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Research Article

Selection, use and the influence of starter cultures in the nutrition and processing improvement of *ogi*

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Abstract

The selection criteria of starter cultures (SCS) used for *ogi* production were reported. These SCS were used with the aim of improving processing technique, and lysine and methionine levels of *ogi*, a lactic acid fermented weaning food limiting in these two amino acids. *Lactobacillus brevis* XO43 and *Saccharomyces cerevisiae* OY4 were used as SCS in a pilot plant study. Fermentation with SCS showed a constant final pH level of 3.35 in modified substrates after fermentation unlike spontaneously fermented; and significantly higher acidity (%TTA) indicative of faster fermentation. The addition of sugar (2% w/w) and soybean flour (1% w/w) also increased the acid levels during fermentation. Fermentation of dehulled maize (DM) grains fortified with glucose (2%w/w) alone by SCS shows the best quality in all the parameters considered except the available niacin yield. The lysine is 24% higher than oven-dried *ogi* flour from the traditionally fermented (TF) and 11% higher than unprocessed whole maize grains (WMG). The methionine is 92% and 77% higher than the TF *ogi* and WMG, respectively. The total amino acids level of the sample was 32% more than the TF *ogi* flour and 55% more than WMG. Although, the soluble protein level was 23% lesser than the unfermented WMG, it was 12% more than the DM substrate and *ogi* from TF. Fermentation of corn into *ogi* led to losses in the initial quantity of niacin. SCS significantly improve the nutrients such as lysine, methionine, total amino acids, soluble protein and niacin more than spontaneous fermentation. Dehulling of grains, dewatering and oven drying significantly reduce nutrients. Ogi fermentation process with the use of SCS and DM guarantee organoleptic qualities, improve ogi production by eliminating wet-sieving, limiting water usage, and creating better nutritional products.

Keywords: *Ogi;* Starter culture; Lysine; Methionine; Niacin; Lactic acid fermentation; Nutritional improvement; Process improvement

Introduction

Ogi is a common West African lactic acid fermented staple food from maize, sorghum, or millet [1,2]. The popularity and general acceptance of *ogi* has encouraged various works on microbiology [1,2], economic impact [3], nutrition [4-7], mycotoxin safety [8-10], the production techniques [11-13] and spoilage [14-16]. Despite all the attention indicated above, most of the efforts have been based on product analyses or evaluations. Only a few works have been focused on the application of starter cultures to solve specific problems related to *ogi* processing and product improvement [17,18]. The Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria, developed a pilot process plant for *ogi* production based on the traditional

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procedure that requires spontaneous fermentation [11]. Although, this has encouraged better product presentation, packaging, increased shelf life and increased output, a more efficient fermentation requires definite SCS. Products resulting from the present spontaneous fermentation process are not likely to be reproducible worldwide due to varying microflora and environmental conditions. The spontaneous fermentation been used without definite microorganisms has discouraged the potential use of modern microbial biotechnology techniques to improve the product quality through the use of defined microbial SCS [19]. The application of SCS or its byproducts during processing can reduce production time, further increase shelf-life and nutritional attributes [16-18]. The *Lactobacillus brevis* and other lactic acid bacteria (LAB) contribute to the sour and acidic taste, while *Saccharomyces cerevisiae* contributes to the aroma of *ogi* and improves the LAB's stability [20,21]. Previous attempts to improve the nutritional qualities of *ogi* in the past have been based mostly on product fortification with legumes such as groundnut, pinto, soybean, pigeon pea and cowpea to boost the deficient amino acid levels, such as lysine levels which are generally limiting in cereals especially those used for *ogi* production raw materials [22-25]; while this has been achieved, a different product emerged that is different from *ogi* in taste, aroma, and general acceptability hence such names as soy-*ogi,* walnut-*ogi,* e.t.c. [6,11,26]. Wang *et al*. [27] noted that an induced increase in kernels' niacin concentration is necessary for improving maize kernels' nutrition. Methionine is also limiting in most legumes used to fortify *ogi* for better nutritive products [28-30].

