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Effect of Ginger and Garlic Inclusion on the Performance of *Lactobacillus plantarum* in Maize (*Zea mays* l.) Fermentation into Ogi

Temitope H. Adejobi[1], Johnson O. Olorunnusi[1], Omolara R. Adegbanke[1], Oladotun O. Oguntoyinbo[2] and Victor N. Enujiugha[1]*

[1]Department of Food Science and Technology, Federal University of Technology, P.M.B. 704, Akure 340252, Nigeria.
[2]Department of Food Science and Technology, Lagos State University of Science and Technology, Ikorodu, Nigeria.
*Corresponding author: vnenujiugha@futa.edu.ng; Tel: +234(0)8034261870

Abstract

Maize grains undergo different indigenous processes involving various microbes (Lactic acid bacteria and yeasts) in order to be converted into intermediate and finished products during the process of fermentation. This study was conducted to evaluate the effect of ginger and garlic inclusion on the performance of *Lactobacillus plantarum* as a single starter in the fermentation of maize into *ogi*. Ginger and garlic powders were prepared and added to the maize *ogi* slurry at different percentages as follows: M100 (100% maize *ogi*), MGG90 (90% maize *ogi* + 5% ginger+ 5% garlic), MGG80 (80% maize *ogi* + 15% ginger + 5% garlic), MGG70 (70% maize *ogi* + 25% ginger + 5% garlic), which was subsequently fermented, dried to flour and then packaged in zip-lock bags. The total viable miicrobial count, pH and total titratable acidity were carried out on the samples during fermentation, while the proximate composition, mineral content, antioxidant properties, functional properties, pasting properties, colour analysis and sensory parameters of the samples were analyzed using standard methods. The results showed corresponding decrease of pH in the spiced *ogi* slurry as total titratable acidity increased during 48 h fermentation. The results revealed that spiced maize *ogi* had high protein content (20.12 ± 0.60% for MGG80), fiber (1.11 ± 0.09 % for MGG70), fat (7.15 ± 0.012% for MGG70) and ash content (0.505 ± 0.008% for MGG70). Minerals like calcium, potassium, sodium, phosphorous, iron and zinc were present in all the samples. The antioxidant properties increased with the addition of ginger and garlic. The bulk density ranged from (0.55- 0.667 g/ml) while sample M100 recorded the highest swelling capacity. Pasting properties showed varying peak viscosity, breakdown and setback values. Sensory analysis showed that sample M100 was the most preferred sample. The study established that the inclusion of ginger and garlic in maize *ogi* positively influenced the performance of *Lactobacillus plantarum* during fermentation, leading to alterations in microbial dynamics and improvements in nutritional properties of maize *ogi*.

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Introduction

Maize (*Zea mays* L.) is a graminous annual plant that serves as a good source of energy and is considered an important food grain in some countries in spite of its deficiency in protein (Chaves-López *et al*., 2020). Maize grains undergo varieties of indigenous processes which involve the use of microbes (lactic acid bacteria and yeasts) for conversion into intermediate or finished products, such as ogi, with fixed shelf life, enhanced digestibility and desirable organoleptic properties (Enujiugha, 2006; Itaman and Nwachukwu, 2021).

Ogi is an inexpensive and easily available health sustaining fermented food in Africa (Ojo and Enujiugha, 2018). It is a traditional porridge produced from either maize, sorghum or millet, and majorly used as a weaning diet for children and staple food for adults in West Africa (Adisa and Enujiugha, 2020; Itaman and Nwachukwu, 2021). The traditional

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preparation of *ogi* is usually spontaneous, which involves soaking of millet, maize or sorghum grains for a period of 2-3 days, wet milling and sieving to eliminate the bran, germs and hulls of the grain (Enujiugha, 2006; Oluwamukomi *et al*., 2005). The residue is left to sediment and the supernatant is decanted to obtain *ogi* which is called *pap, akamu*, and *koko* by West Africans (Emelike *et al*., 2020; Stadlmayr *et al*., 2010). In recent years, traditional processors tend to improve the quality of the products by the inclusion of one or more spices. These spices enhance the flavor of foods, and are composed of essential oils, antioxidants, vitamins and minerals necessary for sustaining healthy living (Adelekan *et al*., 2021).

Ginger (*Zingiber officinale Roscoe*) is a rhizome or underground stem which has been used as a source of spice, food, flavoring agent, and in herbal medicines due to its characteristics such as aroma, pungency, nutrients, pharmacological activity (antioxidant and anti-inflammatory properties) (Makanjuola *et al*., 2016; Ryoiti, 2020). It also contains therapeutic compounds such as paradol, shogaol, gingerol, zingerone (Adelekan *et al*., 2021). Numerous studies have been carried out on ginger to characterize and isolate the bioactive compounds used to explicate the pathway of antimicrobial activity against spoilage and pathogenic microorganisms in food (Beristain-Bauza *et al*., 2019; Makanjuola and Enujiugha, 2018)

Garlic (*Allium sativum*) is one of the common spices used in creating flavors in food, it is a rich source of vitamins and minerals (Olaniran and Abiose, 2019). It has many health benefits due to its bioactive compounds such as organic sulphides, saponins, phenolic compounds and polysaccharides (Shang *et al*., 2019). It has been reported that ginger and garlic exhibits good antioxidant activities, especially high total phenolic content which plays a role in improving food quality (Enujiugha, 2020; Olaniran *et al*., 2015).

Lactic acid bacteria (LAB) are organisms that are naturally present in food materials, fermented products, beverages, and display biosynthetic capacity during fermentation in the production of vitamins, exopolysaccharides, as well as bioactive peptides to enhance the nutritional quality of fermented foods (Enujiugha and Badejo, 2017; Rodrigo-Torres *et al*., 2019). Many LAB species have been found useful in diverse indigenous fermented foods, including sourdoughs (Adepehin *et al*., 2018; Babatuyi *et al*., 2023), ogi and akamu (Adisa *et al*., 2024; Ojo and Enujiugha, 2018), kunun zaki and other beverages (Jolayemi *et al*., 2023), as well as other cereal-based products (Olorunfemi *et al*., 2022).

