Prev. Nutr. Food Sci. 2019;24(3):348-356
https://doi.org/10.3746/pnf.2019.24.3.348
pISSN 2287-1098 · eISSN 2287-8602

Note

Nutritional Evaluation of Enhanced Unsieved *Ogi* Paste with Garlic and Ginger

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ABSTRACT: *Ogi* is a cheap and readily available health-sustaining fermented food in Africa. This study assessed the effect of enhancing unsieved *ogi* paste with garlic and ginger (2% and 4%) both individually and together on organoleptic acceptability and nutritional changes. These pastes were subjected to seven treatments at ambient and refrigerated temperatures for 4 weeks during which sensory analysis was carried out, and mineral content, total antioxidant activities, and proximate composition were evaluated. *Ogi* (maize) enhanced with 2% garlic+2% ginger and *ogi* (sorghum) enhanced with 4% garlic+2% ginger were most preferred. There was no significant difference in organoleptic evaluation of the preferred enhanced *ogi* pastes compared to the control samples. Crude protein ranged between 7.73～9.19% and 9.83～10.08% for control *ogi*, and between 7.76～8.36% and 10.07～10.92% in the maize and sorghum enhanced *ogi* pastes, respectively. The fat contents of all pastes were significantly different at $P<0.05$. Antioxidant properties of *ogi* paste were enhanced by ginger and garlic. *Ogi* supplemented with 4% garlic+2% ginger showed the highest radical scavenging activity (0.75～0.97 IC_{50} mg/mL). The results show that garlic and ginger either alone or in combination have potential to enhance the nutritional value of *ogi* pastes, and demonstrate the acceptability of using maize or sorghum as primary raw materials.

Keywords: garlic, ginger, *ogi* paste, acceptability, food enhancer

INTRODUCTION

Cereals are the most commonly consumed staple food in sub-Saharan Africa and contribute significantly to efforts for achieving global nutritional security for the exponentially growing population in both developed and developing countries (Vila-Real et al., 2017). Sorghum grains play an indispensable role in household food security. Processing of sorghum grains into value added food products on an industrial scale serves as a source of income and an important key to economic development (Bolade et al., 2018). The agricultural economy of sorghum is ranked the fifth largest for cereals globally (Ogunsakin et al., 2015). Sorghum can be consumed by individuals with gluten intolerance and coeliac disease owing to the lack of gluten (Kulamarva et al., 2009). Sorghum has also proven to be a nutritious cereal and an outstanding source of bioavailable iron and zinc; sorghum is also richer in copper and pantothenate than other grains, thus plays an important role in human nutrition (Nyamwaro et al., 2018). Inclusion of quality protein maize (QPM) in daily diet is beneficial for many undernourished communities as it contains high level of essential amino acids (Olaniran and Abiose, 2019). *Ogi* is a fermented porridge of West African origin produced from sorghum (*Sorghum bicolor*), millet (*Pennisetum typhodenum*), and maize (*Zea mays*) (Okafor et al., 2018; Osuntoki and Korie, 2010). Akin-Osanaiye and Oladele (2017) documented *ogi* as the most popular fermented health food in many West African nations. *Ogi* is used for weaning children in most developing countries since it is economical, easy to process and is readily available (Bolaji et al., 2015; Olaniran and Abiose, 2019). Sieving *ogi* leads to loss of vital nutrients. Micronutrient deficiency associated with undernutrition is prevalent in families that are unable to purchase food adequately rich in vitamins and minerals. Common risk groups include women of childbearing age, infants, and elderly in risky situations, especially refugees or displaced persons (Al-Awwadi, 2017). Garlic is a rich source of vitamins and minerals that are crucial to human health. Garlic bulbs are amongst the richest source of minerals such as selenium, calcium, iron, potassium, magnesium, manganese,

Received 6 March 2019; Accepted 6 July 2019; Published online 30 September 2019

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and zinc. Selenium helps maintain a healthy heart and is a vital cofactor for antioxidant enzymes in the body. Selenium also contains iron, which is essential for red blood cell formation (Frank et al., 2014). Ginger extracts are high in vitamins B2 and B12, and add color and improve the acceptability of food (Abdelazim et al., 2017). Ginger and garlic have also been reported to exhibit good antioxidant activities, and their antioxidant capacities and total phenolic contents (TPC) have received attention for their roles in improving food quality (Olaniran et al., 2015). Ginger, the rhizome of *Zingiber officinale*, is a common condiment used in several foods and beverages (Tende et al., 2014), and garlic (*Allium sativum*) is one of the most popular spices used worldwide to flavour food. Ginger and garlic are universally acceptable and relatively inexpensive (Oladipo and Jadesimi, 2013). Both are generally regarded as safe and beneficial to human health, and to be of interest as enhancers for improving *ogi* pastes. Food enhancement is an effective way of counteracting deficiencies among displaced persons as it does not necessitate changing individual diets, rather addition with cheap and accessible supplements while encouraging household production. Therefore, this study evaluated the effects of enhancing unseived *ogi* paste with ginger and garlic on acceptability and nutritional quality.

MATERIALS AND METHODS

Sample preparation

White maize grains (quality protein) were from Institute of Agricultural Research and Training, Ibadan, Nigeria. Sorghum (red variety), fresh ginger rhizomes, and garlic bulbs (white variety) were from local market, Ile-Ife, Nigeria. All samples were rinsed to remove dirt and air dried until use.

