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Nutritional and Quality Characteristics of White Maize *Ogi* Flour Enriched with *Moringa oleifera* Seed

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OAO and KAT designed the study. Author OAO performed the chemical analysis and wrote the first draft of the manuscript. Authors BSO and MMI worked on the technical quality of the manuscript and its revision. Author KAT supervised the project. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Aim is to investigate the effect of boiling and fermentation of *Moringa oleifera* (*M. oleifera*) seed on nutritional quality of enriched maize *ogi* flour.
Place and Duration: The study was carried out in the Department of Food Science and Technology, Obafemi Awolowo University, Ife, Nigeria, between May-December, 2014.
Methodology: Raw and treated *M. oleifera* seed were wet milled together with fermented maize in the ratio 80:20 and sieved to obtain enriched *ogi* slurry. The slurry was dewatered, dried and milled to obtain *ogi* flour. *Ogi* prepared from 100% maize was used as control.
Results: The results showed significant increase (P=0.05) in protein (9.73 - 10.77%), ash (0.67 - 0.91%), and fat (10.84 - 12.34%) contents of the enriched products as compared with control (6.58, 0.53, and 5.05% for protein, ash and fat respectively). Fermentation and boiling of the seed reduced the fat content but boiling indicated the highest protein content while fermentation resulted in highest ash content. Fermentation improved P, Ca, Na and Fe (195.60, 21.80, 31.35

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and 4.57 mg/100g) content of the enriched *ogi*. Results of sensory evaluation showed that sample with fermented *M. oleifera* seed was not significantly different (*P*=0.05) from the control.
Conclusion: The study shows that enriching white maize *ogi* with *M. oleifera* seed improves nutrients quality while fermentation and boiling lower the antinutritional factors without adverse effect on sensory attributes.

Keywords: Moringa oleifera; ogi flour; fermentation; nutrients; antinutrients.

1. INTRODUCTION

Ogi made from fermented maize, is a popular staple food in developing countries and is known to be deficient in various nutrients such as protein, vitamins and minerals. Various studies have been carried out to improve the nutritive value of *ogi*. Improvement in protein and ash content of *ogi* was achieved by fortification with okra seed meal [1]. Likewise, nutritive value of *ogi* was also improved by substitution of maize with soy bean [2], African oil bean [3] and pawpaw [4].

M. oleifera has been termed as 'natural nutrition of the tropics' [5]. The seeds are consumed after frying and reported to taste like peanuts. The seeds of *M. oleifera* have antimicrobial activity and are utilized for waste water treatment. *M. oleifera* seeds have been reported to be rich in protein, minerals and lipids. The seeds are also good source of vitamins, flavonoids and total phenol [6,7] and are also known to contain some antinutritional factors though reported to be within the recommended consumable limit [8]. In addition, *M. oleifera* has also been reported to have bitter and astringent taste as a result of presence of some of these antinutrients such as saponin and alkaloids [9]. Different processing methods have been reported by several researchers to remove or reduced the antinutritional factors in both cereals and leguminous plant. Some of these methods include soaking, fermentation, germination, boiling, microwave cooking, autoclaving, irradiation, selective extraction and enzymatic treatment [9,10]. Ogunsina and Radha [9] used microwave cooking and boiling to debitered *M. oleifera* seed. They established that 35 min of ordinary boiling or 25 min of microwave cooking using seed/water ratio of 1:30 w/v is effective for debittering *M. oleifera* seed. Khokhar and Apenten [10] reported that soaking and cooking is effective in reducing saponin contents of legumes. Fermentation and boiling have also been reported to improve nutritional quality and palatability of food products.

This study therefore investigates the enrichment of *ogi* with *M. oleifera* seeds and the effect of fermentation and boiling of the seeds on the nutritional value and antinutritional factors of the resulting *ogi*. The interference of the antinutritional factors with some of the mineral components and consumer acceptability of the enriched products was also considered with 100% white maize *ogi* as the control.

2. MATERIALS AND METHODS

2.1 Materials Collection

White maize (ART/98/SW05-OB-W) was obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. *M. oleifera* seed was obtained from the Teaching and Research farm of Obafemi Awolowo University, Ile-Ife, Nigeria. All chemicals used were of analytical grade.