The traditional practice of daily replacement of sour water on *ogi* to prolong the shelf life is cumbersome and may reduce the nutritional value through the loss of water-soluble nutrients. The use of starters in controlled *ogi* fermentation has the advantage of utilizing the vast potentials of the lactic acid bacteria and other useful micro-organisms present in the natural fermentation to improve *ogi* shelf life and solve various health and nutritional problems. Olukoya *et al*. [17] developed an improved *ogi* named *`DogiK´* with potential use in the prevention and treatment of diarrhoea by using *Lactobacillus* SCS with antagonistic activity against diarrhoeagenic bacteria (and also possessing amylolytic activity). The product is active against pathogens in cooked and uncooked form and at neutral pH [31,32]. LAB and yeast from *ogi* and other related sources have been identified with important features that enhance quality *ogi* production such as the production of antimicrobial substances against major pathogens and spoilage microorganisms [33-35], various enzymes that are capable of degrading anti-nutritional factors like phytate, protease inhibitors and oligosaccharides [36,37], as well as production of amino acids such as lysine and methionine [5,38]. None production of biogenic amines (BAs) like Histamine and cadaverine that can be formed by converting histidine and lysine via histidine decarboxylase (HDC) and via lysine decarboxylase (LDC), respectively [39] is also a desirable quality. This work is aimed at selecting and demonstrating the ability of the selected lysine- and methionine-producing SCS to improve the lysine and methionine levels of *ogi* in a pilot plant study. Earlier attempts were carried out at the laboratory level. The implication of certain steps employed during processing and their effects on the final product will also be investigated.

Materials and Methods

Screening of starter cultures (SCS)

Isolates of LAB and yeasts cultures obtained during *ogi* processing were screened and further details established to obtain *ogi* potential SCS. SCS were revealed by initially checking for important technical features of the isolates including lysine and methionine production yields. Most importantly, the ability to produce an acceptable *ogi* aroma was carried out in a covered boiling tube study.

Technical features of LAB and yeasts isolates

Isolates of LABs were tested for conformity with the following important technical features such as: pH 4.0 reduction ability [40,41], acid production from oligosaccharides raffinose and stachyose [42], bacteriocin producing microorganisms screening based on significant inhibitions against test microorganisms such as *Listeria monocytogenes*, *Listeria innocua ATCC33090*, *Staphylococcus aureus* ATCC 43300, *Enterococcus faecalis*, *Escherichia coli* ATCC25922, *Klebsiella pneumoniae* and *Proteus vulgaris* by using agar diffusion test. Cell free crude supernatant (24h) of each isolate was obtained by centrifugation at 3,000xg for 20 minutes. The supernatant was adjusted to pH 6.5 with 1M NaOH and subsequently filter sterilized through a 0.2µm membrane filter (Whatman, Germany). Inhibitory activity was determined using agar well diffusion assay [43,44], and phytase production was according to growth on minimal salt medium containing (% w/v): **Dextrose,** 0.5; peptone, 1.0; yeast extract, 0.5; $MgSO_4$, 0.1; $CaCl_2$, 0.1, and sodium phytate, 0.1 (pH 7.0). The differential medium use the disappearance of precipitated calcium and sodium phytate in the medium after incubation period as an indication of phytase enzyme presence [45]. Biogenic amine (BAs) none production [39,46,47] among the isolates tested from different sources were by growing in de Man, Rogosa and Sharpe (MRS) broth (Oxoid CM0359) at 37°C for 24-48 h. Production of BAs from each isolate was determined using the Moller's decarboxylase base broth (MDB) (pH 5.3) containing 0.05% precursor such as L-histidine, L-tyrosine, L-lysine and L-ornithine [48]. The screened isolates were inoculated to the MDB with and without precursor (as control) at 37°C for 4 days and 7 days respectively. The colour of Moller's decarboxylase base medium changed from yellow to purple after incubation

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Teniola OD et al., J Food Sci Nutr Res 2023
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indicates positive for BAs production, whereas if the broth remained yellow, it will indicate negative for BAs production. Both LAB and yeasts isolates were effectively screened for lysine and methionine overproduction as exhibited by the two organisms' growth in minimal growth plates with high concentrations of thialysine and ethionine, respectively [38,49,50].

