THE EFFECT OF CO-FERMENTATION OF MILLET GRAINS WITH SPICES (GARLIC OR GINGER) ON FLOUR PROPERTIES AND PORRIDGE QUALITY

ADEBOWALE, OLALEKAN J.* & AJIBODE, OLUWASEGUN O.
Department of Food Technology, Federal Polytechnic, Ilaro, Nigeria
*Corresponding author; olalekan.adebowale@federalpolyilaro.edu.ng

ABSTRACT
The effect of co-fermentation of millet grains with spices (garlic or ginger) on flour properties and porridge quality was investigated. Millet grains were co-fermented with spices (at 2% and 4% of garlic or ginger) singly and when combined for 72 h at 25±2 ℃, each in a separate container. The resulting fermented mash of each sample was separated into two equal portions, one dried into flour and the other made into porridge. Samples without garlic or ginger were used as a control. Bulk density, water absorption and swelling capacities of flours were determined. At the same time, the porridges were analysed for their pH, total titratable acidity (TTA), specific gravity (SG), and sensory quality using standard procedures. The results showed a significant increase in values of bulk density and swelling capacity, while the water absorption capacity decreased in samples containing ginger or garlic. The pH, TTA and SG increased significantly with adding garlic or ginger. The aroma, viscosity, mouthfeel, aftertaste and residual particles of porridge samples showed significant differences with spice addition. Thus porridge with a combination of 4% garlic and ginger had the highest overall acceptability score. Panellists' preference for porridge prepared from 4% garlic and 4% ginger is higher compared to the other porridges. Porridge made from flours containing individual spices was perceived to exhibit a reduction in viscosity with mouth feel. This suggests that porridge with ginger or garlic could be an ideal weaning diet for the elderly or sick

Keywords: Gruel, millet, spices, weaning food

1.0 INTRODUCTION

Pearl millet is one of the staple cereal crops for people living in sub-Saharan Africa because it is climate-resilient and has great potential to combat hunger and malnutrition and assure food security (Taylor et al., 2022). No wonder the year 2023 was designated for millets by the FAO (Yashvardhan, & Gupta, 2024). The origin of millets in-totality was traced to West Africa, and the production output from this region from 2016 to 2020 exceeded 3,500,000 tons per year (FAOSTAT, 2022). Generally, copper, iron, magnesium, phosphorus, selenium, and zinc are some of the essential mineral elements found in millet (Banwo et al., 2022). For instance, the pearl millet variety contains nearly 14.5% proteins, which is comparable to that of wheat (14.4%) and is also rich in complete essential amino acids (Bombom et al., 2023). Common beverages that have been developed from millets and are widely consumed in African regions are *Uji*, *fura*, *Benkida*, *Ogi*, *Ajon*, and *Bushera* (Bamidele, Adebowale, & Xi, 2023). In light of the qualities associated with millet in general, could co-fermentation of millet and spices like garlic or ginger produce acceptable porridge for the vulnerable or the generality of the populace in sub-Saharan African regions?
Thin porridge is made from fermented cereal slurry after cooking the slurry on an open fire. The cooking procedure for thin porridges begins by making a dilution of the starch slurry or sediment with cool water to the desired consistency and cooking it in boiling water (Ladunni et al., 2020). Consumers derive pleasure by taking the porridge with varieties of protein-rich food products from legume seeds such as *robo* (fried-melon meal cake), *akara* (fried cowpea paste), *moimoi* (steamed cowpea paste), *Jogi* (steamed melon paste), and spiced vegetable sauce (Adebowale & Adeyanju, 2022). The consumption of porridges is becoming the norm among the Islamic faithful in West African sub-regions, especially during the Holy month of Ramadan. Most parts of the sub-Saharan African region traditionally use porridges prepared from cereal grains as a staple food and weaning diet. (Adisa & Enujiugha, 2020). This could be because porridge or gruel being a fermented product, has enhanced digestibility and appetizing sensory quality (Itaman & Nwanchukwu, 2021).
Generally, spices are associated with pleasant, aromatic, and volatile flavours, making them important cooking ingredients in most cuisines (Ryu & Kang, 2017). Spices such as garlic and ginger have bioactive components that chelate free radicals and could promote the health of consumers when incorporated into diets (Oluwasola et al., 2021). Numerous studies have documented the inclusion or co-fermentation of various cereal grains with spices (Olaniran & Abiose, 2019; Olaniran et al., 2019; Adebowale & Adeyanju, 2022; Adejobi et al., 2024). Adebowale and Adeyanju (2022), investigated the physicochemical properties and sensory quality of sorghum-Ogi (gruel) complemented with spices (garlic and ginger). The authors found that a sample with garlic and ginger (1:2) caused a decrease in flour bulk density and gruel viscosity. The low viscosity displayed by the cooked gruel could enhance easy swallowing by vulnerable consumers. Recently, Adejobi et al. (2024) investigated the effect of ginger and garlic inclusion (5-25%, singly and in combination) on the performance of *Lactobacillus plantarum* in maize fermented into Ogi (gruel). The authors found that the inclusion of spices (ginger and garlic) in maize-Ogi had a positive effect on the performance of the microbial strain during fermentation. The authors stress further that an improvement in the nutritional value of maize-ogi was established. However, none of the studies investigated the co-fermentation of millet (pearl-type) with garlic or ginger, with an emphasis on the sensory quality of the porridge.