Lactobacillus plantarum, a major isolate from spontaneously-fermented cereal-based foods (Adisa *et al*., 2019; Adisa and Enujiugha, 2020), is a versatile species/strain with useful properties and majorly found in fermented food products (Behera *et al*., 2018). *L. plantarum* is known to have antimicrobial activity against bacterial pathogens, and spoilage fungi that affect food products, and it aids the production of B-vitamins (B2, B9) (Adisa *et al*., 2024; Rodrigo-Torres *et al*., 2019). Studies have been carried out to assess the influence of garlic and ginger on key microflora associated with the spontaneous fermentation of *ogi* produced from quality protein maize grains (Olaniran *et al*., 2020). This study aimed at investigating the effect of ginger and garlic inclusion on the performance of a single starter culture of *L. plantarum* in maize fermentation into the commonly consumed product, *ogi*. This was with a view to ascertaining the level of influence this microorganism has in the fermentation, and its contributions to the unique sensory experience that ogi consumers are familiar with.

Materials and Methods

2.1. Source of Materials

White maize grains (*Zea mays*), ginger (*Zingiber officinale*) and garlic (*Allium sativum*) were purchased from Oba market, Akure Ondo State Nigeria. The culture (*Lactobacillus plantarum*) was obtained from International Institute of Tropical Agriculture (IITA). All the chemicals and reagents used in the study were of analytical grade.

2.2. Preparation of powdered ginger and garlic

The ginger rhizomes and garlic bulbs were processed by sorting and washing manually with clean water, it was peeled and sliced using a knife, and dried for 12 h at 65 ^{o}C in a hot air oven. The spices were pulverized and sieved to remove shafts, it was then stored in airtight containers (Olaniran and Abiose, 2019).

2.3. Preparation of maize *ogi* with spices

The maize grains was thoroughly sorted and screened to remove any unwanted materials and unwholesome grains, after which the 2.5 kg of maize grains was washed and steeped in 5litres of clean water for 48hours at room temperature. After 48 h, the water was decanted and the maize grains wet milled into slurry using an Attrition mill, a muslin cloth was then used to sieve the milled grain (Enujiugha, 2006; Adelekan *et al*., 2021). The ginger and garlic slurries of different weight was added into the sieved ogi slurry, followed by the addition of *L. plantarum* which was then homogenized using rods giving rise to four different formulations of spiced maize *ogi*. The new formulations was fermented for a period of 48 h after which it was decanted and dried using a laboratory air oven at temperature of 55 ^{o}C for 24 h. It was then milled using a sterile laboratory blender and sieved in order to obtain a fine spiced *ogi* flour. The sample of spiced *ogi* flour was carefully packaged in ziplock bags and stored at room temperature for further analysis (Adelekan *et al*., 2021). The above procedure is presented in Figure 1.

2.4. Proximate analyses

The proximate composition of the maize ogi samples was determined using AOAC (2012) methods. Moisture content was determined after drying at 105 ℃ to constant weight in a hot air oven. The crude fat was estimated by the extraction of a known weight of samples with hexane using Soxhlet extraction apparatus. Total ash was determined gravimetrically after incineration in a muffle furnace (Carbolite AAF UK) for 3 h at 550 ℃ until a white ash is obtained. Protein was determined using Kjeldahl method. The efficiency of the nitrogen values was calculated and multiplied by the factor of 6.25 to obtain the protein value. After the ash-less filter paper containing the insoluble elements from the hydrolysis was burned and the moisture-free defatted sample was washed, the crude fibre was extracted by difference. Carbohydrate content was determined by the difference: 100% - (% MC + % Ash + % Crude protein + % Fat + % Crude fibre). The energy content (E) was calculated using Atwater factor method as described by Emelike *et al*. (2020).

Figure 1: Flowchart for the production of spiced maize ogi (Adelekan *et al*., 2021)

2.5. Mineral composition

The mineral analysis of sodium, potassium, calcium, zinc, iron and phosphorous was conducted with atomic absorption spectroscopy. The samples were dry-ashed in a muffle furnace at 550 ºC for 3 h, the minerals were extracted from the ash with 20 ml of 2.50% HCl which is then heated in a steam bath to reduce the volume to 8 ml. It is filtered into a 50 ml volumetric flask and diluted to volume with deionized water, the extract is then stored in a clean and dry plastic sample bottles and the mineral compositions were determined using atomic absorption spectrophotometer (AAS, Buck Model 20A, Buck Scientific, East Norwalk, CT06855, USA).

2.6. Determination of Antioxidant properties

Total phenolic content was determined as described by Folin–Ciocalteu (Enujiugha, 2010) using gallic acid (Sigma, St. Louis, USA) as standard. The quantity of flavonoids in the extracts was expressed as quercetin equivalents (QE) and determined as described by Olaniran and Abiose (2019). The free radical scavenging activity 2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) of the maize *ogi* samples was determined as described by Chen *et al* (2017). The free radicals scavenging activity of the maize *ogi* samples on 2, 2- Diphenyl-1-picryhydrazyl (DPPH) was determined as described by Enujiugha *et al*. (2012). The Ferric-reducing antioxidant power (FRAP) activity of the maize *ogi* samples was determined using method of Pulido *et al.* (2010).

2.7. Determination of pasting properties

The pasting properties were determined using Rapid Visco Analyzer (RVA) as described by Olaniran *et al*. (2019), the values obtained were conveniently determined using the software provided in the instrument. The ogi samples were each prepared into suspensions (28.0 g) by the addition of 3.0 g dry starch (amount of sample) which was stirred initially at 960 rpm for 10 s and 160 rpm subsequently for the remainder of the test period. Parameters determined includes; peak viscosity (Rapid Visco Unit, RVU), trough viscosity (RVU), breakdown viscosity (RVU), final viscosity (RVU), setback (RVU), peak time (min), peak temperature (ºC).

2.8. Determination of Functional Properties

2.8.1. Water absorption capacity

The water holding capacity was evaluated using the method described by Ogori *et al*. (2022). One gram of the sample was transferred into a 15 ml pre-weighed centrifuge tube containing 10ml distilled water, it was then vortexed for 1 min and allowed to stand for a period of 30 min. It was centrifuged at 7000 x g for 25 minutes at room temperature, and the supernatant was decanted in which the excess water in the upper phase was drained for 15 min and the tube containing the residue was re-weighed to determine the amount of water retained per gram of the sample.

2.8.2. Oil Holding Capacity

The oil absorption of maize ogi sample was determined using the centrifuge method as described by Ogori *et al*. (2022). One gram (1 g) of the sample was dissolved in a 10 ml pure canola oil in a 15 ml pre weighed centrifuge tube. It was vortexed for 1 min and allowed to stand for a period of 30 min, it was then centrifuged at 7000 x g for 25 min at room temperature. The supernatant was decanted, and excess oil at the upper phase was drained for 15 min and the tube containing the residue was weighed again to determine the amount of oil retained per gram of sample.