Preparation of powdered garlic and ginger

250 g of unblemished garlic bulbs and ginger rhizomes were cleaned, peeled, diced, and dried in a hot air oven (Gallenkamp, London, UK) at 65°C for 12 h. Samples were pulverized in a grinder (Marlex Appliances PVT, Mumbai, India), sifted with a 50 to 60 μm mesh and stored in airtight plastic containers (Olaniran and Abiose, 2019).

Production of fermented unsieved *ogi* enhanced with powdered garlic and ginger

The grains (maize and sorghum) winnowed and were sorted. Ten kilograms (10 kg) of QPM and sorghum grains were soaked separately in 20 L of portable water at room temperature (27±2°C) for 72 h. The water was drained, and the grains were wet-milled into smooth paste using an attrition mill; grains were not sieved. The unsieved paste was divided into 8 portions of 400 g each. The first portion was the control (without garlic/ginger). The second portion was supplemented with 2% powdered garlic, and the third was supplemented with 4% garlic. Similarly, the fourth and fifth portions were supplemented with 2% and 4% powdered ginger, respectively. Garlic and ginger powder was added to the sixth, seventh, and eighth portions of *ogi* pastes at ratios of 2:2; 2:4, and 4:2 (w/w), respectively. Distilled water (200 mL) was added to 400 g of each paste, and pastes were evenly homogenized into slurries and fermented for 24 h at ambient temperature (27±2°C). The water was then decanted, reweighed, packaged in 100 g airtight cleaned plastic containers, and labeled (Table 1). The pastes were filled into the containers to 90%, with 10% airspace. Samples were divided randomly in batches and into replicates. One batch was placed on the shelf at ambient temperature (27±2°C) while the other batch was refrigerated (4±1°C) for 4 weeks. The procedure followed was a modified version of that carried out by Akanbi et al. (2003) and Farinde (2015).

Sensory evaluation of *ogi* pastes

Ogi porridge was prepared by adding 10 g *ogi* paste to 15 mL of portable water; boiling water was then added until gelatinization occurred. Samples were randomly served hot on coded plates, and were evaluated based on appearance, colour, aroma, texture, taste, and overall acceptability using a 9 point Hedonic scale with 45 member panels familiar with *ogi* porridge quality. The Department of Food Science, Obafemi Awolowo University research ethics boards approved this study (TP11/12/R/0186). The data obtained were analysed using analysis of variance (ANOVA).

Determination of nutritional quality

Moisture content determination: *Ogi* paste (5 g) was transferred in triplicate into previously weighed cans. Samples were dried to a constant weight at 105°C for 3 h in a forced hot-air oven and were then re-weighed. Samples were then cooled ambient temperature using a desiccator and were weighed again. Sample weight loss was calculated.

Crude protein determination: *Ogi* paste (2 g) was weighed

Table 1. *Ogi* paste labels

Samples	Maize	Sorghum
Control	AM	AS
2% Garlic	BM	BS
4% Garlic	CM	CS
2% Ginger	DM	DS
4% Ginger	EM	ES
2% Garlic+2% Ginger	FM	FS
2% Garlic+4% Ginger	GM	GS
4% Garlic+2% Ginger	HM	HS

into a digestion flask, and 0.8 g of Kjeltec catalyst and concentrated sulphuric acid (15 mL) was added. The flask was heated on previously heated digester (420°C) in a fume cupboard and digested until a clear homogenous mixture was obtained. The flask was removed from the heater after digestion, and was allowed cooling and diluted the content with 50 mL of distilled water. The flask was then placed in an analyzer and NaOH (50 mL) was automatically dispensed. The mixture was heated to release ammonia and was distilled into conical flask containing 2% boric acid (25 mL) as an indicator for 4 min; ammonium borate was then titrated against 0.1 M HCl until a purplish−grey endpoint was observed. The crude protein content was estimated through multiplying by factor 6.25. The experiment was carried out in triplicate and the mean was calculated and recorded (AOAC, 2010).

Crude fat content determination: The fat content of *ogi* paste was determined using a previously dried and weighed Soxhlet extractor with a reflux condenser, and a distillation flask by following a continuous extraction liquid-solid method. *Ogi* paste (2 g) was weighed into a fat free thimble plugged with cotton wool in an extractor fitting chamber. The distillation flask was filled with *n*-hexane until two thirds full, boiled on a heating mantle and the distillate was collected. The heat was adjusted to allow gentle boiling of the solvent until it siphoned, and the *n*-hexane was recovered. The remaining solvent in the mixture was evaporated in a hot-air oven (70°C). The flask was cooled in a desiccator prior to determining the final weight of the flask. The difference between the final and initial weights corresponded to the amount of oil extracted from the sample (AOAC, 2010)

Crude fibre determination: The weighed samples from fat extraction were used to determine crude fibre. Samples were transferred into conical flasks and 100 mL boiling 1.25% H_2SO_4 was added, and were heated for 30 min with frequent rotation. Solutions were filtered, rinsed thrice with 50 mL boiling water, and dried. 1.25% (w/v) NaOH solution (200 mL) was then added and the mixture was boiled for 30 min, filtered, and then washed with 25 mL 1% sulphuric acid, 150 mL boiling water and ethanol (25 mL). The residue was then dried at 100°C to a constant weight, cooled in a desiccator at room temperature and weighed. The weighed residue were ignited at 600°C in a muffle furnace (Gallenkamp) for 30 min, cooled in a desiccator and reweighed.