2.1.1 Preparation of *ogi* and *M. oleifera* seeds

Ogi was prepared in the laboratory as well as boiling and fermentation of the *M. oleifera* seeds as outlined in Fig. 1. Raw, boiled and fermented *M. oleifera* seeds were wet milled to slurry together with fermented maize in the ratio 80:20 and sieved with double layer muslin cloth (ratio 80:20 gave best result among many formulations used for preliminary study). The filtrate was allowed to sediment, dewatered, dried and milled to produce *ogi* flour. *Ogi* flour prepared from 100% maize was used as control. Drying was done using a locally fabricated hot air dryer in the department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife while grinding was done using Marlex Excella dry mill (Marlex Appliances PVT, Daman) to obtain *Ogi-Moringa* flour. The resulted enriched *ogi* flours and the control sample were analysed for proximate, mineral, bioactive compounds, antinutrional and sensory properties.

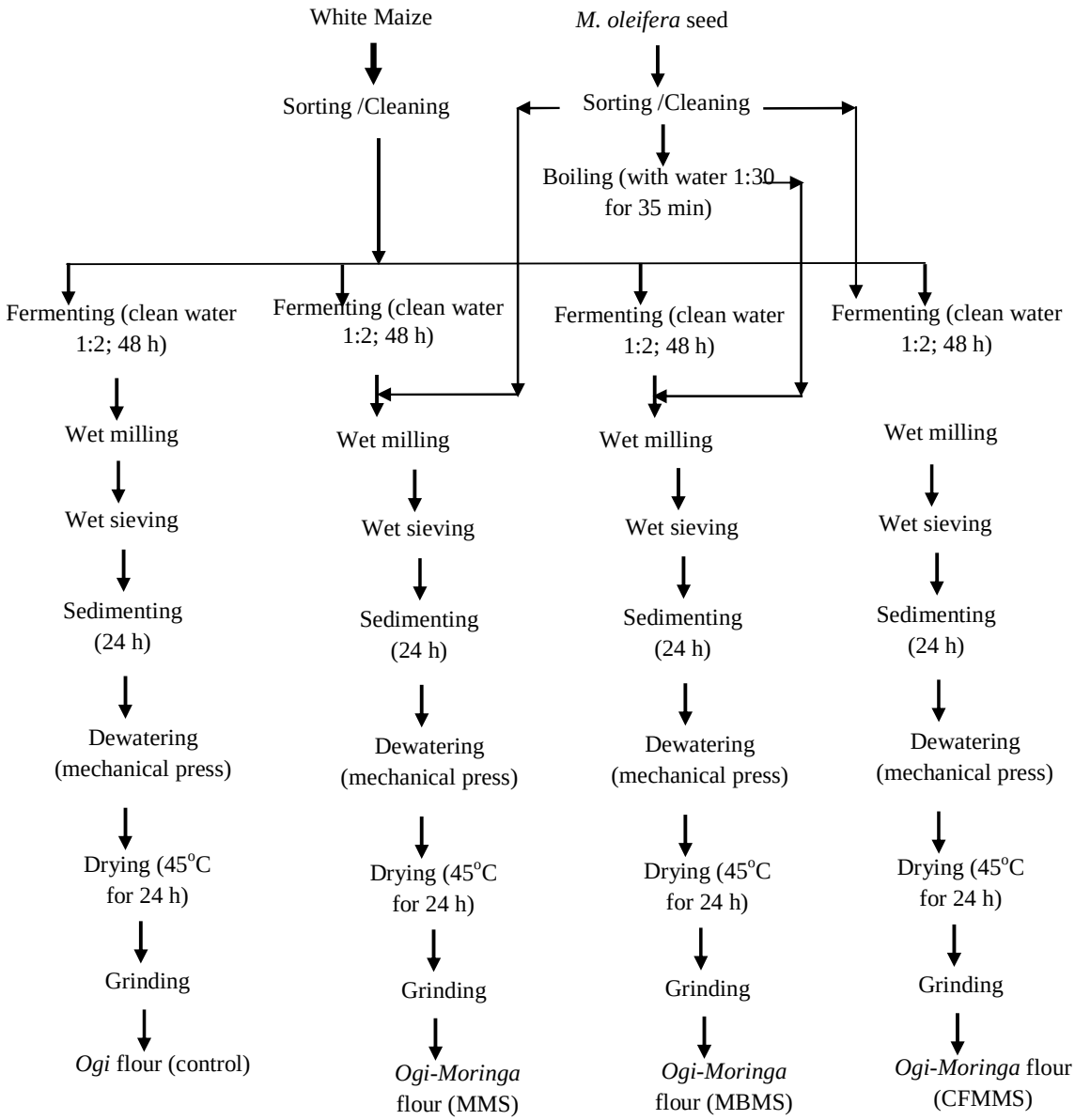

Fig. 1. Preparation of *Ogi-Moringa* seed flour

2.2 Proximate Analysis of the Enriched *Ogi-Moringa* Flour

Crude protein, Crude fat, Total ash, crude fiber and moisture content were determined by standard methods of analysis [11]. Percent nitrogen was estimated by micro-kjeldhal method using automated nitrogen distiller and crude protein content was calculated by multiplying the nitrogen value with 6.25. Crude fat was determined by the continuous solvent extraction method using soxhlet apparatus. Determination of total ash content was done by ashing at 550℃ for 3 h. The crude fibre content of the samples was done by digestion method and moisture content was done by weighing in crucible and drying in oven at 105℃, until a constant weight was obtained. Carbohydrate content was determined by difference.

2.3 Minerals Content Determination

The mineral compositions of the samples were determined according to the method of AOAC

[11]. One gram of sample was digested with nitric acid: perchloric acid: sulphuric acid mixture in the ratio 9:2:1 respectively and filtered. The filtrate was made up to mark in a 5 ml volumetric flask. The filtered solution was loaded to an atomic absorption spectrophotometer (Perking Elmer, model 402) for the determination of calcium, magnesium, manganese, copper, iron and zinc. Sodium and potassium were determined by flame photometry while phosphorous was determined using the Vanodo-molybdate method [11].