Microbial screening of acceptable Ogi SCS

Promising isolates were further tested and selected for use as potential *ogi* SCS. Fresh cultures (24h) of LAB and yeast previously screened for important features of fermentation as indicated above were used. Pure cultures of the test micro-organisms were grown in screw cap tubes containing 10 ml sterile de Man, Rogosa and Sharpe (MRS) broth (Oxoid CM0359) and Sabouraud Dextrose Liquid medium broth (Oxoid CM0147) for LAB and yeast growth, respectively. The 24h-old culture broths were each washed twice in sterile distilled water by centrifugation at 3000 g value for 10 min using Sorvall RC5C refrigerated centrifuge. The pellets obtained from the culture broth were suspended again in sterile distilled water to form inoculum cell suspension containing 10^8-10^{10} c.f.u. /ml viable counts.

The test microorganisms were inoculated into sterile mixture of maize flours (5g) and distilled water. This was prepared by sterilization of the dried flour at 121 ^{0}C in an autoclave for 15 minutes. The cooled sterile dried flour was aseptically hydrated with 20 ml of sterile distilled water at ambient temperature. The well shaken maize flour suspensions were each inoculated with 3 ml of the prepared inoculum suspension (as described above) singly and in combinations. The inoculated maize flour solutions above were incubated at 30 ^{0}C temperature for 24h. After incubation, changes in the pH, TTA, dissolved hydrogen sulphide (H_2S) and odour (acceptability) were noted. The odour changes were obtained by the mean score of a 5-man panel. *Ogi* samples inoculated with sterile distilled water were used as control while freshly produced hydrated *ogi* from the local market served as reference.

Selected starter cultures

Saccharomyces cerevisiae OY4 and a hetero-fermentative *Lactobacillus brevis* XO43 were identified as *ogi* starter cultures with lysine and methionine overproducing capabilities [38]. They were used for the later pilot plant fermentation.

Inoculum production for fermentation

Twenty-four hours cultures of *S. cerevisiae* OY4 and *L. brevis* XO43 on agar slants were prepared as shown above.

Fermentation experiment

The raw materials used for the laboratory studies include maize and soybean flour which were purchased at Idi-Oro market, Mushin, Lagos. Fifteen kilograms (15kg) of DM grains were used for each fermentation. The substrates were made up of substrates: (A) DM grains alone; (B) DM grains and glucose (2%w/w); (C) DM grains, glucose (2%w/w), and soybean flour (1%w/w). These were each mixed with 32 litres of tap water and inoculated with 1.6 litres of well mixed equal proportions of *L. brevis* XO43 and *S. cerevisiae* OY4 prepared inoculum above [10^7-10^8 c. f. u. /ml confirmed by microbial plate count using MRS agar (Oxoid CM 361) and Sabouraud Dextrose Agar (SDA) (Oxoid CM 41)]. A non-inoculated spontaneously fermented set from the substrates described above were used as the control; while WMG spontaneously steeped and fermented as done traditionally was used as a reference control [11]. After 24 h of steeping, the fermented grains were wet-milled using a double grinding mill (Model: Asiko A11, Addis Engineering, Nigeria). The wet-milled mash was further fermented for 48h. The traditionally prepared reference control from WMG was wet-sieved before further fermentation. After fermentation, the pH and percentage total titratable acidity of the fermented mash samples were measured [18]. *Lactobacillus brevis* XO43 and *Saccharomyces cerevisiae* OY4 used as SCS were isolated and confirmed with the stock cultures using various morphological and biochemical tests. The representative samples of each of the fermentation sets were freeze-dried at - 40°C temperature using a Labconco freeze-dryer (Lyph-Lock 6, Labconco Co., Kansas City, USA). The water of the fermented mash samples were removed and the water extract was kept at -20°C temperature for subsequent analyses. The wet-cakes were oven-dried using a Mitchell tray oven-drier (L. A. Mitchell Ltd. Drying Engineers, Ref. No. 008404/63/ Exp, Manchester, England) at 55°C to obtain *ogi* flakes. These flakes were milled into powder in a disk mill (Apex-Mill, Apex Construction Ltd., England) and packaged in polyethylene (plastic) bags. The final samples were stored at -20°C temperature prior to analyses. The experiments were set up in duplicates.