Total ash determination: Total ash was determined by the dry ashing procedure. Samples (2 g) were weighed into previously weighed porcelain crucibles and were incinerated at 550°C for 6 h in a muffle furnace. The remains were removed from the furnace after ashing, cooling using a desiccator and weighed.

Carbohydrate determination: The percentage of carbohydrate was calculated by subtracting the moisture, ash, crude fiber, fat, and protein contents of each respective samples from 100 (AOAC, 2010).

Mineral determination: Ash from the samples was liquefied in 10 mL of 2 M HNO_3, boiled for 5 min, and filtered into volumetric flask. The filtrate was made up with distilled water to 50 mL. The concentrations of magnesium, manganese, iron, and zinc were determined using atomic absorption spectrophotometer (220GF, Buck Scientific Inc., Norwalk, CT, USA). Standard curves for each mineral were prepared from known concentrations of minerals (AOAC, 2010). Sodium content was determined using Jenway flame photometer PFP7 (Cole-Parmer Instrument Co., Ltd., Cambridgeshire, UK).

Total antioxidant content of *ogi*

Extraction for determination of antioxidant content was carried out using the method described by Olaniran et al. (2013). *Ogi* paste (5 g) samples were weighed into extraction bottles and 100 mL of solvents (95% ethanol and water at ratio 1:1) were added; mixtures were then stirred using a magnetic stirrer for 30 min at room temperature and filtered using Whatman No. 1 filter paper. The crude extracts were stored in air tight tubes in a refrigerator, as a stock solution for further analysis.

Estimation of TPC

Ogi extract (0.1 mL) was mixed with 5.9 mL distilled water; 1.0 mL of the solution was then dispensed into 1.0 mL Folin-Ciocateau reagent, incubated at room temperature for 2～5 min, and then 2 mL of Na_2CO_3 (20% w/v) was added. After 30 min of vigorous mixing using a vortex, the absorbance was measured at 725 nm using a spectrophotometer. The results were expressed as gallic acid equivalent (GAE) using a calibration curve using gallic acid as standards (100 mg/mL): $y=0.0022x-0.0292$, $R^2=0.9962$ (Olaniran et al., 2013).

1,1-Diphenyl-2-picrylhydrazyl (DPPH) assay of *ogi* extracts

DPPH radical scavenging activity of *ogi* extracts were measured using the procedure described by Cakir et al. (2003). One milliliter of DPPH solution in 95% ethanol was prepared and 1 mL of the solution was mixed with 3 mL of each sample solution in 95% ethanol. The absorbance was measured at 517 nm using ethanol (95%) as a blank after 30 min. A decrease in DPPH absorbance indicated an increase of DPPH radical scavenging activity. DPPH radical scavenging activity was calculated using the following equation:

$$\% \text{ Free radical scavenging activity} = \frac{\text{Control absorbance} - \text{sample absorbance}}{\text{Control absorbance}} \times 100$$

DPPH solution without sample extract was used as the control.

Determination of total flavonoid content (TFC)

Ogi extracts (0.5 mL) were mixed with 0.5 mL ethanol (80%), 50 μL aluminum chloride (10%), potassium acetate (50 μL), and water (1.4 mL). The mixture was incubated at room temperature for 30 min and the absorbance was measured at 415 nm. Standard quercetin solutions were prepared from an initial solution of 0.01 g quercetin in 20 mL ethanol (Meda et al., 2005). The quantity of flavonoids in the extracts was expressed as quercetin equivalents (QE). Quercetin solution without sample solution served as the control. Experiments were carried out in triplicate.

Statistical analysis

Data from sensory evaluation were analysed using analysis of variance (ANOVA) and differences in mean values were assessed using Duncan's multiple range test. A value of $P<0.05$ was used to indicate statistical significance. Means of the replicates were calculated and separated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

RESULTS

Effects of ginger and garlic on the sensory properties of *ogi*

The colour sensory means scores ranged from 5.55 to 8.64. The colour means score for AM (control *ogi* from maize) and AS (control *ogi* from sorghum) were 7.85 and 7.95, respectively. HM and HS (*ogi* enhanced with 4% garlic+2% ginger) had the most preferred colours (8.64 and 8.19, respectively), whereas EM and ES (samples enhanced with 4% ginger) were the least preferred in terms of colour (5.55 and 7.45, respectively). The appearance mean scores of CM (*ogi* enhanced with 4% garlic) and FS (*ogi* enhanced with 2% garlic+2% ginger) were highest (8.33 and 7.75, respectively) of all the enhanced samples, whereas the lowest appearance mean scores were for EM and DS (enhanced with 2% ginger; 5.44 and 7.33, respectively). There were no significant differences in the mean scores of aroma between AS (control) and DS, ES, and HS. However, samples containing 4% garlic (BM, BS, CM, and CS) were ranked lowest in terms of aroma. There was no significant difference in taste between AS (7.12), ES (7.00), and HS (7.25); there were no significant differences between the tastes of other enhanced pastes, with values ranging from 6.38 to 6.75. Overall acceptability scores showed FM and HS were the most preferred in appearance, taste, texture, and overall acceptability (Table 2).