2.4 Determination of Antinutritional Factors

Antinutrients which include tannin, phytate, saponin and alkaloids were determined as follows:

2.4.1 Tannin determination

Tannin was determined by the modified vanillin-HCl method of Price et al. [12]. A 0.2 g sample was extracted with 10 ml of 1.0% (v/v) HCl-MeOH solution for 1 h with continuous shaking. The mixture was filtered, made up to 10ml mark with extracting solvent. 5 ml of vanillin-HCl reagent was added to 1 ml aliquots, and the colour developed after 20 min at room temperature was read at 500 nm. Another 1 ml aliquot was reacted with 5 ml of 4% HCl-MeOH solution to serve as blank in other to correct for interference from natural pigments in the sample. A standard curve was prepared using catechin (Sigma Chemical, St Louis, MO) after correcting for the blank and tannin concentration was expressed in g/100 g.

2.4.2 Phytate determination

Phytate was determined according to the method of Harland and Oberleas [13]. Phytate was extracted from *Ogi-moringa* flour using 2.4% HCl. The extract was mixed with EDTA/NaOH solution and placed on an ion-exchange column. Phytate was eluted with 0.7M HCl solution and wet digested with mixture of concentrated H_2SO_4 (0.5 ml) and HNO_3 (3 ml) to release phosphate which was measured colorimetrically. Amount of phytate in original sample was calculated as hexaphosphate equivalent.

2.4.3 Alkaloid determination

Alkaloid content was determined by the method of Obomanu et al. [14] with slight modifications. The sample was extracted for 4h using 20% acetic acid in ethanol and concentrated filtrate was precipitated with concentrated ammonium hydroxide. The precipitate was dried and weighed and expressed as alkaloid content percent of weight of sample.

2.4.4 Saponin determination

The spectrophotometric method of Brunner [15] was used for saponin analysis. The sample was extracted for 2 h using isobutyl alcohol and the filtrate mixed with magnesium carbonate to obtain colourless solution. Red blood colour was developed after the addition of 5% $FeCl_3$ which was red along with saponin stock solution in a UV-Spectrophotometer (Cecil CE 2502) at a wavelength of 380 nm.

$$Saponin = \frac{absorbance\ of\ sample \times dil.factor \times gradient\ of\ standard\ graph}{sample\ weight \times 10{,}000.}\left(\frac{mg}{g}\right)$$