There is a paucity of information on the effects of the co-fermentation of millet with spices such as garlic and ginger. Consequently, this study seeks to evaluate the effects of co-fermenting millet (pearl variety) with garlic or ginger on flour properties (including bulk density, water absorption and swelling capacities) and porridge qualities (including pH, Total titratable acidity, specific gravity and sensory quality) to promote value-added porridge.

2.0 MATERIALS AND METHODS

Sourcing of Materials

Millet grains (pearl variety), garlic, and ginger were sourced from a retail market at Kuto market in Abeokuta, Ogun State. All the materials were processed into flours and porridges under hygienic conditions, ensuring their suitability for human consumption. All the analyses and porridge evaluations were carried out in the Department of Food Technology, Federal Polytechnic Ilaro.

Methods

Samples Formulation for Co-fermentations

Samples were formulated as indicated in Table 1

Table 1: Addition of garlic and ginger into Millets for Co-fermentation

Sample	Spices (%)	
	Garlic	Ginger
Pearl Millets (control)	0	0
Pearl Millets +2% garlic	2	0
Pearl Millets +4% garlic	4	0
Pearl Millets +2% ginger	2	0
Pearl Millets +4% ginger	4	0
Pearl Millets +2% garlic+2% ginger	2	2
Pearl Millets +2% garlic +4% ginger	2	4
Pearl Millets +4% garlic +2% ginger	4	2
Pearl Millets +4% garlic+4% ginger	4	4

Co-fermentation of millets with or without garlic or ginger

Whole millet grains and the spices were completely cleaned manually and co-fermented in clean water for 3 days (72 h) at 25±2 °C. The fermented mass was wet-milled and sieved. The filtrate, primarily starch suspension, was allowed to settle overnight, and the floating liquid was decanted. The solid was then compressed to remove inherent moisture using a hydraulic-screw device to obtain a low-moisture cake. The cake was pulverized manually using a traditional shifter, to reduce the particles for quick and uniformly dried matter, using a cabinet dryer that was set at 60±5°C, 5 h). The dried matter was milled into flour (500 µm size), packaged, and kept in the fridge (4 °C) until needed for analyses and porridge preparation.