Proximate composition

The protein content of AM and AS at week 0 was 7.73 and 9.83, respectively. The crude protein and crude fat contents increased in enhanced *ogi* samples while the crude fiber and ash contents decreased during storage at ambient and refrigerated temperatures. The carbohydrate profiles ranged between 57.90～65.32% for *ogi* (maize) and 59.24～66.95% for *ogi* (sorghum) when stored at ambient conditions (Table 3 and 4). Increased moisture content values were observed in AM and AS (control)

Table 2. Evaluation of sensory attributes of enhanced *ogi* paste with garlic and ginger

	Colour	Appearance	Aroma	Taste	Texture	Overall acceptability	Rank
Maize							
AM	7.85±0.02^{bc}	8.44±0.01^{a}	7.22±0.04^{a}	7.75±0.01^{a}	6.75±0.02^{c}	7.45±0.03^{a}	1
BM	6.67±0.01^{bc}	6.44±0.04^{b}	5.22±0.02^{b}	4.88±0.01^{c}	6.11±0.03^{b}	5.55±0.01^{cd}	4
CM	8.52±0.03^{a}	8.33±0.01^{a}	4.25±0.03^{b}	7.22±0.02^{b}	7.33±0.01^{a}	6.67±0.02^{c}	3
DM	6.22±0.01^{c}	6.44±0.02^{b}	6.22±0.01^{a}	5.33±0.01^{b}	6.22±0.04^{a}	5.67±0.01^{c}	3
EM	5.55±0.02^{d}	5.44±0.03^{d}	6.88±0.01^{d}	4.67±0.04^{d}	4.66±0.01^{e}	4.56±0.04^{e}	7
FM	7.35±0.01^{c}	7.78±0.01^{b}	6.77±0.02^{b}	7.44±0.01^{b}	7.00±0.02^{b}	7.11±0.03^{b}	2
GM	5.85±0.04^{e}	5.78±0.02^{c}	6.44±0.01^{a}	5.56±0.03^{a}	6.11±0.01^{b}	5.44±0.02^{cd}	5
HM	8.64±0.01^{a}	7.28±0.01^{a}	5.44±0.05^{c}	4.78±0.02^{c}	5.33±0.03^{d}	4.67±0.01^{e}	6
Sorghum							
AS	7.95±0.01^{b}	7.38±0.03^{b}	7.58±0.01^{a}	7.12±0.02^{b}	7.37±0.04^{b}	7.88±0.01^{a}	1
BS	7.88±0.03^{b}	7.36±0.01^{b}	7.00±0.02^{b}	6.75±0.04^{b}	7.00±0.01^{c}	7.55±0.02^{b}	2
CS	8.01±0.02^{a}	7.38±0.01^{b}	6.25±0.03^{c}	6.50±0.01^{c}	6.88±0.03^{c}	6.88±0.01^{c}	3
DS	7.75±0.01^{b}	7.38±0.03^{b}	7.49±0.05^{a}	6.50±0.01^{c}	7.13±0.02^{c}	7.45±0.03^{b}	2
ES	7.45±0.03^{c}	7.33±0.01^{b}	7.55±0.01^{a}	7.00±0.03^{b}	6.88±0.01^{c}	7.42±0.02^{b}	2
FS	7.80±0.01^{b}	7.75±0.02^{a}	6.93±0.01^{b}	6.38±0.02^{d}	7.88±0.01^{c}	7.39±0.01^{b}	2
GS	7.48±0.04^{c}	7.35±0.01^{b}	7.03±0.03^{b}	6.63±0.01^{c}	6.62±0.03^{d}	7.38±0.02^{b}	2
HS	8.19±0.01^{a}	7.50±0.04^{a}	7.57±0.02^{a}	7.25±0.01^{a}	7.63±0.02^{a}	7.85±0.04^{a}	1

Means followed by different letters (a-e) are significantly different ($P<0.05$) within individual columns (n=45).

Table 3. Proximate composition of enhanced *ogi* (maize) during storage at 27±2°C

Weeks	Protein	Fat	Fiber	Ash	Moisture	Carbohydrate
AM_0	7.73±0.10^{b}	2.68±0.06^{b}	1.73±0.02^{c}	1.01±0.04^{b}	22.11±0.03^{ns}	64.74±0.01^{b}
AM_4	9.19±0.05^{ab}	3.56±0.01^{a}	0.85±0.03^{d}	1.99±0.02^{a}	26.51±0.02	57.90±0.03^{bc}
BM_0	7.83±0.03^{b}	3.05±0.02^{a}	1.85±0.01^{c}	1.29±0.02^{a}	20.20±0.05	65.78±0.02^{a}
BM_4	8.95±0.03^{b}	3.47±0.01^{a}	1.15±0.02^{c}	2.18±0.01^{a}	22.86±0.01	61.39±0.01^{b}
CM_0	8.03±0.01^{ab}	3.04±0.03^{a}	2.21±0.01^{b}	1.37±0.02^{a}	20.27±0.02	65.08±0.01^{a}
CM_4	9.06±0.02^{ab}	3.52±0.01^{a}	1.44±0.01^{b}	1.65±0.01^{ab}	22.63±0.05	61.71±0.01^{b}
DM_0	7.76±0.01^{b}	2.85±0.01^{a}	2.11±0.05^{b}	1.03±0.02^{b}	21.29±0.03	64.96±0.01^{b}
DM_4	8.68±0.01^{b}	2.94±0.01^{a}	1.55±0.02^{b}	1.81±0.01^{a}	24.32±0.06	60.70±0.03^{b}
EM_0	7.83±0.04^{b}	2.97±0.01^{a}	2.40±0.02^{a}	1.07±0.01^{b}	20.41±0.05	65.32±0.03^{a}
EM_4	8.70±0.03^{b}	2.96±0.02^{a}	1.62±0.03^{b}	1.92±0.02^{a}	23.97±0.05	60.83±0.01^{b}
FM_0	8.09±0.05^{ab}	3.11±0.03^{a}	2.33±0.01^{a}	1.31±0.03^{a}	21.56±0.01	63.60±0.02^{b}
FM_4	8.77±0.06^{b}	3.55±0.02^{a}	2.05±0.01^{ab}	1.93±0.02^{a}	22.93±0.03	60.77±0.03^{b}
GM_0	8.34±0.02^{ab}	3.15±0.04^{a}	2.51±0.01^{a}	1.39±0.02^{a}	21.70±0.01	62.91±0.01^{b}
GM_4	9.18±0.02^{ab}	3.75±0.01^{a}	2.18±0.02^{a}	1.16±0.01^{bc}	22.83±0.02	60.90±0.01^{b}
HM_0	8.36±0.06^{ab}	3.20±0.02^{a}	2.35±0.01^{ab}	1.38±0.01^{a}	21.35±0.02	63.35±0.02^{b}
HM_4	9.56±0.03^{ab}	3.89±0.02^{a}	2.20±0.03^{a}	1.15±0.02^{bc}	21.78±0.06	61.33±0.01^{b}