2.5 Determination of Bioactive Compounds

Total phenolic contents of *ogi* samples were determined using Folin-ciocalteu reagent method [16]. Galic acid standard solution was used to prepare calibration curve and the absorbance read at 725 nm. Concentration of flavonoid was estimated spectrophotometrically [17] and Catechin was used to prepare the standard curve with absorbance taken at 500 nm. The concentration in mgCAT/g extract was obtained using the equation below. Total carotenoid was determined spectrophotomerically as reported by Fish et al. [17]. Ascorbic acid content was determined using indophenols titration method (AOAC, 2000).

mgCAT/g extract =

$$\frac{\mu gCAT\ x\ 1\ mg\ x\ mL\ of\ Solvent\ used\ in\ dissolving\ the\ sample\ x\ dilution\ factor}{mL\ X\ 1000\mu g\ x\ mass\ of\ the\ sample\ used}$$

2.6 Sensory Evaluation of the Enriched *Ogi-Moringa* Porridge

Fifty grammes of *Ogi-Moringa* flour was reconstituted in 80 ml cold water and 500 ml boiling water was thereafter added until a viscous porridge was formed. A 100% maize *ogi* was also prepared to serve as the control. The resulted *ogi* porridge was served in small breakable dishes when hot. A fifteen member untrained panel of judges was constituted among students and staffs of Department of Food Science and Technology, Obafemi Awolowo

University, Nigeria based on familiarity with the product. The samples were rated on a 9-point hedonic scale which was quantified from one for dislike extremely to nine like extremely [18].

2.7 Statistical Analysis

Data were analyzed, where necessary, by the analysis of variance (ANOVA) statistical technique, and differences between means were separated using Duncan's Multiple range test.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of *Ogi-Moringa* Seed Flour

The proximate composition of the *Ogi-Moringa oleifera* blends flour is presented in Table 1. The results revealed that substitution of maize with *M.oleifera* seed improved protein, fat and ash contents of blends significantly (*P*=0.05) with lower carbohydrate content. Protein, fat and ash of *Ogi-Moringa* ranged from 9.37-10.77%, 10.84-12.34% and 0.67-0.91% respectively. The control sample (100% maize *ogi*) has 6.58, 5.05 and 0.53% for protein, fat and ash respectively. Addition of *M. oleifera* seed to *ogi* led to a minimum percent increase of 47.87, 26.41 and 144% in crude protein, total ash and crude fat respectively. However, boiling (MBMS) and fermentation (CFMMS) of *M. oleifera* seed increased crude protein (by 10.69% and 10.17%), total ash (by 11.94 and 35.82%) but reduced the fat content (by 4.29 and 12.15%) of the blends when compared with sample MMS (untreated *M. oleifera* seed). The difference in the protein content of sample MBMS (10.77%) and sample CFMMS (10.72%) was not significant (*P*=0.05). This implied that boiling and fermentation of *M. oleifera* seed exerted the same effects on the protein content of the enriched products therefore; either of the pretreatments may be adopted. The increase in the protein content of enriched *ogi* with boiled and fermented *M. oleifera* seed (samples MBMS and CFMMS) may be due to hydrolysis of the protein molecule to amino acid and other simple peptides as a result of boiling and increase in microbial mass during fermentation [19,20]. There was no significant difference (*P*=0.05) in the total ash of sample MMS (0.67%) and MBMS (0.75%) while the total ash of sample CFMMS (0.91%) was significantly higher than MBMS. Higher value observed in total ash content of enriched *ogi* as a result of fermentation suggested that leaching out of soluble inorganic salts during fermentation of *M. oleifera* seed with maize was minimal compared to the leaching out that occured during 35 min boiling of *M. oleifera* seed. Crude fat contents of sample with boiled *M. oleifera* seeds (MBMS-11.81%) was higher than in sample with fermented *M. oleifera* seed (CFMMS-10.84%). Decrease in fat content as a result of fermentation reported in this study was similarly reported by other researchers [21,22]. The result obtained in this study agrees with the findings of other researchers that processing methods such as boiling and fermentation improved the nutritional quality of food products [23,24].