2.8.3. Bulk Density

The bulk density of maize ogi samples was determined using the method as described by Ahaotu *et al*. (2021). A measuring cylinder was filled with tap water until it reached a 10ml mark in which the volume was recorded. The measuring cylinder was then emptied and properly cleaned, the maize ogi samples was poured into the measuring cylinder up to the 10ml mark and tapped for 5 minutes in order to eliminate airspace between the flour blends inside the cylinder, the weight of the sample was noted.

2.8.4. Swelling capacity

The swelling capacity of maize ogi flour was estimated using the method as described by Ahaotu *et al*. (2021). Three gram (3 g) of the sample was weighed and transferred into a clean and dry test tube, in which the weight of both the sample and test tube was ascertained. The sample was dispersed into 50 ml water and undergoes stirring, the suspension was heated at 60ºC for 15 min in a thermostat water bath, in which the slurry is stirred gently to avoid clumping. The slurry was cooled to room temperature and then centrifuged at 2500 rpm for 15 min,

the supernatant was decanted, the residue was weighed and the swelling capacity was calculated as the ratio of the difference in weight of the flour multiplied by 100.

2.8.5. Emulsion capacity

The emulsion capacity of maize ogi samples were determined using the method described by Asunni *et al*. (2024). Two gram (2 g) of the sample was blended with 25 g of distilled water using a blender for 30 s at a speed of 1600 rpm. After complete dispersion, refined oil was added from a burette and blended until there was a separation into two layers of water and fat. The emulsion capacity was expressed as milliliter of oil emulsified by 1 g of flour.

2.8.6. Foaming properties

Foaming capacity was determined following an adaptation of the method described by Asunni *et al*. (2024) using slurries (protein weight basis) that were prepared as sample dispersions in 50 ml graduated centrifuge tubes containing 0.1M phosphate buffer. Sample slurries underwent homogenization at 20000 x g for 1 min using a blender. The capacity of the continuous incorporation of air (foaming capacity) was determined.

2.9. Determination of Color

The CIE L* a* b* colour determination was adopted using the procedure described by Akintayo *et al*. (2020) to analyse the colour of the ogi flour samples and it was evaluated objectively using a colorimeter. The colorimeter operates on the International Commission on Illumination (CIE) L*, a* and b* where L* indicates "lightness" (axis: 0 is black, 100 is white), a* means "red-green" (axis: positive values are red, negative values are green and 0 is neutral), b* indicates "yellow-blue" (axis: positive values are yellow, negative values are blue and 0 is neutral). The instrument was standardized prior to the analyses. Total color difference (ΔE) was calculated as follows:

$\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta L^2}$

Where $\Delta a = a_1 - a_0$

$\Delta b = b_1 - b_0$

$\Delta L = L_1 - L_0$

a_o, b_0, L_0 are corresponding values for the control sample.

2.10. Determination of pH and Total Titratable Acidity

The pH of the maize ogi samples was determined using the procedure described by Olaniran *et al*. (2020). The hydrogen ion concentration (pH) changes of the fermenting maize ogi was measured using a digital pH meter. The pH meter was calibrated using Buffer 4.0 and 7.0, and before immersing it in the sample, the pH probe electrode was sanitized with 90% ethanol.

The total titratable acidity was determined using the procedure described by Malomo and Abiose (2020). This was determined by titrating 0.1M NaOH against 25 ml of the fermenting maize ogi samples using phenolphthalein as the indicator.

2.11. Microbial analysis

Total bacterial counts, lactic acid bacterial count, fungal counts were determined at 48 h fermentation to evaluate the inclusion of ginger and garlic on fermenting microorganisms, spoilage organisms and total bacterial counts. Nutrient agar for the total bacterial count, de Man, Rogosa and Sharpe (MRS) agar for the lactic acid bacterial count, Malt extract agar for fungal count were prepared according to manufacturer's instructions and sterilized by autoclaving at 121 ^oC and 0.15 MPa for 15 min. One milliliter (1 ml) of each sample from 10^{-3} dilution was aseptically taken with the aid of a sterile syringe and transferred to a sterilized petri dish and the molten agar cooled to 42-45 ^oC were added respectively. The plates were inverted and incubated at 35 ^oC for 24 h and 27 ^oC for 48 h, for bacteria and fungi respectively in which during the incubation period, growth and multiplication of cells occurred and the colonies were counted and multiplied by the dilution factor and expressed as CFU/ml sample which indicates the number of microorganisms (Ekwen and Okolo, 2017; Adelekan *et al*., 2021).

2.12. Sensory analysis

The sensory analysis was determined using the procedure described by Olaniran and Abiose (2019) with slight modifications. The ogi gruel was constituted by adding 10 g of ogi paste to 15 ml of portable water, boiling water was also added until gelatinization occurred. Water at room temperature were provided for mouth rinsing in between successive evaluation. Each sample were coded with three (3) random digit code for identification and to avoid bias when displayed for panelist evaluation. The sensory attributes which includes appearance, colour, flavor, consistency, taste and overall acceptability using a 9 point Hedonic scale for the samples were examined by the panelists. The sensory panelists was made up of 30 untrained panelists consisting of students of the Federal University of Technology, Akure (FUTA). The data obtained were analysed using analysis of variance (ANOVA).

2.13. Statistical analysis

The data generated was subjected to analysis using Statistical Package for Social Scientist (SPSS) version 20. Mean, standard deviation, and analysis of variance (ANOVA) were performed. Mean values were also separated by Duncan's multiple range tests at a 5% significance level.

Results and Discussion

3.1. Proximate composition of maize ogi samples with the inclusion of ginger and garlic

The proximate composition of the maize ogi samples are presented in Table 2. The moisture content of the samples ranged from 1.88±0.01% to 4.27± 0.02% with sample MGG70 having the highest moisture content. A significant difference ($p< 0.05$) was observed in the moisture content of the spiced ogi samples. Moisture is a crucial factor influencing the quality and acceptability of products (Batool *et al*., 2012). The low moisture content observed in all samples suggests an improved shelf-life and enhanced storability of the product as reported by studies carried out by Adelekan *et al*. (2021).