Determination of flour properties

Flour properties (bulk density, water absorption and swelling capacities) were determined using the methods outlined previously (Bamidele, Fasogbon, Oladiran, & Akande, 2015). An average of 10 g of sample was carefully weighed into a measuring cylinder (25 ml cap.) and tapped softly on the edge of the laboratory desk until the volume of the cylinder content remained constant. Bulk density (BD) was calculated as shown in Equation i:

$$BD\ (g/ml) = \frac{weight\ of\ the\ sample}{volume\ of\ sample\ after\ tapping} \quad \ldots\ldots Equation\ (i)$$

The water absorption capacity (WAC) was determined by gently introducing a 2 g sample into a centrifuge tube containing hot water (30 ml). The mixture was agitated by vortexing (20 min), at 10 min each on two occasions, followed by centrifugation (4100 x g, 15 min) at 25±2 °C. The floating liquid was decanted, and the sediment was weighed. Water absorption capacity was calculated as shown in Equation ii:

$$WAC\ (g/g) = \frac{W2-W1}{W1} \quad \ldots\ldots Equation\ (ii)$$

W_1= weight of dry sample; W_2 = sample weight after centrifugation

Swelling capacity: The sample (3.0 g) was weighed into a clean graduated cylinder (50 ml), and the volume was recorded. Exactly 30 ml of distilled water was mixed with the samples and swirled. The mixture was left to stand for 60 min and the volume change was recorded at intervals of 15, 30, 45, and 60 min. The swelling capacity was then calculated as a multiple of the original volume.

Porridge preparation

The suspension of 40 g of flour in 100 ml of cold water was mixed into a uniform, thin paste and cooked in a stainless-steel pot containing 300 ml of boiling over an electric hot plate with a uniform burner diameter. To prevent lump formation, the boiling viscous mass was stirred continuously. The porridge was allowed to simmer for 10-20 min at low electric heat while being stirred at intervals (Adebowale, Taylor, & de Kock, 2020).

Determination of Porridge properties

Porridge properties, including pH, total titratable acidity (TTA), and specific gravity (SG), were determined using the procedures described by AOAC (2012). The pH of the porridges was determined using an electrically operated glass electrode pH meter that has been standardized with buffer solutions of pH 4.0 and 7.0. The electrode was inserted into 10 ml sample aliquots. The TTA was determined by taking 10 ml of porridge into 25 ml of distilled water and mixing it in a conical flask. Exactly 200 ml of a 0.1 M aqueous sodium hydroxide (NaOH) solution was titrated against the porridge sample. Three (3) drops of phenolphthalein indicator were used until the formation of a pink colour was sighted, which indicated the endpoint.

$$TTA\ (\%) = \frac{(T2-T1)\ x\ M\ x\ V\ x\ m}{W} \quad \ldots\ldots.Equation\ (iii)$$

V= volume of 0.1 M of NaOH; T_1 = Blank value; T_2 = Titre value; m = ml equivalent of lactic acid (meq) = 0.0640; W = sample weight

For the specific gravity (SG), the principle of density was used to estimate the samples. This procedure involved taking the weight of the dry and empty density bottle. Thereafter, the weight of the bottle was measured after filling it with porridge and again after filling it with distilled water. (Jude-Ojei, Ajayi, & Ilemobayo, 2017).

$$SG = \frac{W2-W1}{W3-W1} \quad \ldots\ldots Equation\ (iv)$$

W_1= weight of empty bottle; W_2= weight of bottle when filled with sample; W_3= weight of bottle when filled with water

Sensory evaluation

Regular consumers of porridge (from the polytechnic community) of about 65 (29 males and 36 females) in number, volunteered for the evaluation. These people were screened and selected, with their ages ranging between 18 and 42 years. Porridges (40 g) were served into 3-digit code plastic cups covered with aluminum foil, in a randomised arrangement. Portable and cleaned water was given to each panel member to cleanse the palate in between sample evaluations. Individual sensory attributes were rated on a 9- 9-point hedonic scale, ranging from 1 (dislike extremely) as the lowest to 9 (like extremely) as the highest value as previously reported by Adebowale et al. (2020).

Statistical analysis

Raw data collated from the experiment was subjected to analysis of variance (ANOVA) a one-way option. Tabulated results were expressed and presented as means ± standard deviations of replicate determinations (n=3). The means of the results were separated using the Duncan New Multiple Range Test evaluated at a 5% significance level (p<0.05). The XLSTAT software for Windows version 2018 (XLSTAT® Addinsoft™, New York).