3.2 Minerals in the *Ogi-Moringa* Seed Flour

Table 2 shows the mineral composition of *Ogi-Moringa* and the computed ratio of some nutritionally important minerals. The content of all the mineral elements examined increased with the inclusion of *M. oleifera* seeds (either treated or untreated seeds) to *ogi*. Phosphorus (P) and magnesium (Mg) were the most abundant mineral found in the enriched products while copper (Cu) and manganese were the least. This trend was also observed by Ijarotimi and Keshinro [25] with infant formula formulated from popcorn, bambaranut and locust bean. The phosphorus content of o*gi* ranged from 142.76 (100% maize *ogi*) to 195.60 mg/100 g (CFMMS) while magnesium ranged from 93.39 (CFMMS) to 247.11 mg/100 g (MBMS). The recommended daily allowance (RDA) of phosphorus and magnesium are 800 mg and 350 mg respectively. This suggested that more than 100g of the products need to be consumed daily. Fermentation of the *M. oleifera* seed resulted in the reduction in magnesium content but improved phosphorus by 16.62% while boiling reduced phosphorus but increased magnesium. Magnesium stimulates gastric and intestinal function while phosphorus serves as the main regulator of energy metabolism in cells. Calcium (Ca) and Sodium (Na) were higher in sample CFMMS (21.80 and 31.15 mg/100 g respectively) than sample MBMS (16.15 and 26.23 mg/100 g respectively). Fermentation of *M. oleifera* enhanced its Na and Ca contents by 16.86 and 17.02% respectively while boiling of the seed did not significantly reduced (*p*=0.05) Na content but led to reduction of about 13.31% in Ca content. Potassium (K) content of the enriched samples were not different from each other implying that neither fermentation nor boiling affected potassium content of the *M. oleifera* enriched *ogi*.

Sodium and potassium are responsible for maintaining osmotic balance of the body fluids. The sodium to potassium ratio of less than 1 is recommended for preventing high blood pressure. The Ca/P and Ca/Mg ratio ranged between 0.10 to 0.11 and 0.07 to 0.23 respectively. The values compared favourably with the recommended ratio of 1.0 and 2.2 respectively [26]. Zinc (Zn) content of *M.oleifera* enriched *ogi* were 7.46, 7.31 and 4.47 mg/100 g for samples MMS, MBMS and CFMMS respectively. There was no significant difference in Zn content of samples MMS and MBMS while fermentation of *M. oleifera* seed led to 40% decrease in Zn content of the enriched *ogi*. Zn is required to prevent mental retardations in humans [26]. Iron (Fe) of the enriched *ogi* was enhanced by boiling and fermentation of *M. oleifera* seed. Sample with fermented *M. oleifera* seed (CFMMS) had the highest Fe content (4.57 mg/100 g) followed by sample MBMS (4.12 mg/100 g) and sample MMS (4.05 mg/100 g). Ijarotimi (2012) reported increase in Ca, K, Na, Mg, Fe, and P but decrease in Zn and Mn of fermented wheat flour as compared with raw wheat flour. This observation has been attributed to bio-synthesis and activities of micro-organism during fermentation [27]. Reduction observed in P, Ca, Na and Zn of sample MBMS as compared with sample MMS may be due to leaching.

3.3 Antinutritional Factors in the *Ogi-Moringa* Seed Flour

Antinutritional factors of the *ogi* flour enriched with raw (MMS), boiled (MBMS) and fermented (CFMMS) *M. oleifera* seed is presented in Table 3. The tannin contents ranged from 0.64 – 0.85 mg/100 g, phytate content from 2.05 – 3.16 mg/100 g, cyanogenic glucoside from 2.77-2.97 mg/kg, saponin from 0.002-0.04% and alkaloids 0.002 to 0.202%.

Table 1. Proximate composition (%) of *Ogi-Moringa* seed flours

Components	MMS	MBMS	CFMMS	100% maize *ogi*
Moisture	8.60±0.19^{b}	8.55±0.07^{ab}	8.52±0.03^{ab}	8.27±0.06^{a}
Crude protein	9.73±0.25^{b}	10.77±0.01^{c}	10.72±0.07^{c}	6.58±0.12^{a}
Crude fat	12.34±0.59^{d}	11.81±0.14^{c}	10.84±0.12^{b}	5.05±0.11^{a}
Ash	0.67±0.04^{b}	0.75±0.05^{b}	0.91±0.21^{c}	0.53±0.04^{a}
Crude fibre	0.85±0.29^{c}	0.88±0.05^{c}	0.58±0.01^{b}	0.52±0.01^{a}
Carbohydrate	67.81±0.64^{a}	67.24±0.49^{a}	68.43±0.01^{a}	79.05±0.72^{b}