The total ash in the samples increased with a corresponding rise in the percentage of the spices that was added and ranged from 0.15±0.002% to 0.5±0.008% with the sample MGG70 having the highest value. The ash content serves as an indicator of the overall mineral quantity in a food sample. An increase in its concentration during microbial fermentation might be attributed to the incomplete breakdown of minerals by fermenting organisms during their metabolic processes (Adelekan *et al*., 2021). Dietary fat serves as a reservoir of

stored energy and plays a crucial role in human nutrition, especially in the synthesis of essential fatty acids such as linoleic and linolenic acids, along with fat-soluble vitamins (Vitamin A, D, E, and K) (Ejigbo *et al*., 2018). Fat content ranged from 3.79± 0.01% in M100 to 7.15± 0.01% in MGG70, in which the oils present in garlic and ginger might be a contributing factor to the observed rise in the fat content of ogi supplemented with the spices as similar findings were observed by Olaniran and Abiose (2019).

The protein content of the maize ogi samples ranged from 4.61± 1.42% to 20.12± 0.60 % and demonstrated a significant increase upon inclusion of certain percentage of ginger and garlic. The rise in protein content may be attributed to the metabolic activities of microorganisms, leading to the production of proteolytic enzymes, or the organisms might have synthesized proteins from the substrates (Ogodo *et al*., 2019). It might also indicate that spices are abundant in protein content owing to the presence of active proteinous metabolite which aligns to the research observed by Otunola *et al*. (2010).

The crude fiber content ranged from 0.69±0.005% to 1.11±0.09% increasing with a corresponding rise in the percentage of the ginger and garlic that was added, with the sample MGG70 having the highest value. There was no significant differences ($p<0.05$) in the crude fiber content between sample M100, MGG90 and MGG80. High dietary crude fiber serves a crucial role by offering roughage or bulk that facilitates the process of digestion, regulate serum lipids and glycemic index, consequently mitigating the risks associated with high cholesterol and chronic heart diseases (Chen *et al*., 2020).

The carbohydrate content of the ogi samples ranged from 88.86±1.42% to 67.12±0.58% with the sample M100 having the highest content. These values are in accordance with the research carried out by Adelekan *et al*. (2021) Carbohydrates serves as an excellent source of energy, and is desirable in meals at high concentrations (David *et al*., 2015). Energy values ranged from 484.22 ± 2.90 to 412.14 ±7.07 kcal with the control sample M100 as the lowest, while sample MGG80 was the highest. There was no significant differences in the energy values between sample MGG80 and MGG70. The protein, fat, and carbohydrate compositions of the ogi contributed to the overall energy value of the samples (Atwater factor). The energy values obtained from this study align closely with those previously reported by Emelike *et al*. (2020) for ogi spiced with ginger and cinnamon (387.77-391.98 kcal).

Table 2: Proximate composition of maize *ogi* samples with the inclusion of ginger and garlic

Samples	Moisture content (%)	Ash content (%)	Crude fat (%)	Crude protein (%)	Crude fibre (%)	Carbohydrate (%)	Energy value (kcal)
M100	1.88± 0.01^{d}	0.15±0.002^{d}	3.79± 0.012^{d}	4.61±1.42^{c}	0.69±0.0056^{b}	88.86±1.42^{a}	412.14±7.07^{c}
MGG90	2.99± 0.01^{c}	0.199±0.001^{c}	4.85± 0.019^{c}	10.36± 0.09^{b}	0.65±0.007^{b}	80.92±0.12^{b}	436.41± 0.41^{b}
MGG80	3.08± 0.007^{b}	0.30±0.004^{b}	5.33± 0.016^{b}	20.12± 0.60^{a}	0.71± 0.028^{b}	70.43±0.62^{c}	484.22± 2.90^{a}
MGG70	4.27± 0.026^{a}	0.50± 0.008^{a}	7.15± 0.012^{a}	19.82± 0.48^{a}	1.11± 0.091^{a}	67.12±0.58^{d}	475.57± 1.99^{a}

Values are Mean±standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$
Key: M100: 100% Maize *Ogi*; MGG90: 90% Maize *Ogi*: 5% Ginger: 5% Garlic; MGG80: 80% Maize *Ogi*: 15% Ginger: 5% Garlic; MGG70: 70% Maize *Ogi*: 25% Ginger: 5% Garlic.

3.2. Mineral composition of maize *ogi* samples with inclusion of ginger and garlic

The mineral composition of the maize *ogi* samples are presented in table 3. Minerals play an important role in promoting growth, development, and also overall health (Ejigbo *et al*., 2018). It is an integral components of molecules like hemoglobin, adenosine triphosphate (ATP), and deoxyribonucleic acid (DNA) (Bukuni *et al*., 2022). The sodium content ranged from 39.80±0.28 to 49.05±0.070 ppm, with M100 (100% maize *ogi*) having the highest concentration of sodium. Sodium, in conjunction with chloride, plays a role in preserving extracellular fluids, thereby maintaining the body's water and electrolyte balance. It is essential for regulating blood pressure and also necessary for the proper functioning of nerves and muscles (Okafor *et al*., 2017).

Potassium aids in preserving fluid balance, and increased consumption contributes to improved blood pressure according to American Heart Association (Corleone, 2012). One crucial role of potassium is to preserve the excitability of nerve and muscle tissues (Ojo and Enujiugha, 2016). The results of potassium (K) content ranged from 89.40±0.84 to 75.15± 0.35 ppm in which there was no significant difference ($p<0.05$) in sample MGG80 and MGG70.

Calcium performs important functions in human physiology, which includes blood clotting, development of bones and teeth, and also contraction of muscles (Bukuni *et al*., 2022). The concentration of calcium (Ca) in the maize *ogi* samples ranged from 39.75±0.35 to 45.70±0.42 ppm in which MGG80 had the highest concentration of calcium.. The iron (Fe) of the samples ranged from 0.703±0.009 to 1.155± 0.077 ppm with sample MGG90 (90% maize *ogi* + 5% ginger + 5% garlic) having the highest concentration of iron. Iron is essential for humans and animals, and a significant constituent of haemoglobin. It plays an essential role in the metabolism of major food components, such by facilitating their oxidation in the body, and also in controlling weight, which is a risk factor in diabetes (Camaschella, 2017).

