respective enzymatic hydrolysates.

Preparation of white maize ogi and enriched white maize ogi flours

The method described by Oluwamukomi *et al* (2005) was employed in the preparation of maize *ogi* powder. Maize grains were sorted and cleaned. It was then rinsed using clean water. The rinsed grain was steeped by the addition of water to 1:2 w/v (maize: water) for 48 h. It was then wet-milled, sieved, sedimented and fermented for 24 h. The fermented mixture was de-watered using double layered muslin cloth and dried for 45 ^{0}C for 12 h to obtain maize *ogi*. The dried *ogi* was milled to obtain homogenous product ogi powder. Okra seed whole flour, defatted flour, protein concentrate, isolate and hydrolysates were incorporated in the maize *ogi* at 2.5, 5.0 and 10.0 % levels of incorporations.

Determination of proximate composition

The proximate composition of the samples, including moisture, ash, crude fibre, crude fat, crude protein and carbohydrates were determined following the AOAC (2012) method.

Evaluation of some physicochemical and functional properties

Titratable acidity

About 10% suspension of ogi powder in water was prepared inside a conical flask and Ten millimeters of the suspension was diluted with ten millilitres of water and used for titratable acidity as described by AOAC (2012). Three drops of phenolphthalein will be used as indicator in the mixture in the conical flask. The mixture was then titrated against 0.1M NaOH. Titration continued until a pink colouration is observed and the corresponding burette reading will be taken. Blank titration was carried out by substituting the sample with water. Titratable acidity was calculated as percentage of lactic concentration in the powder.

$$\text{Titratable acidity } (\%) = \frac{(\text{molarity of NaOH} \times (\text{titre value of sample} - \text{blank}) \times 0.06404}{\text{mL of sample}} \times 100$$

0.6404 =mL equivalent of lactic acid for 1M NaOH (i)

pH

The pH was measured by making a 10% w/v suspension of the sample in distilled water inside a clean beaker. The suspension was mixed thoroughly and the pH was measured with a Hanna checker pH meter (Model H198107, Deutschland) after standardization with buffer

Loose bulk density (BD)

The BD was determined according to the method of Okezie and Bello (1988). A 10 ml graduated cylinder, previously tarred, was gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench for about 20 times until there is no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

Swelling and solubility capacities

Swelling capacity and solubility was determined at 60, 70, 80 and 90 °C using a modified method of Sathe and Salunke (1981). Forty milliliters (40mL) of 1% flour suspension (w/v) were prepared in a previously tarred 50 ml centrifuge tube. The tube was slowly shaken to keep the flour agitated and the temperature (60, 70, 80 and 90 °C) was maintained constantly in water bath for 30 min. The suspension was then centrifuged at 2200 x g for 20 min, the supernatant decanted and the tube with the residue weighed. Swelling power was expressed as the weight of swollen granules (final weight) divided by the initial weight. The supernatant (10 ml) was dried in an air oven at 100 °C for 4 h in a crucible to constant weight and percentage solubility was calculated as shown below.

$$\text{Swelling capacity} = \frac{w3 - w2}{w1} \quad (g) \qquad \text{(ii)}$$

W_3 = Weight of tube + sample after centrifuging and decanting

W_2 = Weight of tube + sample before centrifuging

W_1 = Weight of sample

$$\text{Solubility index} = \frac{\text{dry weight at } 100^0C\ (g)}{\text{sample weight } (mL)} \times 100 \qquad \text{(ii)}$$

Pasting properties of enriched *ogi* powder

The pasting characteristics of the samples was determined using a Rapid Visco Analyser (Newport Scientific Pty Ltd. Warriewood NSW 2120, Australia, 1998) connected to a computer (PC) with window operating system via a UBS port. The moisture content of the sample was determined first to obtain the correct sample weight and amount of water required for the test. An aqueous suspension of sample was then made and spun at 75 rpm. The temperature-time conditions included a heating step from 50 °C to 95 °C at 6 °C/min (after an equilibration time of 1min at 50 °C), a holding phase at 95 °C for 5 min, a cooling step from 95 °C to 50 °C for 2 min. Readings were displayed on the monitor in a numerical and graphical form. Viscosities will be expressed in rapid viscosity units (RVU).

Statistical analysis

Analyses were performed in triplicates and the results subjected to analysis of variance using SPSS version 18.0. The statistical significance of differences ($p < 0.05$) between mean values were determined using the Duncan Multiple Range Test

Results and Discussion

Proximate composition

Moisture content

The proximate composition of maize ogi enriched with protein bye products of okra seeds is shown in Table 1**.** The moisture content of the samples ranged between 12.01 to 13.24 %. There was no significant ($p>0.05$) difference in the moisture contents of ogi enriched with okra seed whole flour (WF), defatted flour (DF), protein concentrate (PC), protein isolate (PI) and pepsin hydrolysate (PH_P). The moisture contents of ogi enriched with pancreatin and trypsin hydrolysates compared well with other samples, irrespective of the level of addition to the okra seed products into the maize ogi. Previous studies on maize ogi supplemented with mushroom reported 9.08-10.42 % (Ajala and Taiwo, 2018), 6.30-10.70 % for maize ogi enriched with okra seed flour (Otunola et al., 2007). There is a dearth of literature that reported moisture content values on the use of protein isolate and hydrolysates in maize ogi. The reduction in the moisture content of the maize ogi enriched with pancreatin and trypsin may be related to the release of amino acids with low water binding sites that discouraged trapping or retaining water from within or in the environment (Gani et al., 2015). High moisture content in food is not desirable (Makinde and Laadipo, 2012) as this could be an indicator for microbial proliferation in food, leading to deterioration.

Ash content

Ash content is an index of micronutrients in foods (Adetuyi and Adelabu, 2011). The ash content of the samples ranged between 0.95 to 1.99 % as shown in Table 1. Addition of the okra seed bye products enhanced the ash content of the enriched samples. There were increases in the ash contents of the enriched samples as the level of seed flours, protein concentrate and isolate as well as hydrolysates increased from 2.5 to 10 % in the enriched samples. Maize ogi enriched with okra seed whole flour had the highest ash content (1.95-1.99 %), which was closely followed by the ash contents of the samples enriched with defatted flour (1.05-1.19 %).