Means followed by different letters (a–c) are significantly different (P<0.05) within individual columns according to Duncan's multiple range test.
Subscript 0, initial value at beginning of storage; subscript 4, value after storage for four weeks.
^{ns}Not significant.

Table 4. Proximate composition of enhanced *ogi* (sorghum) during storage at 27±2°C

Weeks	Protein	Fat	Fiber	Ash	Moisture	Carbohydrate
AS_0	9.83±0.07^{ns}	2.34±0.01^{c}	2.32±0.01^{a}	0.32±0.05^{c}	21.42±0.06^{a}	63.78±0.01^{b}
AS_4	10.08±0.02	2.46±0.01^{b}	1.47±0.01^{b}	1.08^{c}±0.05	25.67±0.01^{a}	59.24±0.01^{bc}
BS_0	10.25±0.05	2.44±0.01^{c}	2.35±0.04^{a}	0.31±0.01^{c}	18.40±0.02^{b}	66.25±0.01^{a}
BS_4	10.73±0.01	2.62±0.02^{b}	2.21±0.01^{a}	1.17±0.01^{bc}	16.32±0.02^{b}	66.95±0.02^{b}
CS_0	10.28±0.02	2.46±0.01^{b}	2.37±0.02^{a}	0.28±0.03^{c}	18.29±0.01^{b}	66.32±0.01^{a}
CS_4	10.92±0.02	2.57±0.01^{b}	2.26±0.01^{a}	1.44±0.03^{ab}	17.98±0.03^{b}	64.83^{a}±0.01^{b}
DS_0	10.07±0.03	2.89±0.02^{a}	2.41±0.01^{a}	0.38±0.01^{c}	20.86±0.02^{a}	63.39±0.01^{b}
DS_4	10.63±0.01	3.04±0.01^{a}	2.23±0.02^{a}	1.20±0.01^{b}	22.33±0.05^{a}	60.57±0.01^{b}
ES_0	10.10±0.01	2.91±0.01^{a}	2.32±0.02^{a}	0.36±0.05^{c}	18.60±0.05^{b}	65.71±0.01^{a}
ES_4	10.76±0.06	3.06±0.01^{a}	2.20±0.02^{a}	1.18±0.01^{bc}	19.91±0.01^{a}	62.89±0.01^{ab}
FS_0	10.26±0.01	2.58±0.02^{b}	2.36±0.02^{a}	0.37±0.01^{c}	19.04±0.01^{a}	65.39±0.01^{a}
FS_4	10.43±0.03	2.83±0.01^{a}	2.28±0.01^{a}	1.17±0.02^{bc}	18.95±0.05^{a}	64.34±0.01^{ab}
GS_0	10.30±0.04	2.55±0.02^{b}	2.41±0.05^{a}	0.29±0.03^{c}	19.80±0.03^{a}	64.65±0.01^{b}
GS_4	10.71±0.01	2.82±0.01^{a}	2.30±0.01^{a}	1.26±0.01^{b}	20.54±0.05^{a}	62.37±0.02^{b}
HS_0	10.28±0.05	2.62±0.01^{b}	2.42±0.01^{a}	0.31±0.01^{c}	18.53±0.01^{b}	65.84±0.01^{a}
HS_4	10.43±0.03	2.74±0.01^{a}	2.28±0.01^{a}	1.13±0.05^{bc}	16.51±0.03^{b}	66.91±0.01^{a}

Means followed by different letters (a–c) are significantly different (P<0.05) within individual columns according to Duncan's multiple range test.
Subscript 0, initial value at beginning of storage; subscript 4, value after storage for four weeks.
^{ns}Not significant.

samples during storage (increases from 22.11% to 26.51 %, respectively and 21.42% to 25.67%, respectively). AM (4 weeks) had the highest moisture content (26.50%) whereas BS had the lowest content (16.32%). However, the decrease in moisture content in *ogi* samples during the 4 weeks study at ambient temperature (27±2°C) ranged from 21.35 to 24.32 and from 16.32 to 22.33 for pastes produced from maize and sorghum, respectively.