Values are means of replicate determination (±SD).
Means with same letters on same row are significantly different (P=0.05)
MMS (fermented maize + raw Moringa oleifera seed); MBMS (Fermented maize + boiled Moringa oleifera seed): CFMMS (Co-fermented Maize and Moringa oleifera seed)

Table 2. Mineral composition of the *Ogi-Moringa* seed flours (mg/100 g)

Nutrients	MMS	MBMS	CFMMS	100% maize *ogi*
K	68.75±0.82^{b}	68.75±0.53^{b}	68.75±0.12^{b}	62.50±0.29^{a}
P	168.58±2.63^{c}	150.52±3.42^{b}	195.60±1.72^{d}	142.76±2.06^{a}
Mg	211.57±1.60^{c}	247.11±1.87^{d}	93.39±6.06^{a}	117.36±1.72^{b}
Ca	18.63±0.08^{c}	16.15±0.04^{b}	21.80±0.11^{d}	14.95±0.07^{a}
S	13.98±0.14^{c}	12.17±0.69^{b}	3.75±0.33^{a}	3.10±0.62^{a}
Na	26.63±1.59^{a}	26.23±0.66^{a}	31.15±0.8^{b}	30.34±0.84^{b}
Zn	7.46±0.12^{b}	7.31±0.64^{b}	4.47±0.22^{b}	0.52±0.34^{a}
Fe	4.05±0.59^{b}	4.12±0.55^{b}	4.57±0.59^{c}	3.66±0.16^{a}
Cu	0.89±0.03^{a}	0.93±0.07^{a}	1.20±0.03^{c}	1.05±0.05^{b}
Mn	1.47±0.86^{ab}	1.49±0.09^{b}	1.22±0.13^{a}	1.40±0.06^{ab}
K/Na	2.62	2.58	2.21	2.06
Ca/P	0.11	0.11	0.11	0.10
Ca/Mg	0.09	0.07	0.23	0.13
K/(Ca+Mg)	0.30	0.26	0.60	0.47

Values are means of replicate determination (±SD).
Means with same letters on same row are significantly different (P=0.05)
MMS (fermented maize + raw Moringa oleifera seed); MBMS (Fermented maize + boiled Moringa oleifera seed): CFMMS (Co-fermented Maize and Moringa oleifera seed)

Table 3. Levels of antinutritional factors in the *Ogi-Moringa* seed flours

Antinutrients	MMS	MBMS	CFMMS	100% maize *ogi*
Tannin (mg/100 g)	0.77±0.37[b]	0.77±0.15[b]	0.64±0.05[a]	0.85±0.37[c]
Phytate (mg/100 g)	2.41±0.57[b]	2.35±0.14[b]	2.05±0.25[a]	3.16±0.45[c]
Saponin (%)	0.040±0.001[c]	0.029±0.002[b]	0.032±0.004[b]	0.002±0.001[a]
Alkaloid (%)	0.202±0.005[c]	0.074±0.001[b]	0.195±0.002[c]	0.002±0.000[a]
Phytate/ Ca	0.078	0.088	0.057	nd
Phytate/ Zn	0.32	0.32	0.46	nd
Phytate/Fe	0.51	0.48	0.38	nd

Values are means of replicate determination (±SD).
Means with same letters on same row are significantly different (P=0.05)
nd means not determined
MMS (fermented maize + raw Moringa oleifera seed); MBMS (Fermented maize + boiled Moringa oleifera seed): CFMMS (Co-fermented Maize and Moringa oleifera seed)