Table 1: Proximate composition (%) of maize ogi incorporated with okra seed flours, protein powders and protein hydrolysates

Okra seed bye-product added (%)	Moisture Content	Ash content	Fat content	Fibre content	Protein Content	Carbohydrates
0	13.00±0.35^{a}	0.95±0.04^{c}	6.05±0.43^{f}	2.18±0.74^{e}	6.97±1.04^{k}	70.85±1.11^{a}
WF: 2.5	13.05±0.67^{a}	1.95±0.03^{c}	6.97±0.11^{c}	2.28±0.23^{c}	7.43±1.31^{j}	68.30±0.75^{a}
5.0	13.07±0.43^{a}	1.97±0.07^{c}	7.21. ±0.06^{b}	2.36±0.55^{b}	8.84±0.99^{i}	66.53±1.11^{b}
10.0	13.24±0.84^{a}	1.99±0.08^{a}	7.37±0.04^{a}	2.47±0.21^{a}	9.31±0.54^{h}	66.36±0.94^{b}
DF: 2.5	13.13±0.85^{a}	1.05±0.03^{a}	6.50±0.55^{e}	2.33±0.03^{c}	7.85±0.98^{j}	69.02±1.40^{a}
5.0	13.14±0.31^{a}	1.17±0.07^{a}	6.74±0.91^{d}	2.39±0.06^{b}	8.88±1.23^{i}	67.68±2.04^{b}
10.0	13.20±0.11^{a}	1.19±0.31^{b}	6.85±0.21^{d}	2.48±0.11^{a}	10.94±0.63^{g}	66.23±1.31^{c}
PC: 2.5	13.05±0.06^{a}	1.05±0.03^{b}	6.07±0.22^{f}	2.20±0.07^{d}	9.75±0.66^{h}	68.86±1.43^{b}
5.0	13.12±0.53^{a}	1.07±0.11^{b}	6.10±0.04^{f}	2.24±0.31^{d}	11.97±0.78^{f}	65.65±0.94^{d}
10.0	13.16±0.84^{a}	1.08±0.04^{b}	6.13±0.22^{f}	2.29±0.41^{c}	15.11±0.55^{c}	63.05±1.88^{e}
PI: 2.5	13.01±0.84^{a}	1.05±0.07^{b}	6.07±0.06^{f}	2.18±0.34^{e}	11.95±0.99^{f}	65.76±0.94^{d}
5.0	13.07±1.04^{a}	1.05±0.09^{b}	6.07±0.91^{f}	2.18±0.09^{e}	15.41±0.41^{c}	62.25±0.94^{e}
10.0	13.12±0.94^{a}	1.06±0.06^{b}	6.09±0.68^{f}	2.19±0.51^{e}	19.40±0.85^{b}	58.20±0.78^{h}
PH_P: 2.5	13.00±0.23^{a}	1.03±0.02^{b}	6.06±0.44^{f}	2.18±0.15^{e}	12.04±0.85^{e}	65.73±1.10^{d}
5.0	13.06±1.04^{a}	1.04±0.04^{b}	6.06±0.74^{f}	2.18±0.94^{e}	16.20±0.78^{c}	61.50±0.99^{f}
10.0	13.05±0.53^{a}	1.04±0.12^{b}	6.06±0.84^{f}	2.18±0.12^{e}	21.43±0.52^{a}	65.75±1.01^{d}
PH_{PC}: 2.5	12.01±0.04^{a}	1.01±0.07^{b}	6.06±0.18^{f}	2.18±0.11^{e}	11.95±1.11^{f}	66.80±1.04^{c}
5.0	12.50±0.74^{b}	1.02±0.21^{c}	6.06±0.74^{f}	2.18±0.13^{e}	13.14±0.51^{d}	65.14±0.74^{d}
10.0	12.20±0.78^{b}	1.03±0.11^{c}	6.06±0.15^{f}	2.18±0.51^{e}	15.32±0.88^{c}	66.52±0.32^{c}
PH_T: 2.5	12.21±0.07^{b}	0.99±0.09^{c}	6.06±0.55^{f}	2.18±0.12^{e}	12.04±1.03^{e}	66.53±1.03^{c}
5.0	12.80±0.42^{b}	1.01±0.12^{c}	6.06±0.54^{f}	2.18±0.05^{e}	13.14±0.53^{d}	64.82±0.84^{d}
10.0	12.60±0.78^{b}	1.10±0.24^{b}	6.06±0.22^{f}	2.18±0.04^{e}	18.77±0.55^{b}	59.29±0.89^{g}

WF: whole flour; **DF**: Defatted flour; **PC**: Protein concentrate; **PI**: Protein isolate; **PHp**: pepsin protein hydrolysate; **PHpc**: Pancreatin protein hydrolysate; **PHt**: Trypsin protein hydrolysate. Values in the same column with different superscript are significantly ($p<0.05$) different from one another.

The ash contents of the maize *ogi* enriched with protein concentrate (1.05-1.08 %), protein isolate (1.05-1.06 %) were not significantly different (p>0.05) from the 1.03-1.04 % obtained for the maize *ogi* enriched with pepsin hydrolysate. In a similar manner, there was no significant difference (p>0.05) in the ash content of maize *ogi* enriched with pancreatin hydrolysate (1.01-1.03 %) and trypsin hydrolysate (0.99-1.10 %). The higher ash contents of the maize *ogi* enriched with okra seed whole flour, compared with the other samples may be attributable to the processing methods such as defatting, solubilization/precipitation, neutralization and hydrolysis applied to the other okra seed protein bye products. Some other studies reported ash content of maize *ogi* enriched with okra seeds, ranging from 0.05-0.11 % (Otunola *et al.*, 2007) and 0.85-1.21 % (Aminigo and Akingbala. 2004). Ajanaku *et al.* (2017) also reported 6.54-8.94 % for maize *ogi* enriched with offal wheat flour.