At refrigerated temperatures, the moisture content of both controls (AM and AS), DS, ES, BS, CS, and GS samples increased. However, the moisture content of FM, GS, and HS samples decreased (data not shown).

Mineral content

Sample sodium contents ranged from 3.78 to 6.25 mg/100 g for *ogi* maize, and from 11.30 to 15.41 mg/100 g for *ogi* sorghum. For *ogi* maize, magnesium, zinc, and iron contents ranged from 7.48 to 9.47 g/100 g, 0.77 to 1.07 g/100 g, and from 0.65 to 0.87 g/100 g, respectively. For *ogi* sorghum, magnesium, zinc and iron contents ranged from 2.18 to 2.91 g/100 g, 0.24 to 0.31 g/100 g, and 0.61 to 1.62 g/100 g, respectively (Table 5).

Table 5. Mineral content of enhanced *ogi* paste with garlic and ginger (unit: mg/100 g)

Sample code	Sodium	Magnesium	Zinc	Iron	Manganese
A_M	3.78±0.06^{de}	7.61±0.01^{b}	0.77±0.01^{ab}	0.65±0.01^{c}	0.09±0.01^{b}
A_S	11.30±0.01^{b}	2.18±0.01^{e}	0.24±0.01^{c}	0.61±0.01^{c}	0.10±0.01^{b}
B_M	4.93±0.03^{cd}	8.18±0.01^{ab}	0.83±0.01^{ab}	0.74±0.01^{bc}	0.12±0.01^{b}
B_S	11.92±0.05^{b}	2.46±0.02^{d}	0.29±0.01^{c}	1.14±0.01^{b}	0.17±0.02^{ab}
C_M	5.03±0.02^{cd}	8.24±0.01^{ab}	1.02±0.03^{a}	0.76±0.01^{bc}	0.18±0.01^{ab}
C_S	12.12±0.01^{b}	2.51±0.01^{d}	0.30±0.01^{c}	1.16±0.01^{b}	0.19±0.01^{ab}
D_M	3.96±0.01^{de}	7.48±0.01^{b}	0.78±0.01^{ab}	0.65±0.01^{c}	0.17±0.02^{ab}
D_S	12.45±0.01^{b}	2.44±0.02^{d}	0.28±0.01^{c}	1.19±0.01^{b}	0.10±0.01^{b}
E_M	4.03±0.02^{d}	7.54±0.01^{b}	0.80±0.01^{ab}	0.66±0.01^{c}	0.17±0.01^{ab}
E_S	12.17±0.01^{b}	2.49±0.03^{d}	0.27±0.01^{c}	1.49±0.05^{a}	0.10±0.01^{b}
F_M	5.05±0.01^{cd}	8.20±0.01^{ab}	0.95±0.02^{a}	0.84±0.02^{bc}	0.21±0.01^{ab}
F_S	13.01±0.01^{b}	2.52±0.01^{d}	0.30±0.01^{c}	1.52±0.01^{a}	0.20±0.01^{ab}
G_M	5.75±0.05^{c}	8.25±0.01^{ab}	1.04±0.02^{a}	0.86±0.01^{bc}	0.22±0.01^{ab}
G_S	15.15±0.01^{a}	2.58±0.01^{c}	0.30±0.01^{c}	1.53±0.04^{a}	0.22±0.01^{ab}
H_M	6.25±0.02^{c}	9.47±0.01^{a}	1.07±0.01^{a}	0.87±0.01^{bc}	0.23±0.01^{ab}
H_S	15.41±0.03^{a}	2.91±0.01^{c}	0.31±0.01^{c}	1.62±0.01^{a}	0.30±0.05^{a}

Values are means±SD (n=3).
Means followed by different letters (a-e) are significantly different (P<0.05) within individual column according to Duncan's multiple range test.

Total antioxidant activity of *Ogi*

The TPC of all *ogi* samples except AS increased during storage at ambient temperature (Fig. 1). HS showed the greatest increase in TPC during storage of samples enriched with garlic and ginger (168.00 to 226.50 mg GAE/100 g) whereas DS showed the lowest (127.00 to 193.68 mg GAE/100 g). At refrigerated temperatures, the TPC of AM, and all enhanced samples composed from maize increased throughout the 4 weeks (Fig. 2). However, during the first 2 weeks, the TPC of AS showed a slight increase from 141.50 to 147.00 mg GAE/100 g, followed by a decrease to 132.68 mg GAE/100 g at the end of storage. The TPC of CS, ES, FS, and HS increased during the first 2 weeks, and then stabilized until week 4. Antioxidant activities were expressed as IC_{50} (mg/mL) values, which represent the concentration of sample required to scavenge 50% of free radicals. A lower IC_{50} values indicates greater antioxidant activity. The antioxidant radical scavenging activities increased for AM (1.14~2.22 mg/mL) and AS (0.77~0.86 mg/mL) during the first 2 weeks of storage at ambient temperature, and then decreased to 1.23 mg/mL and 0.87 mg/mL, respectively, during the 4th week of storage. However, the radical scavenging activities of DS and ES were stable for 2 weeks, and then decreased until the end of the study. Moreover, the activities of EM (1.00 mg/mL) gradually increased during the first 2 weeks but were then relatively stable until the end of storage (0.97 to 0.96 mg/mL). DM showed increased antioxidant radical scavenging activity from 1.03 mg/mL to 0.79 mg/mL during storage. The activities of FM, GS, and HS followed similar trends during storage. The TFC of *ogi* samples stored at ambient temperature ranged from 45.32 and 79.35 mg QE/100 g in *ogi* (maize) and from 58.00 and 89.25 mg QE/100 g in *ogi* (sorghum). The TFC of both AM and AS controls decreased throughout the storage period from 53.60 to