Zinc (Zn) is an essential trace element and plays a vital role in various cellular processes, including normal growth, brain development, behavioural response, bone formation, and wound healing in man (Camaschella, 2017). The values for Zinc ranged from 0.89±0.002 to 1.45±0.02 ppm, with sample MGG80 having the highest concentration of zinc (Zn). Phosphorus plays a crucial role in the development, growth, and repair of body tissues. It plays a role in storing and transferring energy obtained from metabolic fuels, and also activates numerous catalytic proteins through a process known as phosphorylation (Okafor *et al*., 2017). The phosphorous content of the different samples ranged from 6.05± 0.23 to 9.20± 0.14 ppm with M100 having the highest phosphorous content.

Table 3: Mineral composition of maize ogi samples with inclusion of ginger and garlic

Samples	Na(ppm)	K(ppm)	Ca(ppm)	Fe(ppm)	Zn(ppm)	P(ppm)
M100	49.05±0.070^{a}	81.85±0.919^{b}	41.90± 0.565^{b}	0.81± 0.016^{bc}	1.04±0.0742^{b}	9.20± 0.141^{a}
MGG90	40.90±0.141^{c}	89.40±0.848^{a}	39.75±0.353^{c}	1.15± 0.077^{a}	0.89±0.0021^{c}	6.03± 0.233^{d}
MGG80	44.10± 0.282^{b}	77.80±1.838^{c}	45.70±0.424^{a}	0.70±0.009^{c}	1.45±0.023^{a}	8.17±0.212^{b}
MGG70	39.80±0.282^{d}	75.15± 0.353^{c}	42.00±0.141^{b}	0.86± 0.009^{b}	1.07±0.037^{b}	7.43±0.098^{c}

Values are Mean±standard deviation. Mean values with the same superscript along the same column are not significantly different at $p<0.05$
Key: M100: 100% Maize *Ogi*; MGG90: 90% Maize *Ogi*: 5% Ginger: 5% Garlic; MGG80: 80% Maize *Ogi*: 15% Ginger: 5% Garlic; MGG70: 70% Maize *Ogi*: 25% Ginger: 5% Garlic.

3.3. Microbial loads of maize *ogi* samples with inclusion of ginger and garlic

Table 4 illustrates the microbiological changes occurring in the spiced maize ogi sample investigated at the 48-hour mark of the secondary fermentation stage. Lactic acid bacteria in the sample ranged from 2.4 x 10^4 in sample MGG70 to 4.1 x 10^4 in sample M100 during the period of fermentation. In this study, ginger and garlic did not negatively affect LAB populations in the samples.

The total bacterial count in the sample ranged from 1 x 10^5 CFU/ml in sample MGG70 to 3.2 x 10^{35} CFU/ml in sample M100 during the period of fermentation. The reduced total bacterial count observed in the ogi slurry sample treated with spices can be ascribed to the occurrence of diffusible gingerols, allicin, and shogaol, each possessing antimicrobial properties which are present in ginger and garlic, and can be linked to findings reported by Olaniran *et al*. (2015). The total bacterial count was lower than the total count of lactic acid bacteria (LAB), potentially due to the anaerobic nature of LAB, requiring a more specialized medium for growth. These organisms might not thrive on a general medium, like the plate count agar used for total bacterial counts (Adisa *et al*., 2019).

Fungal count (10^4) was recorded in all the samples during fermentation, and the count ranged from 1.5 x 10^4 CFU/ml in the sample MGG70 to 2.9 x 10^4 CFU/ml in the sample M100 (control). Fungi, predominantly yeasts, play a crucial role in introducing the distinctive flavor and aroma during the fermentation process of *ogi* (Adelekan *et al*., 2021). The introduction of garlic and ginger in combination with maize *ogi* slurry, enhanced the lactic acid bacteria flora and decreased microbial loads during fermentation. Encouraging the inclusion of garlic and ginger during fermentation can be beneficial in eliminating undesirable microorganisms in maize *ogi* production (Olaniran *et al*., 2020).

Table 4: Microbial Load (CFU/ ml) of maize *ogi* with inclusion of ginger and garlic

Samples	Lactic acid bacteria count (cfu/ml)	Total bacteria count (cfu/ml)	Total fungal count (cfu/ml)
M100	4.1 x 10^4	3.2 x 10^5	2.9 x 10^4
MGG90	3.7 x 10^4	1.2 x 10^5	2.3 x 10^4
MGG80	2.8 x 10^4	1.3 x 10^5	1.8 x 10^4
MGG70	2.4 x 10^4	1 x 10^5	1.5 x 10^4

Key: M100: 100% Maize *Ogi*; MGG90: 90% Maize *Ogi*: 5% Ginger: 5% Garlic; MGG80: 80% Maize *Ogi*: 15% Ginger: 5% Garlic; MGG70: 70% Maize *Ogi*: 25% Ginger: 5% Garlic.

3.4. pH and total titratable acidity of the maize *ogi* slurry with inclusion of ginger and garlic

Figures 2 and 3 show the changes in pH and TTA during fermentation of spiced maize *ogi*. There was a general steady reduction in pH and simultaneous significant increase in TTA during the 48 h fermentation period.

The decreased pH values in the maize ogi samples can primarily be linked to acid production by microorganisms during the fermentation process. This outcome aligns with the observations made by Singh *et al*. (2012) regarding the impact of fermentation on cereals. The quality of fermented products is also dependent on the populations of fermenting microorganisms, a factor associated with the rise in lactic acid concentration resulting from the activity of lactic acid bacteria (Adebowale and Adeyanju, 2022). This effect, stemming from elevated counts of lactic acid bacteria and the accumulation of lactic acid and organic acids produced during fermentation, contributes to the safety of maize *ogi* which is an addition to the impact of the added spices (ginger and garlic) (Adesokan *et al*., 2008).

The total titratable acidity (TTA) values of all ogi samples increased during fermentation while the pH of all *ogi* samples decreased throughout fermentation period. Previous studies as reported by Adeyanju *et al*. (2019), the rise in total titratable acidity during fermentation can be linked to the increased microbial population, including total aerobic bacteria and lactic acid bacteria, leading to the production of lactic acid at higher levels. The initial generation of carboxylic acid and the subsequent increase in total titratable acidity play a crucial role in preventing the growth of undesirable organisms, which could result in sub-optimal fermentation (Itaman and Nwachukwu, 2021).