Fat and fibre contents

As shown in Table 1, the fat content of fermented maize *ogi* powder (6.05 %) was lower when compared to the fat contents of maize *ogi* enriched with okra seed proteins bye-products (6.06-7.21 %). There was no significant difference (p>0.05) in the fat contents of maize *ogi* and the samples enriched with protein concentrate, isolate and hydrolysate. The fat contents of the samples enriched with okra seed whole flour was the highest (6.97-7.37 %), which was closely followed by maize *ogi* samples enriched with defatted flour (6.50-6.75 %). The high fat contents of the WF-enriched *ogi* samples may be attributable to the fact that the WF was not defatted when it was added to the *ogi* samples. The various processes for protein purification, such as the defatting, concentration, isolation and hydrolysis may have reduced or totally eliminated the fats in the samples, resulting into low fat content of the resulting enriched maize *ogi* compared with the samples enriched with the whole flour.

The fibre content of the samples is also shown in Table 1. The values ranged between 2.18 to 2.48 %. The fibre content of the maize *ogi* sample was not significantly (p>0.05) different from the fibre contents of the samples enriched with okra seed protein isolate and the hydrolysates. At each level of substitution, the fibre content of the maize *ogi* enriched with defatted flour was significantly higher (p<0.05) when compared to the values of the maze *ogi* enriched with okra seed whole flour. The higher fibre content of the sample enriched with the defatted flour may be related to fibre concentration in the defatted flour as a result of the defatting process. In a similar manner, the low values of fibre recorded in the maize *ogi* enriched with protein isolate and hydrolysates may be connected to the gradual removal of the fibre in the samples during various protein enrichment processes of the okra seeds, from isolation to enzymatic hydrolysis. Previous reported results on maize *ogi* enriched with okra whole flour ranged between 0.27-0.34 % (Otunola *et al.*, 2007), 0.51-0.64 % (Aminigo and Akingbala, 2004).

Protein and carbohydrate contents

The protein contents of the enriched samples were in the range of 7.43 to 21.43 %. The result showed improvement in the protein contents of the enriched samples as a result of the addition of the okra seed protein bye-product. At each of the enrichment level, the protein content of the maize *ogi* enriched with pepsin hydrolysate was significantly (p>0.05) higher when compared with other samples while the maize *ogi* enriched with whole flour was lowest. These patterns may be related to the history of the protein contents of the okra

seed bye products as reported in Nnamezie (2020) where the protein content of pepsin hydrolysate was highest compared when compared to either pancreatin, trypsin, protein isolate or the concentrate. The results also indicated that increase in the level of addition of okra protein bye-products increased the protein content of the resulting maize ogi samples. Similar pattern of increase in the protein content was observed in the previous reports of Gani *et al.* (2015) on the addition of lima bean hydrolysate, whey/casein protein hydrolysate and rice bran protein concentrate respectively on wheat bread. The values (7.5-11.3 %, 5.98-11.38 %) reported for the protein contents of okra seed enriched maize *ogi* obtained in the previous works (Adetuyi *et al.*, 2012) were comparable with the values (7.43 – 10.94 %) reported in this study for whole and defatted flours of okra seed enriched maize *ogi* samples. The results of the protein contents from this study suggest that okra seed protein bye -products stand a good chance of addressing the challenge of protein malnutrition being experienced in tropical Africa. The carbohydrate content of the enriched maize *ogi* (61.50 to 69.02 %) was significantly ($p>0.05$) lower when compared with the value (70.85 %) obtained for maize *ogi* without enrichment. The trend of results may be attributable to the addition of protein rich okra flour bye-products.

Physicochemical properties

Titratable acidity and pH

Titratable acidity (TTA) of food samples are measures of amounts of acids and the values are shown in Table 2. Since maize *ogi* is a product of fermentation, measurement of TTA becomes important so as to determine the level of acids released during the process. The values obtained for the TTA ranged between 0.06 to 0.21 mg NaOH/g sample, with no significant difference ($p>0.05$) between the 100 % maize *ogi* powder and the powder enriched with whole and defatted flours. The TTA value of maize *ogi* without enrichment (0.06 mg NaOH/mg) was not also significantly different ($p>0.05$) from the values obtained for the maize *ogi* enriched whole and defatted flours, protein concentrate and the protein isolate (0.06-0.08 mg NaOH/g). The values were comparable with maize *ogi* enriched with offal wheat (0.04-0.08 mg NaOH/g) as reported by Ajanaku *et al.* (2017). The TTA values of the 100 % maize *ogi* was not also significantly different ($p>0.05$) from the maize *ogi* enriched with 2.5 and 5.0 % pancreatin and trypsin okra seed protein hydrolysates. Among the maize *ogi* enriched with protein hydrolysates (PH), pepsin hydrolysate enriched maize *ogi* exhibited the highest values, suggesting greater concentration of acid in the samples.

The pH of fermented product such as maize *ogi*, is a measure of the degree of acidity. The pH values ranged between 3.4 to 4.5. *Ogi* samples enriched with 10 % defatted and whole flours significantly ($p<0.05$) had higher pH values (low acidity) as shown in Table 2. The low acidity of the samples enriched with whole and defatted samples may be attributable to the fact that the okra seeds flours had not been purified, before addition to maize *ogi*, unlike protein isolate and concentrate which had undergone steps into protein purification. Although, being a fermentation product, maize *ogi* is an acidic food material (pH of 3.70), addition of protein rich products such as isolate and protein hydrolysates is expected to enhance the strong acidity of the resulting food products as observed in previous reports (Ajanaku *et al.*, 2017; Ojokoh and Wei, 2011). However, the non-significant improvement in the acidity of the resulting *ogi* flours upon addition of okra seed protein bye products suggest that the amounts of acids in the amounts added is not sufficient to cause a

significant increase in the pH levels of the resulting enriched *ogi* samples. Acidity in food material is beneficial to the food products due to enhanced shelf stability, as only a few micro-organisms could survive in an acidic environment (Ojokoh and Wei, 2011).