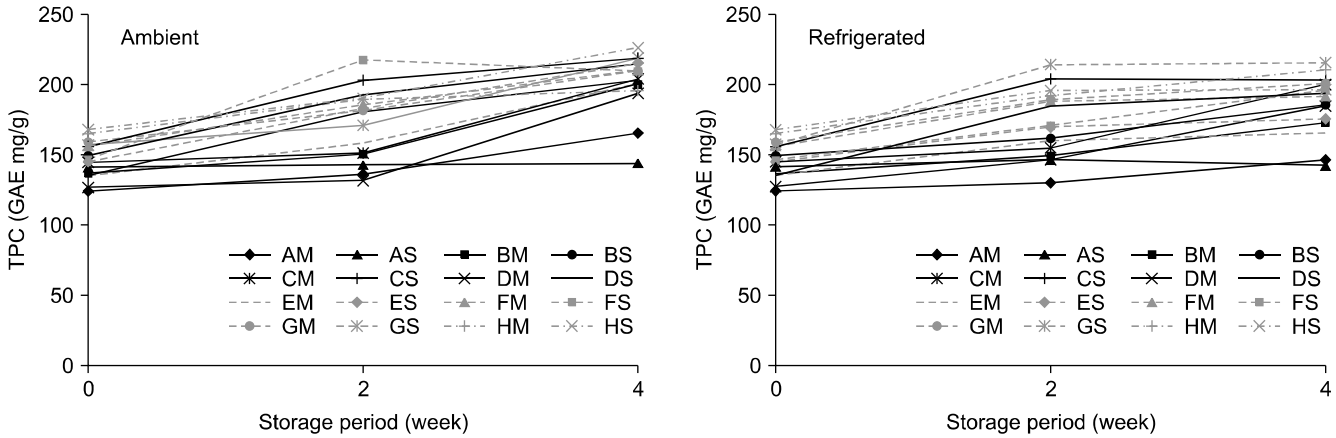

Fig. 1. Total phenolic content (TPC) of *ogi* paste supplemented with garlic and ginger. GAE, gallic acid equivalent.

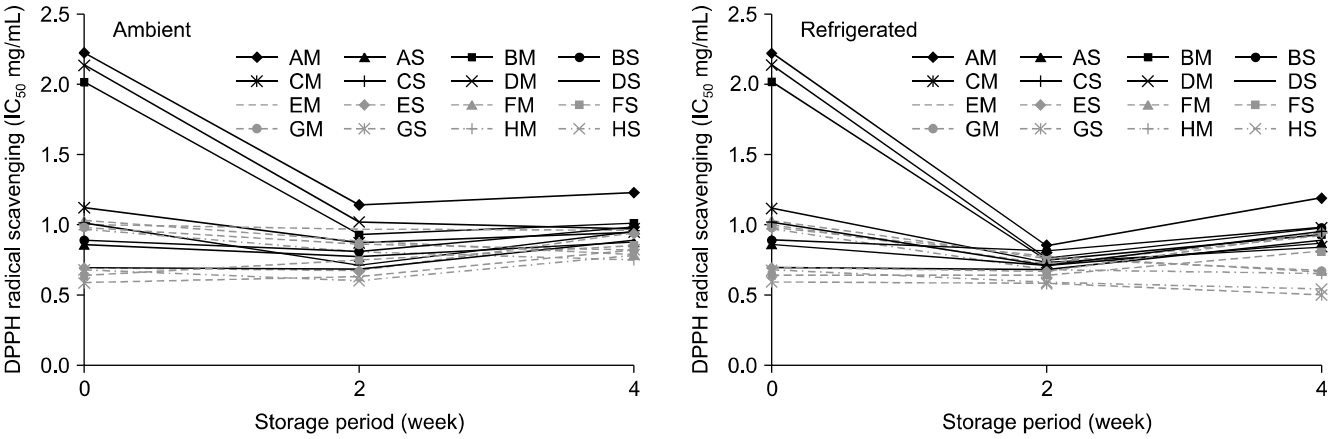

Fig. 2. 1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activities of enhanced *ogi* paste supplemented with garlic and ginger.