Samples with boiled *M. oleifera* seed (MBMS) had the lowest level of saponin (0.029%) and alkaloids (0.074%) while fermented *M. oleifera* seed sample (CFMMS) had lowest level of tannin (0.64 mg/100 g) and phytate (2.05 mg/100 g). The reduction in phytate content during fermentation may be due to phytase activity naturally present in the cereals and the activity of fermentative microrganism in the fermenting medium [28]. This result implies that fermentation is more effective than boiling in reducing tannin and phytate while boiling is more effective than fermentation for the reduction of saponin and alkaloids found in *M. oleifera* seed. However, the antinutritional values obtained in this study are lower than the recommended lethal dose and those reported by other researchers for fluted pumpkin seed flour, soyabean, ogi with 20% Afrcan oil bean (2.91 mg/100 g for tannin), asparagus beans, and cocoyam flour [3,10,19, 20,29]. Sallau et al. [30] reported that boiling caused a significant reduction in the level of antinutritional content of *M. oleifera*. Studies have shown that processing methods such as cooking, dehulling, soaking, fermentation and germination reduce or eliminate the anti-nutrient factors of food products [19,31,32]. The presence of phytate in foods has been associated with reduced mineral absorption due to the structure of phytate which has high density of negatively charged phosphate groups. The phosphate form stable complexes with mineral ions causing their non-availability for intestinal absorption. To predict the effect of phytate on bioavailability of Ca, Fe and Zn, phytate to nutrients molar ratio were calculated (Table 3) and compared with the critical values. The Phytate/Ca ranged from 0.05 – 0.07, Phytate/Zn from 0.32 – 0.45 and Phytate/Fe from 0.38 – 0.51. Sample CFMMS had the least molar ratio for Phytate/Fe (0.38) and Phytate/Ca(0.057) while sample MBMS had the least Phytate/Zn (0.03) molar ratio. The critical molar ratio (mol/kg) as reported by Morris and Ellis (1985) for phytate/Ca, phytate/Zn and phytate/Fe are 0.24, 15, 1.0 respectively. Phytate mineral molar ratio obtained in this study are below the critical molar ratios implying that the phytate in the enriched *ogi* cannot impair the bioavailability of these minerals (Fe, Zn and Ca) in the body. The ratio greater than the critical values has been associated with biochemical and or clinical evidence of Zinc, Iron and Calcium deficiency [33].

3.4 Bioactive Compounds in the *Ogi-Moringa*

Bioactive compounds of *Ogi-Moringa* are shown in Table 4. The presence of phenol and flavonoid in the products (*Ogi-Moringa*) indicates the products have antioxidative capacity. Total phenol of the enriched samples ranged from 33.50 to 65.00 mg/100 g of sample. Sample with fermented seed has higher total phenol (65.00 mg/100 g) than sample with boiled seed (34.00 mg/100 g). There was no significant difference (*P* = 0.05) in the total phenol of sample MBMS and MMS. This is an indication that total phenol of the enriched products is more enhanced by fermentation. Total flavonoid ranged from 3.10 to 6.90 mg/100 g of sample. Sample MBMS contain more flavonoid (6.9 mg/100 g) than sample CFMMS (3.1%) while flavonoid content of sample MMS was (4.7 mg/100 g). This implied boiling enhanced flavonoid while portion of flavonoid of the sample was lost as a result of fermentation.

Ogunmoyole et al. [34] reported that boiling markedly improved phenolics and flavonoids of *D. edulis* when compared with the unboiled samples. It has been suggested that boiling may solubilise and release some of the phenols and flavonoids that are insoluble at room temperature

resulting in an increase in its contents [34]. Total phenols obtained in this study (33.50 – 56.00 mg/100 g) is small compared with 20.6, 18.2, 15.4 mg/g reported by Luo et al. [35] for whole soybean, wheat and oat respectively, likewise total flavonoid. This may be due to milling and sieving of maize and *M. oleifera* seed during processing into *ogi*. Phenols and flavonoids play a significant role as physiological and dietary antioxidants, thereby augmenting the body's natural resistance to oxidative damage [36]. Total carotenoid content of the *Ogi-Moringa* ranged from 16.80 µg/g (CFMMS) and 32.40 µg/g (MBMS) while the control sample (100% maize *ogi*) has 12.00 µg/g. Carotenoid content of boiled *M. oleifera* seed *ogi* is significantly higher than 24.40 ug/g for *ogi* with raw *M. oleifera* seed and 16.80 µg/g for sample with fermented *M. oleifera* seed. Boiling enhanced carotenoid content while fermentation reduced it, the reason for this is not known. However it may be that boiling of *M. oleifera* seed before further processing with maize into *ogi* prevents the loss of carotenoid in this seed during processes like milling, sieving, removal of wash water, and drying. Ascorbic acid ranged from 0.23 mg/g (MBMS) to 0.36 mg/g (MMS). Fermentation and boiling of *M. oleifera* seeds led to reduction in the ascorbic acid content of the enriched product but its content in sample MBMS (0.23 mg/g) was not significantly different (*P*=0.05) from 0.26 mg/g of sample CFMMS. Ascorbic acid is water soluble and may get oxidized at boiling temperature because its unstable at such high temperature thereby reducing it content [34]. Ascorbic acid has been referred to as a powerful water soluble antioxidants and its established role is to prevent scurvy [37]. Carotenoid and ascorbic acid are referred to as non-Enzymatic antioxidant in which their intake reduces the risk of coronary heart disease and cancer [38,39]. The antioxidants may mediate their effects by directly reacting with reactive oxygen molecules, quenching them and/or chelating the catalytic metal ions [40].