Table 2: Some Physicochemical Properties of Maize Ogi Incorporated with Okra Seed Proteins and Enzymatic Hydrolysates

Okra seed bye -product added (%)	Titratable acidity (mg NaOH/g sample)	Bulk density (g/mL)	pH	Solubility index	Swelling index (g/g)
0	0.06±0.01 ^{c}	0.56±0.03 ^{c}	3.70±0.02 ^{b}	0.45±0.05 ^{f}	0.99±0.10 ^{a}
WF: 2.5	0.06±0.01 ^{c}	0.59±0.02 ^{c}	3.70±0.04 ^{b}	0.45±0.05 ^{f}	0.96±0.05 ^{a}
5.0	0.06±0.01 ^{c}	0.68±0.04 ^{b}	3.70±0.04 ^{b}	0.40±0.03 ^{h}	0.96±0.08 ^{a}
10.0	0.06±0.02 ^{c}	0.75±0.04 ^{a}	4.50±0.03 ^{a}	0.37±0.03 ^{i}	0.94±0.13 ^{a}
DF: 2.5	0.06±0.01 ^{c}	0.57±0.05 ^{c}	3.70±0.09 ^{b}	0.45±0.06 ^{f}	0.96±0.06 ^{a}
5.0	0.06±0.01 ^{c}	0.64±0.06 ^{b}	3.70±0.08 ^{b}	0.42±0.02 ^{g}	0.95±0.11 ^{a}
10.0	0.06±0.02 ^{c}	0.74±0.02 ^{a}	4.40±0.01 ^{a}	0.35±0.03 ^{i}	0.91±0.03 ^{b}
PC: 2.5	0.06±0.01 ^{c}	0.56±0.03 ^{c}	3.80±0.09 ^{b}	0.45±0.04 ^{f}	0.97±0.08 ^{a}
5.0	0.06±0.02 ^{c}	0.61±0.04 ^{b}	3.80±0.04 ^{b}	0.43±0.05 ^{g}	0.95±0.06 ^{a}
10.0	0.08±0.01 ^{c}	0.70±0.04 ^{a}	3.70±0.05 ^{b}	0.40±0.02 ^{g}	0.90±0.07 ^{b}
PI: 2.5	0.06±0.01 ^{c}	0.56±0.04 ^{c}	3.70±0.05 ^{b}	0.45±0.05 ^{f}	0.86±0.08 ^{b}
5.0	0.07±0.02 ^{c}	0.68±0.02 ^{b}	3.70±0.03 ^{b}	0.48±0.06 ^{f}	0.62±0.07 ^{e}
10.0	0.08±0.02 ^{c}	0.65±0.04 ^{b}	3.60±0.05 ^{b}	0.50±0.04 ^{f}	0.50±0.06 ^{f}
PH_P: 2.5	0.10±0.01 ^{b}	0.56±0.07 ^{c}	3.60±0.07 ^{b}	0.45±0.07 ^{f}	0.88±0.10 ^{b}
5.0	0.12±0.01 ^{ab}	0.59±0.06 ^{b}	3.60±0.03 ^{b}	0.60±0.02 ^{e}	0.74±0.04 ^{d}
10.0	0.21±±0.06 ^{a}	0.60±0.04 ^{b}	3.40±0.05 ^{b}	0.66±0.08 ^{d}	0.67±0.08 ^{e}
PH_{PC}: 2.5	0.08±0.02 ^{c}	0.57±0.07 ^{c}	3.70±0.06 ^{b}	0.46±0.06 ^{f}	0.97±0.04 ^{a}
5.0	0.08±0.01 ^{c}	0.57±0.04 ^{c}	3.70±0.06 ^{b}	0.63±0.07 ^{e}	0.96±0.08 ^{a}
10.0	0.13±0.05 ^{ab}	0.63±0.06 ^{b}	3.60±0.02 ^{b}	0.70±0.09 ^{c}	0.89±0.06 ^{b}
PH_T: 2.5	0.08±0.01 ^{c}	0.56±0.08 ^{c}	3.70±0.08 ^{b}	0.49±0.07 ^{f}	0.93±0.05 ^{a}
5.0	0.08±0.02 ^{c}	0.58±0.03 ^{c}	3.70±0.02 ^{b}	0.89±0.04 ^{b}	0.81±0.90 ^{c}
10.0	0.10±0.04 ^{b}	0.62±0.06 ^{b}	3.60±0.05 ^{b}	0.98±0.10 ^{a}	0.69±0.05 ^{e}

WF: whole flour; **DF**: Defatted flour; **PC**: Protein concentrate; **PI**: Protein isolate; **PHp**: pepsin protein hydrolysate; **PHpc**: Pancreatin protein hydrolysate; **PHt**: Trypsin protein hydrolysate. Values in the same column with different superscript are significantly ($p<0.05$) different from one another.

Bulk density

The bulk densities of maize *ogi* samples enriched with okra seed protein products are shown in Table 2. The values ranged between 0.56 to 0.75 g/ml. There was increase in the bulk densities of the resulting enriched *ogi* samples as the level of inclusion increased and then sample enriched with 10 % protein concentrate. The values obtained in this study were comparable with 0.73 to 0.76 g/ml obtained for plantain flour enriched with okra seed flour (Adetuyi and Adelabu, 2011). Bulk density is a measure of heaviness of flour and an important parameter that determines the suitability of food powders for ease of packaging and transportation (Adejuyitan *et al.*, 2009; Shittu *et al.*, 2005). Food samples, having bulk density <1.0 mg/ml are considered low bulk density and such food materials are categorized as foods that digest easily in the digestive systems (Nelson-Quartey *et al.*, 2007). The low bulk densities of the enriched maize *ogi* in this study suggest their potential utilization as infant formulation and nutritionally, would promote easy digestion of infant foods, particularly those with tender digestive systems (Osundahunsi *et al.*, 2003).