Chemical analyses

The pH and total titratable acidity (TTA) were determined directly from the fermentation mash prior to drying according to the method of Okoroafor et al [18]. Total amino acids assessment was according to Rosen [51] while the method of Waterborg, and Matthew [52] was used for the total soluble protein determination.

Determination of lysine, methionine and niacin

Test materials were prepared according to AOAC methods. The samples were analysed for the availability of lysine, methionine, and niacin by microbiological assays [49,53].

Organoleptic (sensory) evaluation test

A 7-man trained panel who were familiar with *ogi* were asked to assess the qualities of the 48 h fermented samples

fortune Journals
Teniola OD et al., J Food Sci Nutr Res 2023
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considering the colour or appearance, aroma, taste, sourness after taste, mouth feel consistency and overall acceptability as reported. This was then analysed statistically as described by analysis of variance (ANOVA) using the statistical software SPSS 20.0, and means were compared by the Duncan`s Multiple Range Test (0.05 level) as described by Cass [54].

Data availability statements

The data that support the findings of this study are available from "Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria"; where the corresponding author works during the duration of the practical work, but restrictions apply to the availability of these raw data, which were used under license for the current study, and so are not publicly available. Data are however available from the corresponding author upon reasonable request and with permission of "The Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria".

Results

Important characteristics of the screened LAB isolates vary depending on LAB groups as shown in table 1. It was observed that *Pediococcus* has the highest percentage population (96.92%,) to be able to reduce the pH of MRS broth below 4.0. This is followed by homo-fermentative *Lactobacillus* at 91.4%, then *Enterococcus* (20%), hetero-fermentative *Lactobacillus* (8%) and *Lactococcus* (4.17%). The highest frequency of phytase degraders was found amongst homo-fermentative *Lactobacillus* (57.14%). These were followed by *Pediococcus* (36.92), *Lactococcus* (37.5%), hetero-fermentative *Lactobacillus* (16%) and *Enterococcus* (5%). Out of the different groups of 170 isolates, only *Lactococcus* was able to produce bacteriocin (12.5%). The degradation of oligosaccharides such as stachyose and raffinose by different categories of lactic acid bacteria was analyses. Stachyose degradation was most profound in homo-fermentative *Lactobacillus* (45.71%) followed by *Enterococcus* (45%), *Pediococcus* (44.62%), *Lactococcus* (25%) and hetero-fermentative *Lactobacillus* (16%). Lastly raffinose sugar degradation is most frequent in homo-fermentative *Lactobacillus* (94.29 %), followed by *Pediococcus* (90.77%). *Enterococcus* showed 65 % degraders of raffinose, followed hetero-fermentative *Lactobacillus* (48%) and *Lactococcus* (33.33%). Only one culture of the *Leuconostoc* was isolated, which was however negative to all the features tested (table 1). It was also established from the study that none of the isolates screened produced biogenic amines.