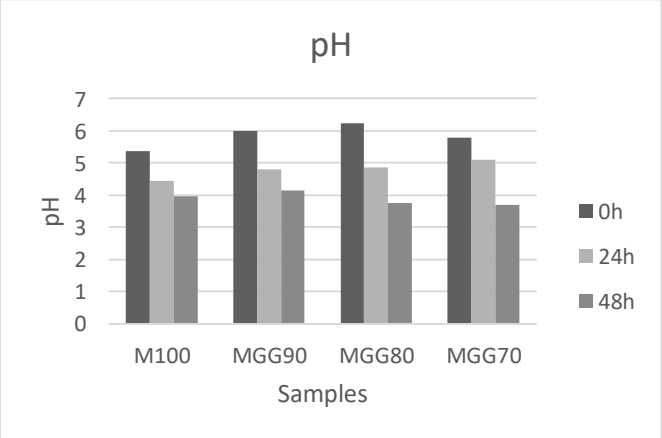

Figure 2: pH of maize *ogi* samples with inclusion of ginger and garlic
M100: (100% Maize *Ogi*); MGG90: (90% Maize *Ogi*: 5% Ginger: 5% Garlic); MGG80: (80% Maize *Ogi*: 15% Ginger: 5% Garlic); MGG70: (70% Maize *Ogi*: 25% Ginger: 5% Garlic)

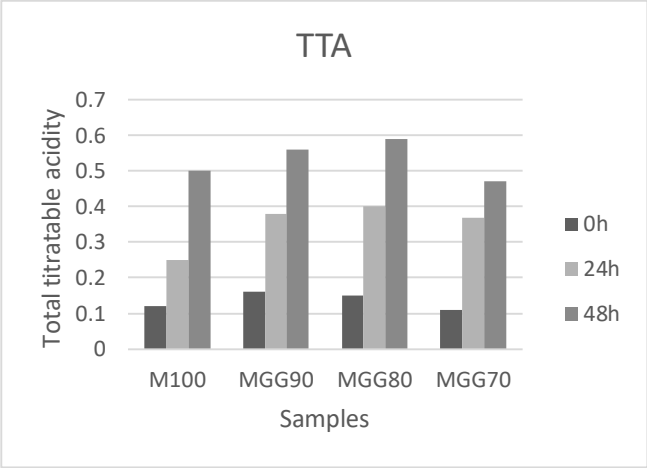

Figure 3: Total titratable acidity of maize *ogi* samples with inclusion of ginger and garlic
M100: (100% Maize *Ogi*); MGG90: (90% Maize *Ogi*: 5% Ginger: 5% Garlic); MGG80: (80% Maize *Ogi*: 15% Ginger: 5% Garlic); MGG70: (70% Maize *Ogi*: 25% Ginger: 5% Garlic)

The total flavonoid ranged from 0.05± 0.005 to 0.207± 0.005(mg/g) Flavonoids constitute a natural group of phenolic compounds known for their antioxidant properties (Jaiyeoba *et al*., 2019). Flavonoids are secondary metabolites whose antioxidant potentials depend on the position and quantity of free hydroxyl groups and have a wide range of health-promoting effects, especially in managing and preventing several diseases (Oboh *et al*., 2016).

The ferric reducing power of a food product reflects its antioxidative activity, as stated by Chandrasekara and Shahidi (2011). The capacity of a food product to convert Fe^{3+} to Fe^{2+} at 593nm serves as an indicator of its reducing potential, with increased absorbance signifying higher reducing power. The ferric reducing antioxidant potential (FRAP) of the maize *ogi* samples ranged from 3.08 ± 0.021 to 23.67 ± 0.021 (mg/g). There was significant difference ($p<0.05$) in the reducing power activities of the maize *ogi* samples with increased percentage of ginger and garlic that was incorporated.

The DPPH scavenging ability of the maize *ogi* samples ranged from 23.04±0.10 to 79.98± 0.10%. There was an increase in DPPH radical scavenging activity as the percentage of ginger and garlic included in the maize *ogi* increases. A combination of garlic and ginger exerted a synergistic effect on the radical scavenging activities of *ogi* samples with the highest effect observed in sample MGG70. The ABTS (2, 2-azino-bis (3-ethylbenthiazoline-6-sulphonic acid) radical scavenging activity increases as the percentage of ginger and garlic increases. The ABTS scavenging ability of the maize *ogi* samples ranged from 0.0076 ± 0.00007 to 0.0256± 0.00007Mmol/g.

Table 5: Antioxidant properties of maize *ogi* samples with inclusion of ginger and garlic

Samples	Phenol (mg/g)	Flavonoid mg/g	FRAP mg/g	ABTS Mmol/g	DPPH %
M100	3.04± 0.042^{d}	0.050± 0.005^{d}	3.08 ± 0.021^{d}	0.0076 ± 0.000078^{d}	23.04±0.108^{d}
MGG90	6.97± 0.042^{c}	0.103± 0. 005^{c}	11.62± 0.021^{c}	0.0188 ± 0.000079^{c}	69.43± 0.109^{c}
MGG80	8.21± 0.042^{b}	0.153± 0. 005^{b}	16.38± 0.021^{b}	0.0215± 0.000078^{b}	68.73± 0.109^{b}
MGG70	11.83± 0.042^{a}	0.207± 0.005^{a}	23.67± 0.021^{a}	0.0256± 0.000078^{a}	79.98± 0.109^{a}

Key: M100: 100% Maize *Ogi*; MGG90: 90% Maize *Ogi*: 5% Ginger: 5% Garlic; MGG80: 80% Maize *Ogi*: 15% Ginger: 5% Garlic; MGG70: 70% Maize *Ogi*: 25% Ginger: 5% Garlic.

3.5. Functional properties of maize *ogi* samples with inclusion of ginger and garlic

The functional properties of the maize *ogi* samples are presented in table 6 which is shown below. The water absorption capacity ranges from 1.66±0.003 to 1.80±0.11 (g/g). The water absorption capacity of a food product gauges its capability to bind with accessible water when it is restricted. Intrinsic factors, including protein conformation, amino acid composition, and hydrophobicity or surface polarity, have been recognized as influential factors that can affect the water and oil binding capacity (Ahaotu *et al*., 2021).