Swelling and solubility indices

As indicated in Table 2, the swelling index of the enriched maize *ogi* ranged between 0.50 and 0.97 g/g. Maize *ogi* without any enrichment had the highest swelling capacity (0.99 g/g), while the least value was obtained in maize *ogi* with 10 % protein isolate. There was no significant difference ($p>0.05$) in the swelling indices of 100% maize ogi and those enriched with whole flour, defatted flour and protein concentrate. The results also showed reductions in the swelling index of the enriched maize *ogi* samples as the level of the okra seed flours bye-products increased in the mixtures. The lower swelling index of the enriched maize ogi compared to the 100 % maize ogi suggested that the okra seed bye-product has low swelling capacities. This is expected because swelling index has been found to be influenced by the amylose/amylopectin ratio of starch, which may be higher in the 100 % maize ogi than the maize ogi enriched with okra seed protein bye products (Chen et al., 2003). The lower swelling index obtained for maize *ogi* enriched with okra seed protein products may mainly be due to the levels of proteins used to replace carbohydrate-based materials in 100 % maize ogi and therefore negatively imparted swelling (Adepeju *et al.*, 2011). The addition of okra seed protein products may have also reduced the quantity of amylopectin/amylose contents of the starch fractions of the contents of the enriched samples and hence, lower expansion of the sample molecules, resulting in low swelling capacities.

Solubility index is a measure of protein solubility in food materials and dictates some important functionalities of protein in foods. The solubility index of maize *ogi* enriched with okra seed protein bye products showed that samples enriched with trypsin hydrolysates had the highest values (0.49-0.98 %) while the least values was obtained in maize *ogi* samples enriched with okra seed whole flour (0.35-0.40 %). The results also showed that increase in the amounts of okra seed whole flour, defatted and protein concentrates reduced the solubility indices of the resulting samples while those enriched with protein isolate and hydrolysates had a different trend, in that, higher concentration resulted in greater solubility indices. Though the reason for variations in the solubility is not well understood, it may be connected with the differences in the conformations and the qualities of the proteins and the solubility profiles of the different okra seed protein bye products. The pattern of the results obtained for isolate and hydrolysates enriched maize ogi samples agreed with the pattern of results reported by Ajala and Taiwo (2018) and Olorode et al. (2013) on the fortification of maize *ogi* with Oyster mushroom flour and Moringa leaf powders at different concentrations.

Pasting properties

One of the most common parameters used to estimate the pasting properties of starch-based products is the amylographic-pasting properties. The pasting properties of the okra seed protein enriched maize ogi samples are shown in Table 3. The peak viscosities ranged between 157.38 to 201.38 centipoise. The highest peak viscosity was obtained in maize ogi sample enriched with 2.5 % okra seed trypsin hydrolysate while the lowest peak viscosity was obtained in sample enriched with 10 % okra seed protein isolate. Among the samples enriched with protein hydrolysate, sample fortified with 10 % pancreatin hydrolysate had the least peak viscosity while maize ogi sample containing 2.5% trypsin hydrolysate had the highest peak viscosity, suggesting that higher concentration of okra protein hydrolysate reduced the trough viscosity of the resulting

samples. The peak viscosity of samples is an indication of cooking time which also suggests the viscosity where the starch granules reach highest swelling while cooking (Jude-Ojei *et al.*, 2017). The values (157.38 to 218.38 cp) reported for the peak viscosity in the present study compared well with values (90 to 212 cp) reported for maize ogi enriched with differently processed okra seed meal (Otunola *et al.*, 2007). Differences in the peak viscosity is a function of solubility, swelling and gel concentrations of samples. The results also indicated that samples enriched with 2.5 % okra seed protein products had significantly ($p<0.05$) higher peak values compared with 100 % maize ogi, suggesting that the increase in the concentration of the okra protein products may have affected the cooking time and the level of balance of amylose and amylopectin of the starch in the samples (Otunola *et al.*, 2007).

Table 3: Pasting Properties of Maize Ogi Enriched with Okra Seed Products

Okra seed bye - product added (%)	Peak viscosities (cp)	Trough (cp)	Breakdown (cp)	Final Viscosity (cp)	Setback (cp)	Peak Time (minutes)	Pasting Temp (°C)
0	157.17±0.12 j	106.88±4.07 g	50.29±2.19 j	164.71±0.29 j	57.83±2.37 k	5.57±0.24 a	75.85±1.06 b
WF: 2.5	188.74±2.94 c	145.94±1.45 a	70.95±0.99 f	213.47±0.84 b	87.85±1.04 e	4.85±0.05 b	74.22±1.23 c
5.0	188.53±2.99 c	133.94±1.06 b	74.74±1.03 e	205.84±0.55 c	78.48±0.53 g	5.00±0.84 a	74.35±1.03 c
10.0	188.17±2.47 c	121.54±1.94 d	80.63±0.53 b	198.08±2.95 f	76.54±1.00 h	5.53±0.00 a	75.05±0.54 b
DF: 2.5	177.99±0.85 e	126.95±1.22 c	48.32±0.54 k	174.83±1.23 i	96.86±1.03 c	4.53±0.23 b	73.45±1.06 d
5.0	168.11±1.55 h	113.94±1.43 e	52.84±0.99 j	163.22±1.11 j	74.96±1.13 h	4.67±0.54 b	75.05±0.95 b
10.0	158.33±0.54 j	101.08±0.55 h	57.25±0.33 i	153.67±0.33 k	52.58±0.55 l	5.20±0.22 a	76.65±0.55 b
PC: 2.5	189.84±2.66 c	133.85±1.54 b	60.94±1.03 h	182.83±1.94 h	70.85±0.75 i	5.89±1.04 a	73.85±0.55 d
5.0	183.67±1.30 d	120.00±0.24 d	63.67±1.53 g	194.29±1.12 g	74.29±1.36 h	5.53±0.04 a	75.10±1.06 b
10.0	175.79±2.77 f	109.54±1.83 f	66.25±1.60 g	183.71±2.78 h	74.17±1.60 h	5.27±0.09 a	75.43±0.60 b
PI: 2.5	178.88 ±1.85 e	124.85 ±1.22 d	60.84 ±1.24 h	203.74 ±1.23 d	88.84 ±1.93 e	5.87 ±0.84 a	78.84 ±0.66 a
5.0	166.58± 2.64 i	112.69± 5.31 e	53.89± 1.31 j	181.03± 1.53 h	68.33± 1.83 j	5.53± 0.20 a	75.83± 0.80 b
10.0	157.38±1.59 l	102.96±1.71 h	44.42±1.30 l	141.33±1.48	38.38±1.19 n	5.40±0.00 a	73.50±0.07 d
PH_P: 2.5	176.79 ±2.56 f	105.17 ±1.66 j	78.85 ±0.99 d	200.83 ±0.32 e	96.59 ±0.85 c	4.50 ±1.93 b	73.44 ±1.23 c
5.0	164.54±2.77 i	99.21±1.71 i	65.33±1.06 g	183.13±1.24 h	83.92±0.47 f	5.20±0.02 a	74.25±0.34 c
10.0	158.33±1.53 j	105.17±1.19 g	53.17±1.72 j	163.63±0.53 j	58.46±0.72 k	5.40±0.09 a	74.73±0.53 c
PH_{PC}:2.5	173.95 ±1.85 g	91.84 ±1.45 j	84.95 ±0.83 c	210.83 ±0.75 b	112.84 ±1.11 b	4.79 ±0.34 b	71.85 ±0.88 e
5.0	164.54±2.77 i	99.21±1.71 i	65.33±1.06 g	183.13±1.24 h	83.92±0.47 f	5.20±0.02 a	74.25±0.34 c
10.0	161.53±2.80 k	105.42±3.50 g	46.11±0.12 l	153.50±2.06 k	48.08±1.26 m	5.51±0.04 a	76.97±0.92 b
PH_T: 2.5	218.74 ±2.45 a	132.94 ±1.84 b	103.45 ±1.22 a	235.95 ±1.04 a	124.95 ±0.94 a	5.40 ±0.84 a	72.95 ±1.23 d
5.0	201.38±1.00 b	119.17±2.71 d	82.28±3.71 d	213.17±4.12 a	94.00±1.41 d	5.23±0.05 a	73.55±1.43 d
10.0	169.50±0.71 h	102.54±1.24 h	66.96±1.54 g	161.63±0.53 j	59.08±1.77 k	5.07±0.09 a	74.28±0.04 c