RESULTS AND DISCUSSION

Table 2 below presents the functional properties, including bulk density (BD), water absorption capacity (WAC), and swelling capacity (SC), of the flour obtained from millet grains co-fermented with garlic and ginger. The BD, WAC and SC of the fermented flour samples showed significant differences ($p < 0.001$) with the inclusion of garlic and ginger in pearl millets. The bulk density and swelling capacity values increased, while the water absorption capacity of samples with spices decreased steadily when compared to that of the sample without spices (control). The slight change in BD suggests that fermented millet with the spices created more porous and less compact compared with the control (Adebowale & Adeyanju, 2022). The samples' respective values for bulk density, water absorption capacity, and swelling capacity ranged from 0.67–0.89 g/ml, 166.5–186.7 (g/g), and 3.64–4.78 (g/g). Bulk density which is useful for measuring heaviness in packaging and transportation shows that grain flour. Lower BD is desirable for easy dispersibility when dissolved in water and reduction of paste viscosity, which is an essential factor in infant feeding (Bamidele, Oladiran, Kayitesi, & Ogundele, 2020). Water absorption capacity measures wholly, the amount of hydrated flour per gram of protein as a result of protein molecules reactions of other solutes with water. Swelling capacity measures the tendency of flour to absorb water during heating from 30 °C to 90 °C in an aqueous suspension (Shiqi, Mario, & Benjamin, 2019).

Table 2: Flour Properties of Co-Fermented Millets-Garlic and Ginger

Samples (Flour)	Flour Properties		
	BD (g/ml)	WAC (g/g)	SC (g/g)
Pearl Millet (Control)	0.67±0.02^{cd}	184.4±2.8^{b}	3.76±0.01^{g}
Pearl Millet +2% garlic	0.68±0.01^{cd}	180.3±2.1^{d}	4.78±0.03^{e}
Pearl Millet + 4% garlic	0.71±0.04^{bcd}	175.7±2.1^{f}	4.17±0.01^{c}
Pearl Millet + 2%ginger	0.68±0.02^{cd}	181.5±2.1^{c}	3.94±0.04^{f}
Pearl Millet +4% ginger	0.72±0.03^{bc}	171.3±6.4^{g}	4.23±0.02^{b}
Pearl Millet +2% garlic+2% ginger	0.87±0.02^{a}	166.5±3.5^{h}	4.24±0.03^{b}
Pearl Millet +2% garlic+4% ginger	0.71±0.07^{bcd}	186.7±1.4^{a}	4.38±0.05^{a}
Pearl Millet + 4 garlic+2% ginger	0.74±0.06^{b}	177.3±5.6^{e}	3.64±0.01^{h}
Pearl Millet +4% garlic+4% ginger	0.89±0.03^{a}	156±2.8^{i}	4.08±0.08^{d}
p-value	***	***	***

The results are means (±standard deviation) of three determinations. Means with different superscripts within the column are significantly different at $p < 0.0001$
Key:
BD = bulk density
WAC = water absorption capacity
SC = swelling capacity
*** = $p < 0.001$

Porridge properties

Table 3 presents the physicochemical properties of fermented porridge made from pearl millet, garlic, and ginger, as measured by pH, total titratable acidity (TTA), and specific gravity (SG). The pH, TTA and SG of the porridge samples ranged from 4.22-4.37, 0.35-0.80 and 76.5-76.9, respectively. The low pH values recorded for all the porridge samples suggest that the fermenting microorganisms produced lactic acid or other organic acids during fermentation (Adeyanju, Krugar, Taylor, & Duodu, 2019; Olaniran & Abiose, 2019). The pH and titritable acidity are well known to be inversely related, and so, the slight increase in pH values of some samples could be attributed to the decrease in total titritable acidity (Rehman et al., 2014). The increase in TTA of samples with garlic and/or ginger could be attributed to the potency antimicrobial activities of the spices (Yinusa, Malomo, & Fagbemi, 2022). In other words, high TTA levels of porridge samples can retard or inhibit the population or growth of non-aciduric microorganisms (Oluwasola et al., 2021). The decrease observed in the values recorded for the specific gravity of the porridge samples could be attributed to the reduction of grain matter for certain volumes despite an increase in moisture content.