The result from this study shows that oil absorption capacity of maize *ogi* samples ranged from 1.074±0.003 to 1.34±0.021 (g/g), in which there was no significant differences ($p< 0.05$) in the oil absorption capacity of sample MGG90 and MGG80 . The observations from reports by Bolaji *et al*. (2015) noted that the oil absorption capacity of *ogi* powder falls within the range of 0.8-1.05 g/g. The primary chemical constituent of food influencing oil absorption capacity is recognized to be the protein content (Ahaotu *et al*., 2021). The bulk density of maize *ogi* and maize *ogi* fortified with different proportions of ginger and garlic were within the range of 0.55± 0.0039 - 0.66± 0.0007 g/ml. There is no significant difference ($p>0.05$) in the bulk density among the spiced maize *ogi* flour (Sample MGG90, MGG80 and MGG70). The bulk density of flour impacts the strength, quantity of packaging material, texture, energy density, and mouth feel (Ahaotu *et al*., 2021).

The swelling capacity of the samples ranged from 282.79± 1.38 % to 333.33±0.00% with M100 (100% maize *ogi*) having the highest swelling capacity and showed a significant difference ($p< 0.05$) from the other spiced maize *ogi* samples. The swelling capacity of maize *ogi* flour samples decreased with the increasing addition of ginger and garlic powder. Low swelling capacity values of the spiced maize *ogi* samples may be as a result of the breakdown of starch components, notably amylose and non-reducing sugar. The swelling capacity of flour refers to its ability to increase in volume relative to its initial volume when immersed in water (Aluge *et al*., 2016).

The emulsion capacity of the samples ranged from 40.79±0.35 % to 56.71±0.49% with MGG90 (90% maize *ogi*+ 5% ginger + 5% garlic) having the highest emulsion capacity. The formation and stabilization of emulsions, is facilitated by the protein content in food products, and has applications in specific food products like cakes, frozen desserts, and coffee whiteners which is stated according to Jude-Ojei *et al*. (2017).

The foaming capacity of the samples ranged from 0.78 ±0.006 % to 1.55±0.013 % with MGG80 (80% maize *ogi*+ 15% ginger + 5% garlic) having the highest foaming capacity. Foam capacity refers to the protein's ability to withstand gravitational and mechanical stresses (Bukuni *et al*., 2022). Foams are generated when protein substances are dispersed and subsequently held at the air-water interface, leading to a reduction in surface tension as the proteins become partially or fully unfolded (Ogori *et al*., 2022).

Table 6: Functional properties of maize *ogi* samples with inclusion of ginger and garlic

Samples	Water holding capacity (g/g)	Oil holding capacity (g/g)	Swelling capacity (%)	Emulsion capacity (%)	Foaming capacity (%)	Bulk density (g/ml)
M100	1.66±0.003^{b}	1.16±0.026^{b}	333.33±0.00^{a}	51.09± 0.438^{c}	0.786±0.0068^{c}	0.552±0.0039^{b}
MGG90	1.87±0.074^{a}	1.07±0.003^{c}	312.20± 4.40^{b}	52.320±0.453^{b}	1.025±0.0088^{bc}	0.657±0.0135^{a}
MGG80	1.69±0.040^{ab}	1.07±0.003^{c}	269.99± 4.70^{d}	56.711±0.491^{a}	1.559±0.0135^{a}	0.667±0.00070^{a}
MGG70	1.80±0.110^{ab}	1.34±0.021^{a}	282.79± 1.38^{c}	40.794±0.353^{d}	1.315±0.348^{ab}	0.652±0.0039^{a}

Key: M100: 100% Maize *Ogi*; MGG90: 90% Maize *Ogi*: 5% Ginger: 5% Garlic; MGG80: 80% Maize *Ogi*: 15% Ginger: 5% Garlic; MGG70: 70% Maize *Ogi*: 25% Ginger: 5% Garlic.

3.6. Pasting properties of maize *ogi* samples with inclusion of ginger and garlic

The result of pasting properties of maize *ogi* samples produced are shown in Table 7. The peak viscosity ranged from 2740.0±28.28 to 3719.50±41.71 RVU. There was no significant differences ($p<0.05$) between samples M100, MGG80, MGG70 respectively. A high peak viscosity suggests a substantial amount of pure starch content in a sample (Odunlade *et al*., 2019).

Trough viscosity values for the maize *ogi* and spiced maize *ogi* samples as presented in Table 7 ranged between 1705.50±7.77 to 2127.50±38.89 RVU. The trough is a significant pasting parameter for starchy foods that typically undergoes an extended period of constant temperature after reaching their peak viscosity (Akintayo *et al*., 2020).

The breakdown reveals the capacity of the materials to create a viscous paste or gel after boiling and cooling, and there are significant differences ($p<0.05$) among the samples. The breakdown values ranged from 1052.00±4.24 to 1880.50±2.12 RVU. It was noted that fortification had a significant difference ($p < 0.05$) on the breakdown viscosities of the fortified samples, as indicated by the declines in the breakdown viscosities. This reduction could be attributed to variations in the carbohydrate content among the samples (Odunlade *et al*., 2019).

The final viscosity values of maize ogi and spiced maize ogi samples as presented inTable 7 ranged between 3058.00±11.31 to 3645.0±63.64 RVU, in which there is no significant difference ($p<0.05$) in the final viscosity of MGG80 and MGG70. The final viscosity represents the degree of stability of starch granules (Odunlade *et al*., 2019). Setback viscosity reflects the degree to which dissolved starch macromolecules, particularly solubilized amyloses, can re-associate by forming a three-dimensional network, leading to the formation of a gel (Aviara *et al*., 2010). The setback viscosities of the maize *ogi* samples ranged between 1347.50±10.60 to 1648.50±12.02 RVU.

The pasting temperature of the samples ranged from 75.12 ℃ to 76.75 ℃ with MGG70 (70% Maize *ogi* + 25% Ginger + 5% garlic) having the highest value. The pasting temperature for all the samples was below 100 ℃, causing all samples to form a paste in hot water below its boiling point (Olaniran *et al*., 2019). The pasting temperature is the measure of the temperature at which the viscosity of flour starts to increase during the cooking process, offering insights into the energy cost associated with preparing the maize ogi (Ojo and Enujiugha, 2016). The peak time of the samples, on the other hand, ranged between 4.45±0.07 to 4.635±0.049 min which is a measure of the cooking time required by the product to form a paste (Odunlade *et al*., 2019).