WF: whole flour; **DF**: Defatted flour; **PC**: Protein concentrate; **PI**: Protein isolate; **PHp**: pepsin protein hydrolysate; **PHpc**: Pancreatin protein hydrolysate; **PHt**: Trypsin protein hydrolysate. Values in the same column with different superscript are significantly ($p<0.05$) different from one another

Trough viscosity is the minimum viscosity at constant temperature phase of the pasting profile, which indicates the ability of paste to withstand breakdown during cooling (Smolin and Grosvenor, 2003). The values ranged between 99.21 to 145.94 centipoise and some of the values were significantly ($p<0.05$) different from one another. The highest value was the maize ogi enriched with 2.5 % okra whole flour and the value was not significantly ($p<0.05$) different from the value obtained for ogi sample enriched with 2.5% okra protein concentrate (120.00 cp) and maize ogi enriched with 2.5% trypsin

hydrolysate (132.94 cp). The least value for the trough was obtained in sample of ogi enriched with 5% pepsin hydrolysate of okra seed (99.21 cp). Generally, there was decrease in the trough values of the samples as the concentration of the okra seed products reduced in the resulting flours, suggesting high amounts of okra seed flours affected the ability of the resulting flours to withstand breakdown.

Breakdown is another characteristic of the pasting properties of flour samples. The values ranged between 44.42 to 103.45 centipoise and some of the values were significantly ($p<0.05$) different from one another. The highest breakdown value (103.45 cp) was obtained in maize ogi sample enriched with 2.5% trypsin hydrolysate while the least value was obtained in maize ogi sample enriched with 10 % okra seed protein isolate. Except the value obtained for the 10 % ogi enriched with 10% protein isolate, all other enriched samples were higher than the values reported for the 100 % maize ogi. Breakdown viscosity is an index of stability of starch granules within the molecules of starch rich materials (Jude Ojei *et al.*, 2007) and the higher the breakdown viscosity, the more stable the sample. The pattern of results indicated that enriching maize ogi samples with some of the okra seed protein products and hydrolysates improved the stability of the final mixtures and that the lower the amounts of okra seed protein products in the resulting flour, the better the stability of the product.

The final viscosity of the samples ranged between 141.33 to 213.17 cp. There was progressive decrease in the final viscosity of the samples as the quantity of okra seed proteins reduced in the samples. The highest final viscosity was obtained in maize ogi enriched with 2.5 % trypsin hydrolysate while the least was obtained in 10 % protein isolate enriched maize ogi. Similarly, the addition of higher amounts of okra seed protein bye products to maize ogi may be detrimental to the structures of the starch granules, and this may account for lower values in samples that contained higher percentages especially beyond 2.5 %.

The values obtained for the setback of the samples ranged between 38.38 to 94.00 cp and the values were significantly ($p<0.05$) different from one another. The least setback value (38.38 cp) was obtained in maize ogi enriched with 10 % okra protein isolate while the highest value (94.00 cp) was obtained in maize ogi enriched with 2.5% okra trypsin hydrolysate. The setback value for the 100 % maize ogi was 57.83 cp and this value was not significantly ($p>0.05$) different from 58.46 cp reported for maize ogi enriched with 10 % okra seed pepsin hydrolysate. The setback values obtained for the maize ogi enriched with 2.5% okra protein products were all significantly ($p<0.05$) higher than the value obtained for 100 % maize ogi sample. For the 10 % level of enrichment, maize ogi sample enriched with okra seed protein isolate and pancreatin hydrolysate had lower values than 100% maize ogi while the setback value for every other 10 % level of enrichment had higher setback values compared to 100 % maize ogi sample. The setback values indicate the ability of starch rich samples to form gels or the tendency to exhibit retrogradation which is a function of the amylase enzyme of the starch (Onuoha et al., 2014). The higher the setback values, the faster the gelling and retrogradation ability of the samples. The results therefore suggest that maize ogi enriched with 2.5% okra seed protein products would exhibit greater tendency towards retrogradation which would result in the formation of resistant starch. This resistant starch is not very digestible and it is of functional value to the body due to its low glycemic index when ingested (Smolin and

Grosvenor, 2003).