3.5 Sensory Evaluation of *Ogi-Moringa*

Table 5 shows the results of taste panel assessment of prepared *ogi* porridge made from the enriched *ogi* flour samples. The texture of the enriched *ogi* porridge was not significantly different (*P*=0.05) the control (100% maize *ogi* porridge) while colour and aroma of the enriched samples were significantly different from each other. However, the overall acceptability of *ogi* porridge with fermented *M. oleifera* seed was not significantly different (*P*=0.05) the control and *ogi* porridge from MBMS and MMS was not significantly different from each other. This implies that fermenting *M. oleifera* seed with maize may produce *ogi* porridge as acceptable as porridge from 100% maize *ogi* and porridge from samples with boiled and raw *M. oleifera* seed may not be as acceptable as 100% maize *ogi* by the consumer.

Table 4. Bioactive compounds of *Ogi-Moringa* seed flours

Bioactive compounds	MMS	MBMS	CFMMS	100% maize ogi
Total carotenoids (µg/g)	24.40±2.82^{b}	32.40±0.57^{c}	16.80±2.26^{a}	12.00±2.26^{a}
Ascorbic acid (mg/g)	0.36±0.05^{c}	0.23±0.04^{b}	0.26±0.01^{b}	0.13±0.10^{a}
Total flavonoid (mg/100 g)	4.70±0.01^{b}	6.90±0.04^{c}	3.10±0.01^{a}	ND
Total phenol (mg/100 g)	33.50±0.21^{b}	34.00±0.14^{b}	65.00±0.14^{c}	2.10±0.00^{a}

Values are means of replicate determinations (±SD).
Means with same letters on same row are significantly different (P=0.05)
ND means not detected
MMS (fermented maize + raw Moringa oleifera seed); MBMS (Fermented maize + boiled Moringa oleifera seed): CFMMS (Co-fermented Maize and Moringa oleifera seed)

Table 5. Mean sensory score for *Ogi-Moringa* flours

Sensory attributes	MMS	MBMS	CFMMS	100% maize ogi
Taste	3.87±0.99^{c}	3.00±0.92^{ab}	3.53±0.91^{bc}	2.33±1.11^{a}
Colour	2.87±1.05^{c}	2.60±0.99^{ab}	2.53±0.64^{ab}	2.07±0.96^{a}
Flavour	3.40±1.05^{b}	3.73±0.79^{b}	3.13±1.30^{ab}	2.40±0.91^{a}
Texture	3.07±0.96^{a}	3.13±1.19^{a}	2.67±0.74^{a}	2.47±1.29^{a}
Overall acceptability	3.40±1.24^{b}	3.73±0.88^{b}	2.40±0.91^{a}	2.27±1.45^{a}

Values are means of replicate determinations (±SD).
Means with same letters on same row are significantly different (p=0.05)
MMS (fermented maize + raw Moringa oleifera seed); MBMS (Fermented maize + boiled Moringa oleifera seed): CFMMS (Co-fermented Maize and Moringa oleifera seed)

4. CONCLUSIONS

The study shows that *M. oleifera* seed can be used to improve protein and mineral element quality of *ogi*. Fermentation and boiling of *M. oleifera* are effective in reducing the antinutritional factors of *ogi* enriched with *M. oleifera* seed. Interaction between phytate and the mineral elements improved the bioavailabilty of the minerals. Boiling is more effective in improving the flavonoid and carotenoid content of the enriched *ogi* while fermentation led to a significant increase in total phenol content. Fermenting *M. oleifera* seeds produced *ogi* porridge acceptable to the consumers as porridge from 100% maize *ogi*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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