Table 7: Pasting properties of maize *ogi* samples with inclusion of ginger and garlic

Samples	Peak viscosity	Trough viscosity	Breakdown	Final viscosity	Setback	Peak time	Pasting temperature
M100	3645.00±63.64^{a}	1804.00±5.657^{c}	1880.50±2.12^{a}	3317.00±24.04^{b}	1513.00±18.38^{b}	4.46±0.014^{b}	75.125±0.035^{b}
MGG90	2740.0±28.28^{b}	1705.50±7.778^{d}	1052.00±4.24^{d}	3058.00±11.31^{c}	1347.50±10.60^{c}	4.635±0.049^{a}	76.725±0.035^{a}
MGG80	3719.50±41.71^{a}	2016.50±23.335^{b}	1733.00±24.04^{b}	3645.00±63.64^{a}	1648.50±12.02^{a}	4.45±0.070^{b}	75.85±0.070^{ab}
MGG70	3708.00±11.31^{a}	2127.50±38.891^{a}	1555.50±7.77^{c}	3661.50± 16.26^{a}	1509.00±12.72^{b}	4.515±0.021^{ab}	76.75±1.060^{a}

Key: M100: 100% Maize Ogi; MGG90: 90% Maize Ogi: 5% Ginger: 5% Garlic; MGG80: 80% Maize Ogi: 15% Ginger: 5% Garlic; MGG70: 70% Maize Ogi: 25% Ginger: 5% Garlic.

3.7. Colour determination of maize *ogi* samples with inclusion of ginger and garlic

The colour analysis obtained from this study is shown in Table 8. The results revealed that there was a significant difference ($p<0.05$) in the degree of L*(Lightness), and b* (yellow-blue). The value of L* obtained from the maize *ogi* samples ranged from 87.1567±0.0450 to 99.76± 0.0173 with sample M100 having the highest value which indicates the degree of lightness tending to 100. The L* values of the spiced maize ogi was lesser than that of the control sample M100

The values of a*(red-green) obtained from the maize ogi samples ranged from 15.09±0.06 to 29.99±0.29, with sample M100 (control) having the highest value. There was no significant differences in the a* values of sample MGG90, MGG80, MGG70

The values of b* obtained from the maize *ogi* samples ranged from -3.70±0.030 to 8.776±0.056, with sample MGG70 having the highest value. There were colour changes (ΔE) calculated from colour parameters L*, a* and b* of maize ogi with inclusion of ginger and garlic ranging from MGG90, MGG80 and MGG70 compared with M100 (100% maize *ogi*) which serves as the control. In which the values ranged from 18.22±0.224 to 22.98±0.295.

Table 8: Colour determination of maize ogi samples with inclusion of ginger and garlic

Samples	L*	a*	b*	ΔE
M100	99.76± 0.01732^{a}	29.99±0.294^{a}	-3.70±0.030^{d}	
MGG90	92.76±0.09292^{b}	15.09±0.063^{b}	4.13±0.017^{c}	18.22±0.224
MGG80	89.17±0.03512^{c}	15.20±0.020^{b}	5.50±0.052^{b}	20.42±0.252
MGG70	87.15±0.04509^{d}	15.37±0.210^{b}	8.776±0.056^{a}	22.98±0.295

Key: M100: 100% Maize Ogi; MGG90: 90% Maize Ogi: 5% Ginger: 5% Garlic; MGG80: 80% Maize Ogi: 15% Ginger: 5% Garlic; MGG70: 70% Maize Ogi: 25% Ginger: 5% Garlic

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3.8. Sensory evaluation of maize *ogi* samples with inclusion of ginger and garlic

The result of the sensory evaluation for appearance, taste, flavour, consistency, and overall acceptability of the spiced maize ogi is shown in Table 9. Sample M100 (100% Maize ogi) was the preferred sample in terms of appearance with the highest hedonic scale of 7.87 when compared with the lowest hedonic scale of 5.77 for sample MGG70 (70% Maize ogi + 25% ginger + 5% garlic). Sample M100 (100% Maize ogi) was highly preferred than all other samples for appearance, taste, flavour, consistency and overall acceptability. This could be due to the source of the sample which is 100% corn which the panelists were used to (Emelike *et al*., 2020). Likely, the increased proportion of ginger and garlic in samples MGG90, MGG80, and MGG70 diminished their preference concerning color, taste, and aroma. This alteration might result from the heightened percentage of spices in the ogi sample, which influenced the overall acceptability of the samples (Adelekan *et al*., 2021).

Table 9: Sensory evaluation of maize ogi samples with inclusion of ginger and garlic

Samples	Appearance	Taste	Flavour	Consistency	Overall acceptability
M100	7.87± 0.81^{a}	7.50± 1.00^{a}	7.10± 1.26^{a}	7.33± 1.21^{a}	7.77± 0.97^{a}
MGG 90	6.80± 1.62^{b}	6.70± 1.55^{ab}	6.57± 1.38^{ab}	6.50± 1.63^{ab}	6.87± 1.40^{b}
MGG80	6.37± 1.88^{bc}	5.93± 1.96^{b}	5.77± 2.25^{b}	6.50± 1.71^{ab}	6.53± 1.52^{b}
MGG70	5.77± 2.12^{c}	4.53± 2.17^{c}	4.83± 2.11^{c}	5.77± 1.88^{b}	5.57± 1.79^{c}

Key: M100: 100% Maize Ogi; MGG90: 90% Maize Ogi: 5% Ginger: 5% Garlic; MGG80: 80% Maize Ogi: 15% Ginger: 5% Garlic; MGG70: 70% Maize Ogi: 25% Ginger: 5% Garlic

Conclusion

In conclusion, this study showed that the inclusion of ginger and garlic in the fermentation of maize ogi enhanced the lactic acid bacteria flora and decreased microbial loads. This indicates that incorporating ginger and garlic during fermentation is advisable to inhibit undesirable microorganisms in ogi production. The addition of spices (ginger and garlic) to maize ogi improved significantly the nutritional composition of the samples with respect to the proximate, mineral, pasting, functional content values with an increase in the percentage of ginger and garlic.

The free radical scavenging activity total phenolic and flavonoid content demonstrated a corresponding increase with the antioxidant activity of the maize ogi samples on addition with ginger and garlic.

Sensory evaluation showed that M100 (100% maize ogi) had the highest acceptability, with respect to appearance, taste, flavour and consistency respectively, while the maize ogi with the higher percentages of ginger and garlic were not acceptable. Deduction from this study is that ginger and garlic could be added effectively during fermentation of ogi without affecting probiotic microorganisms involved in the process of fermentation and can be used for fortification in the improvement of nutritional quality of maize ogi.

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