Table 3: Porridge Properties of Co-Fermented Millets-Garlic and Ginger

Samples	Porridge Properties		
	pH	TTA	SG
Pearl Millet (Control)	4.29±0.06^{abc}	0.30±0.14^{bc}	76.5±0.1^{d}
Pearl Millet +2% garlic	4.20±0.01^{d}	0.35±0.07^{bc}	76.8±0.3^{ab}
Pearl Millet + 4% garlic	4.32±0.05^{ab}	0.60±0.05^{ab}	76.8±0.1^{ab}
Pearl Millet + 2%ginger	4.37±0.02^{a}	0.50±0.28^{abc}	76.7±0.4^{c}
Pearl Millet +4% ginger	4.31±0.06^{ab}	0.50±0.14^{abc}	76.5±0.2^{d}
Pearl Millet +2% garlic+2% ginger	4.32±0.00^{ab}	0.20±0.02^{c}	76.9±0.3^{ab}
Pearl Millet +2% garlic+4% ginger	4.22±0.01^{cd}	0.20±0.03^{c}	76.8±0.5^{ab}
Pearl Millet + 4 garlic+2% ginger	4.25±0.04^{bcd}	0.85±0.21^{a}	76.9±0.1^{a}
Pearl Millet +4% garlic+4% ginger	4.22±0.03^{cd}	0.80±0.28^{a}	76.7±0.08^{c}
p-value	*	*	***

The values are means and standard deviation of three determinations. Means with same letter(s) within the column are not significantly different.

Key
TTA = Total titratable acidity
SG = Specific gravity
* = $p < 0.05$
*** = $p < 0.001$

Sensory Evaluation of Co-Fermented Millet-Garlic and Ginger Porridge

The sensory attributes including appearance, aroma, flavour, taste, mouth feel, aftertaste, residual taste, and overall acceptability of the co-fermented millet-garlic and ginger porridges are presented in Table 4. Samples co-fermented with the spices, whether individually or combined, had significantly ($p < 0.05$) higher scores compared to porridge without spices. However, porridge without spices (7.2) and that with 4% garlic (7.4) exhibited a higher overall acceptability compared to some of the porridges with added spices (ranging between 6.5 and 7.0). Generally, porridge with 4% garlic and 4% ginger received the highest overall acceptability score (7.9) among the samples, indicating it is the most preferred by the panellists, while the least was that with 2% garlic (6.5). This could be because the combined spices, each at 4%, provide a better aroma and flavour to the porridges compared to when they are added separately. This could be that the combined spices at 4% each impart a better aroma or flavour in the porridges making the porridges more acceptable to the panellists than the naturally fermented millet porridge. The improvement in the sensory attributes of the fermented millet could be attributed to the flavour compounds present in both garlic and ginger (Li et al., 2016). Porridge with a higher concentration of pure garlic (4%) recorded lower preference and was highly objectionable to the panellists. and this may account for its lower preference. Therefore, co-fermenting millet with spices such as garlic and ginger can improve the sensory quality of porridge. This statement agrees with some other previously documented reports on maize and sorghum gruels (Olaniran & Abiose, 2019; Adebowale & Adeyanju, 2022).