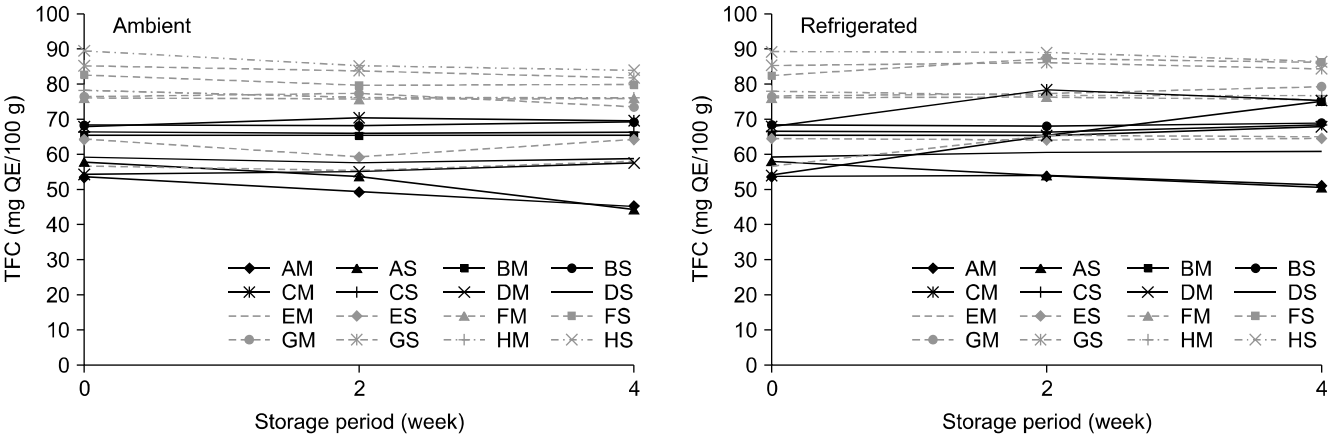

Fig. 3. Total flavonoid contents (TFCs) of enhanced *ogi* paste supplemented with garlic and ginger. QE, quercetin equivalents.

45.32 mg QE/100 g and from 58.00 to 44.20 mg QE/100 g, respectively. A similar trend was observed for these samples at refrigerated temperature. However, the TFC of all *ogi* samples enhanced with garlic and ginger were relatively stable during storage at ambient temperature (Fig. 3).

DISCUSSION

Addition of garlic either on its own or with ginger at different ratios improved the colour and texture of all samples, whereas use of ginger improved the aroma. The strong pungency of garlic and concentrations used in this study trigger the low sensory acceptability of *ogi* porridge with 4% garlic. From the sensory evaluation, we found that the preferred samples were *ogi* paste made from quality protein maize supplemented with 2% garlic+2% ginger, and *ogi* paste made from sorghum supplemented with 4% garlic+2% ginger. This may be due to the percentage inclusion of ginger and garlic, which was able to mask and improve the sensory properties of *ogi* resulting from presence of terpenes, allyl sulfide, diallyl trisulfide, diallyl disulfide, and 2-propen-1-ol, as reported by Li et al. (2016).

All treatments were assumed to give an effect compared to control in terms of proximate composition. Reduction in the mass of samples with either garlic and/or ginger may be due to its differences in water absorption capacities (Olaniran et al. 2019). The carbohydrate contents were in accordance with findings reported by Ikujenlola et al. (2013), and the protein content of samples were within the range reported for unsieved *ogi* (Farinde, 2015). The presence of oils in garlic and ginger may have contributed to the observed increase in fat content of *ogi* supplemented with garlic and ginger (Olaniran et al., 2013). The general reduction in crude fiber content after storage in all samples could be due to the ability of fermenting microorganisms to metabolize fiber (Okafor et al., 2018; Omemu, 2011). The decrease in moisture content of enhanced samples during storage suggests garlic and ginger may potentially influence the shelf life of *ogi* by lowering its water capacity and limiting amounts of spoilage microbes. Addition of garlic and ginger also increased iron, sodium, zinc, magnesium, and manganese contents of the *ogi* samples. Garlic and ginger have previously been reported to be rich in zinc, manganese, magnesium, iron, sodium, and potassium (Nwinuka et al.,

2005; Otunola et al., 2010), and thus increase the bioavailable content of these micronutrients in *ogi* paste. Garlic and ginger have high phenolic contents and considerably contributed to the antioxidant property of *ogi*. Important and direct relationships were found between phenolic content and antioxidant activity, suggesting that phenolic compounds are essential for antioxidant activity (Al-Awwadi, 2017; Frank et al., 2014). Supplementation with 4% garlic and 2% ginger showed the highest synergy effect on radical scavenging activity for the *ogi* paste samples produced from sorghum. Garlic and ginger are rich in antioxidants and possess good free radical scavenging abilities that can used as radical inhibitors (Al-Qattan et al., 2008; Ryu and Kang, 2017). Garlic showed stronger radical scavenging activity than ginger, hence antioxidant activity of garlic has been previously reported by Asimi et al. (2013). Garlic and ginger are both good sources of flavonoids in food (Neeraj et al., 2014; Babajide et al., 2013; Udu-Ibiam et al., 2014; Suleria et al., 2015). Supplementation of *ogi* with garlic and ginger did not only enhance the quality of *ogi* pastes, but also improved their sensory properties so that they were acceptable to panellists. Garlic and ginger are good sources of antioxidants and mineral elements. Therefore, supplementing *ogi* paste with garlic and ginger should be strongly considered in the bid to improve sensory and nutritional qualities of cereal products.

In conclusion, the present study demonstrates potential of ginger and garlic as food enhancers, either singly or as a blend, to enhance the nutritional quality of *ogi* derived from maize and sorghum. Despite other uses of ginger and garlic (medicinal, flavorant, and condiment), these results show these supplements can be used to enhance the nutritional status of *ogi* pastes, and may therefore be used to help combat micronutrient deficiency in war-torn nations. Thus, the potential of garlic and ginger as food enhancers in local food for improving food nutritional quality may contribute to global initiatives of mitigating the level of food insecurity.

ACKNOWLEDGEMENTS

I appreciate the support of Prof. Bridget Omafuvbe and Dr. Obuotor who made available some reagents and materials during the cause of this work. All the staff of the Department of Food Science and Technology, Obafemi Awolowo University, for their support and services rendered during the research work.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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