The peak time of the maize ogi enriched with okra seed protein and hydrolysates ranged between 4.50 to 5.89 min. The highest peak time was obtained in maize ogi enriched with 2.5 % protein concentrate while the least was obtained in ogi enriched with 2.5 % protein hydrolysate. The peak time of the samples enriched with protein hydrolysates increased as the quantity of the hydrolysates increased in the mixture. However, the presence of the okra seed whole and defatted flours, protein concentrate and protein isolate improved the peak time as their concentration increased in the mixture. The differences in the peak times of the maize ogi enriched with proteins and the hydrolysates may be attributable to differences in the structures of these okra seed proteins and the hydrolysates. The use of enzymes to produce hydrolysates from the protein isolate may have caused a change in the intrinsic structures, leading to a change in the peak times in the resulting enriched samples. Peak time is a measure of the cooking time of the samples (Jude-Ojei et al., 2007). Similar observation was made by Aminigo and Akingbala (2004) when maize ogi enriched with differently processed okra seeds flours.

The pasting temperature of the samples ranged between 73.45 to 78.84 °C. The highest pasting temperature was obtained in maize ogi sample enriched with 2.5% protein isolate while the least was obtained in sample enriched with 2.5 % whole flour. The pasting temperature of 100 % maize ogi was 75.85 °C and the value was not significantly ($p>0.05$) different from maize ogi samples enriched with 2.5 and 5.0 % whole flour, defatted flour and protein concentrate. The results also indicated a gradual decrease in the pasting temperature of the samples as the quantity of okra seed products increased in the mixtures, which indicate that low the lower the addition of the okra seed flours and protein bye-products, the higher the pasting temperatures. Pasting temperature is an index that characterized the initial change due to swelling of starch (Akingbala *et al.*, 2005). The pasting temperature in this study was similar to the values 75.00 to 77.09 °C reported for maize ogi enriched with roasted okra seed whole and defatted flour (Aminigo and Akingbala, 2004).

Conclusion

The study evaluated the potential of okra seed flours, protein concentrate, protein isolate and hydrolysates in the enrichment of food commodity such as maize *ogi*. Addition of okra seed flours and bye products improved the ash content, protein and fibre contents of the enriched samples. However, the pasting properties of the enriched maize *ogi* were affected, depending on the amount of the okra seed bye products in the mixtures. The study therefore suggested okra seed proteins especially the hydrolysates may find good applications in the development of new functional foods

Authors' contribution

FAMUWAGUN Akinsola Albert (FAA) assisted in performing the analysis, data interpretation and wrote the draft manuscript; NNAMEZIE Anastasia Amaka (NAA) performed the analysis, interpreted the data; GBADAMOSI Saka Olasunkanmi (GSO) conceived the idea, supervised and corrected the final draft.

Funding

This research received no external funding

Acknowledgment

The Authors thank the Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria for the facilities used for this research

Conflict of Interest

The Authors declare that there are no conflicts

of interest in the submission and eventual publication of this work.

References

Adetuyi, F. O. and Adelabu, H. A. (2011). Impact of Okra (*Abelmoschus esculentus)* Seed Flour on Nutrients, Functional Properties and Zinc Bioavailability of Plantain Flour Nutrients, Functional Properties and Zinc Bioavailability of Plantain Flour. *Mal J of Nutr*, 17(3): 359 – 366.

Adetuyi, F., Ajala, L. and Ibrahim, T. (2011). Effect of the addition of defatted okra seed (*Abelmoschus esculentus*) flour on the chemical composition functional properties and Zn bioavailability of plantain (Musa paradisiacal Linn) flour. *J. of Microbio, Biotechn and Food Sci, 2(1): 69-82.*

Adetuyi, F. O. and Komolafe, E. A. (2011). Effect of the Addition of Okra Seed (*Abelmoschus esculentus*) Flour on the Antioxidant Properties of Plantain *Musa paradisiaca* Flour. *Annual Rev and Res in Bio,* 1(4): 143-152.

Adejuyitan, J. A., Otunola, E. T., Akande, E. A., Bolarinwa, I. F. and Oladokun, F. M. (2009). Some physicochemical properties of flour obtained from fermentation of tigernut (*Cyperus esculentus*) sourced from a market in Ogbomoso, Nigeria. *Afr J of Food Sci,* 3(2): 51-55.

Adepeju, A. B., Gbadamosi, S. O., Adeniran, A. H and Omobuwajo, T. O. (2011). Functional and pasting characteristics of breadfruit (*Artocarpus altilis*) flours. *Afr J of Food Sci, 5(9):* 529-535.

Ajala, A. S. and Taiwo, T. F. (2018). Study on supplementation of 'ogi' with oyster mushroom flour (*Pleurotus ostreatus*). *J of Nutr Health & Food Eng*, 8: 3 -10.

Ajanaku, K. O., Ademosun, O. T., Siyanbola, T. O., Akinsiku, A. A., Ajanaku, C. O. and Ckukwuemeka, N. O. (2017). Improving Nutritive Value of Maize-*Ogi* as Weaning Food Using Wheat Offal Addition. *J of Nutri*, 2:1-10.

Ajanaku, K. O., Ogunniran, K. O., Ajani, O. O., James, O. O. and Nwinyi, O. C. (2010). Improvement of nutritive value of sorghum ogi fortified with Pawpaw (Carica papaya L.). Fruit Vegetable, *Cereal Sci Biotech,* 4: 98–101.

Akingbala, J. O., Akinwande, B. A. and Uzo-Peters, P. I. (2005). Effects of color and flavor changes on acceptability of *ogi* supplemented with okra seed meals. Plant Foods Human Nutrition, 58:1-9.

Akinrinola, A. A. M., Idabor, V., Oliseh, C., Sanni, R., Oshagbemi, H. and Oyefuga, O. (2014). Dietary Fortification of Ogi (Maize slurry) with Okra seed flour and its Nutritional value. *J of Agri Sci*, 4(4), pp. 213-217

Aminigo, E. R. and Akingbala, J. O. (2004). Nutritive Composition and Sensory Properties of Ogi Fortified with Okra Seed Meal. *J of Appl Sci and Environ Mana*, 8 (2) 23 – 28.