Table 4: Sensory Properties of Co-fermented Millet-Garlic and Ginger Porridges

Samples (Porridge)	Sensory Properties								Willingness-to-buy
	Colour	**Taste**	**Aroma**	**Viscosity**	**Mouth feel**	**After taste**	**Residual Particle**	**Overall acceptability**	
Pearl Millet (Control)	$7.2±0.6^{ab}$	7.0±1.13	$6.8±0.7^{bc}$	$7.0±1.1^{bc}$	$7.2±1.1^{abc}$	$7.2±1.2^{a}$	$6.9±1.0^{b}$	$7.2±1.0^{abc}$	$6.8±0.9^{c}$
Pearl Millet +2% garlic	$6.6±0.8^{b}$	6.9±0.96	$6.3±0.9^{c}$	$6.6±0.8^{c}$	$6.4±0.9^{d}$	$6.4±0.9^{b}$	$6.1±0.6^{c}$	$6.5±0.7^{d}$	$6.8±1.0^{c}$
Pearl Millet + 4% garlic	$6.8±0.7^{b}$	7.2±0.94	$6.7±0.7^{bc}$	$6.7±0.7^{c}$	$7.0±1.1^{bcd}$	$6.9±0.8^{ab}$	$6.7±0.9^{bc}$	$7.4±0.9^{abc}$	$7.2±0.5^{abc}$
Pearl Millet + 2%ginger	$6.8±1.3^{b}$	7.1±1.25	$6.8±1.1^{bc}$	$6.8±0.8^{bc}$	$6.8±1.1^{bcd}$	$6.8±1.0^{ab}$	$6.8±1.0^{bc}$	$6.8±0.9^{cd}$	$6.8±1.1^{c}$
Pearl Millet +4% ginger	$7.0±1.2^{ab}$	7.0±1.16	$6.8±0.9^{bc}$	$6.8±1.2^{bc}$	$7.0±1.0^{bcd}$	$6.8±1.3^{ab}$	$6.8±0.9^{b}$	$7.0±0.8^{bcd}$	$7.0±0.8^{bc}$
Pearl Millet +2% garlic+2% ginger	$6.7±1.2^{b}$	7.0±1.13	$6.3±0.9^{c}$	$6.8±0.8^{bc}$	$6.6±1.3^{bcd}$	$6.7±1.2^{ab}$	$7.0±1.0^{ab}$	$7.0±1.4^{bcd}$	$6.9±1.2^{bc}$
Pearl Millet +2% garlic+4% ginger	$7.2±0.9^{ab}$	7.2±1.10	$6.7±0.8^{bc}$	$7.0±0.9^{bc}$	$6.5±0.8^{cd}$	$6.9±1.2^{ab}$	$6.8±1.1^{b}$	$6.8±1.0^{cd}$	$7.0±1.0^{abc}$
Pearl Millet + 4 garlic+2% ginger	$7.2±0.8^{ab}$	6.9±0.88	$7.1±1.0^{ab}$	$7.4±0.8^{ab}$	$7.3±1.1^{ab}$	$7.0±1.1^{ab}$	$7.1±1.0^{ab}$	$7.5±1.1^{ab}$	$7.6±0.9^{ab}$
Pearl Millet +4% garlic+4% ginger	$7.7±0.46^{a}$	7.4±0.91	$7.6±0.9^{a}$	$7.8±0.8^{a}$	$7.9±0.4^{a}$	$7.4±0.5^{a}$	$7.6±0.8^{a}$	$7.9±0.7^{a}$	$7.7±0.7^{a}$
p-value	ns	ns	*	*	**	ns	*	***	*

The values are presented as mean and standard deviations of evaluation in two sessions using the same panellists. Mean values with the different superscripts are significantly different.
Key
ns = not significant
* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

CONCLUSION

Co-fermented millet grains with spices-garlic or ginger, separately or in combination were studied. The sample had an increase in bulk density and swelling capacity, while the water absorption capacity decreased. The resulting porridges from flour samples containing garlic or ginger have a lower pH, a higher total titratable acidity, and a higher specific gravity. Porridge aroma, viscosity, mouthfeel, aftertaste, and residual particles are significantly different. Intense garlic aroma is associated with porridges fermented with a larger amount of garlic alone, which led to porridge's lower preference by the panellists. Thus, porridge with a combined 4% garlic and 4% ginger had the highest overall acceptability score over other samples. A reduction in porridge viscosity, especially in samples co-fermented with garlic or ginger, was detected by the panellists. Low viscous porridge could be recommended as a meal for the elderly and the sick, as this could be swallowed easily and conveniently by the vulnerable group. Increasing food utilization of pearl millet and, garlic or ginger could enhance more value-added products, and promote food security and economic development.

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