Aremu, M. O., Osinfade, B. G., Basu, S. K. and Ablaku, B. E. (2011). Development and nutritional quality evaluation of kersting's groundnutogi for African weaning diet. *Ame J of Food Techn*, 6: 1021–1033. https://doi.org/10.3923/ajft.2011.1021.1033

AOAC (2012). Official Methods of Analysis of the Association of Official Analytical Chemists, 20th ed.

Chen, Z., Schols, H. A. And Voragen,A. G. J. (2003). Physicochemical properties of starches obtained from three different varieties of chinese sweet potatoes. *J*

Food Sci, 68: 431-437.

Famuwagun, A. A. and Gbadamosi S. O. (2016). Studies on The Proximate Composition, Functional Properties and Effect of pH and Salt Concentrations on Some Functional Properties of *Ackee* Apple Aril Flours. *Ife J of Sci*, 18(3).

Gani A., Broadway, A. A., Masoodi, F. A., Wani, A. A., Maqsood, S., Ashwar, B. A., Shah, A., Rather, S. A. and Gani, A. (2015). Enzymatic hydrolysis of whey and casein protein- effect on functional, rheological, textural and sensory properties of breads. *J of Food Sci and Techn*, DOI 10.1007/s13197-015-1840-1

Garba, U. and Kaur, S. (2013). Review-Protein Isolates: Production, Functional Properties and Application. *Int Res J of Chem,* (IRJC) ISSN 2321 – 2845(Online), 2321 – 3299 (Print) http://irjc.petsd.org Page | 22

Gbadamosi, S. O., Abiose, S. H. and Aluko, R. E. (2012). Amino acid profile, protein digestibility, thermal and functional properties of Conophor nut (*Tetracarpidium conophorum*) defatted flour, protein concentrate and isolates. *International J of Food Sci and Techn,* 47: 731-739.

Gopalan, C., S., Sastri, B.V and Balasubramanian, S. (2007). Nutritive Value of Indian Foods. National Institute of Nutrition (NIN), ICMR, India Arapitsas, P., 2008. Identification and quantification of polyphenolic compounds from okra seeds and skins. *Food Chem*, 110: 1041-1045

Jude-Ojei, B. S., Lola, A., Ajayi, I. O. and Ilemobayo, S. (2017). Functional and Pasting Properties of Maize 'Ogi' Supplemented with Fermented Moringa Seeds. *J of Food Proc Techn*, 8:5 DOI: 10.4172/2157-7110.1000674

Makinde, F. M. and Ladipo, A. T. (2012). Physicochemical and microbial quality of sorghum-based complementary food enriched with soybean *(Glycine max)* and sesame *(Sesamum indicum). J of Food Techn,* 10(2): 46-49.

Mbata, T. I., Ikenebomeh, M. J., and Alaneme, J. C. (2009). Studies on the microbiologial, nutrient composition and antinutritional contents of fermented maize flour fortified with bambara groundnut (*Vigna subterranean* L.). *Afri J of Food sci,* 3(6), 165–171.

Nelson-Quartey, F. C., Amagloh, F. K., Oduro, I. and Ellis, W. O. (2007). Formulation of an infant food based on breadfruit (*Artocarpus altilis*) and breadnut (*Artocarpus camansi*). *Acta Horti*. (ISHS) 757:212-224.

Nnamezie, A. A., Famuwagun, A. A., Gbadamosi, S. O. (2021). Characterization of okra seed flours, protein concentrate, protein isolate and enzymatic hydrolysates. *Food Prod, Proc and Nutri*, **Springer Open, 3 : 1 4 .** https://doi.org/10.1186/s43014-021-00059-9.

Ojokoh, A. O. and Wei, Y. (2011). Effect of fermentation on chemical composition and nutritional quality of extrued and fermented soya products. *Int J of Food Eng*, 7(4) Article 6:doi10.2202/1556-3758-1857

Olorode, O. O., Idowu, M. A., Ilori, O. A. (2013). Effect of Benoil (*Moringa oleifera*) Leaf Powder on the Quality Characteristics of 'ogi'. *J of Food Nutri*, 2013;3(2):83–89.

Okezie, B. O *and Bello, A.* B. *(*1988). Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. *J of Food Sci*, 53*:* 450–*45*4.

Oluwamukomi, M. O., Eleyinmi, A. F. and Enujiugha, V. N. (2005). Effect of soy supplementation and its stage of inclusion on the quality of ogi – a fermented maize meal. *Food Chem*, 91: 651-657.

Omoni, A. and Aluko, R.E. (2006). Mechanism of the inhibition of calmodulin-dependent neuronal-nitric oxide synthase by flaxseed protein hydrolysates. *J of Ame Oil Chem,* 83: 335–340.

Onuoha, O. G., Chibuzo, E. and Badau, M. (2014). Studies on the potential of malted *Digitaria exilis*, *Cyperus esculentus* and *Colocasia esculenta* flour blends as weaning food formulation. *Nig Food J*, 32: 40-47.

Otunola, E. T., Elizabeth, O. S. and Aderonke, O. (2007). Influence of the Addition of Okra Seed Flour on the Properties of 'Ogi', a Nigerian Fermented Maize Food. Conference on Int Agri Res for Dev, 1-7.

Osundahunsi, O.F., and Aworh, O.C. (2003): Nutritional evaluation, with emphasis on protein quality of maize-based complementary foods enriched with soya bean and cowpea tempe. *Int J of Food Sci and Tech*, 38, 809-813.

Oyarekua, M. A. (2009). Co-fermentation of cassava/cowpea/carrot to produce infant complementary food of improved nutritive quality. *Asian J of Clinic Nutr*, 1: 120–130.

Sathe, S.K. and D.E. Salunkhe, (1981). Functional properties of Lupin seed (Lupinus mutabilis) proteins and concentrates. *J of Food Sci*, 46: 149-197.

Shittu, T.A., Sanni, L.O., Awonorin, S. O. and Maziya-Dixon, B. (2005). Multivariate techniques in studying flour making characteristics of some Cassava Mosaic disease resistant cassava clones. *Afr Crop Sci Conf Proc*, 7: 621-630.

Smolin, L.A and Grosvenor, M.B. (2003). Nutrition: Science and Application. 3rd ed. Wiley and Sons.