Natural lysine and methionine production study of *Lactobacillus* spp and yeasts in batch fermentation of *ogi* showed that 43% of the *Lactobacillus* and 83% of the yeast isolates tested were capable of lysine overproduction while 25% of the *Lactobacillus* and 88% of the yeast isolates overproduced methionine. The profile features of the selected SCS isolates of *Lactobacillus brevis* XO43 and *Saccharomyces cerevisiae* are shown in table 2. The changes in the pH and the percentage total titratable acidity (%TTA) of the fermented mash after 3 days of fermentation are presented in table 3. Fermentation substrates pre-inoculated with SCS showed a similar pH level of 3.35 after fermentation in contrast with the variable pH readings for the spontaneously fermented. The pH 3.35 level was slightly lower but close to the pH 3.40 observed in the traditional fermented reference *ogi* sample from WMG. Fermentation with SCS gave products with higher acidity (%TTA) than the spontaneous fermentations (table 3). Addition of sugar and soybean flours also increased the acid levels during fermentation. Nutrients such as lysine, methionine, total amino acids, soluble protein and niacin reduced when WMG were dehulled (tables 4 and 5). Freeze-dried *ogi* analyses indicated that the use of SCS increased the levels of the available lysine and methionine. The total amino acids and soluble protein also increased more after fermentation when compared with spontaneously fermented freeze-dried controls and the unfermented DM grains used as the substrates (tables 5). Fermentation of DM grains fortified with glucose (2%w/w) alone by SCS shows the best quality in all the parameters considered except the available niacin (tables 4 and 5). It is 24% higher than oven-dried *ogi* flour from the traditional fermentation and 11% higher than unprocessed WMG. The methionine level of the sample from

Table 1: Characteristics of lactic acid bacteria screened as ogi starter cultures

Lactic acid bacteria groups	Number of isolates	Cell morphology	Reduction of MRS pH<4.0	Phytate degradation	Amine Production	Bacteriocin production	Acid from oligosaccharides	
							Stachyose	Raffinose
Homo-fermentative Lactobacillus	35	Rods	32	20	0	0	16	33
Hetero-fermentative Lactobacillus	25	Rods	2	4	0	0	4	12
Pediococcus	65	Cocci	6	24	0	0	29	59
Lactococccus	24	Ovoids	1	9	0	3	6	8
Leuconostoc	1	Ovoids	0	0	0	0	0	0
Enterococcus	20	Ovoids	4	1	0	0	9	13

fortune journals
Teniola OD et al., J Food Sci Nutr Res 2023
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this fermentation fortified with added glucose and fermented with SCS was 92% and 77% higher than the traditionally prepared *ogi* sample and unfermented whole maize grains, respectively. The total amino acids level of the sample was 32% more than the traditionally fermented *ogi* flour and 55% more than WMG. Although, the soluble proteins level was 23% lesser than the unfermented WMG, it was still 12% more than the DM substrate and *ogi* from traditional process. The reduced lysine and methionine levels when maize substrate added with glucose (substrate B) was further fortified by adding 1% (w/w) soybean flour as additional nitrogen source (substrate C) was against our expectation based on earlier physiological studies on the starter cultures (tables 4,5). The results show that fermentation of corn into *ogi* led to losses in the initial quantity of niacin that is available in the raw materials. All the fermentation products

Table 2: Technical profiles of the two selected starter culture microorganisms for ogi production.

Starter culture isolates	Number of isolates	Cell morphology	Reduction of MRS pH<4.0	Phytate degradation	Amine production	Bacteriocin production	Acid from oligosaccharides		LYS	METH
							Stachy-ose	Raffi-nose		
Lactobacillus brevis XO43	1	Rods	+	+	-	-	NA	+	+	+
Saccharomyces cerevisiae OY4	1	Ovoids	-	+	NA	NA	NA	+	+	+

LYS, Lysine overproduction; METH, Methionine overproduction; +, Positive; -, Negative; NA, Not Available

Table 3: Changes in pH and percentage total titratable acidity (%TTA) of 3-day fermented ogi gruel*

Substrate used	Fermentation Type	pH	Percentage total titratable acidity (%TTA)
Whole maize grains	Unfermented#	#6.40^{e}	#0
	Spontaneous	3.40^{bc}	0.934^{a}
	(traditional method)		
Dehulled maize grains alone	Unfermented#	#6.40^{e}	#0
	Spontaneous	3.25^{a}	0.937^{a}
	Starter cultures	3.35^{b}	0.991^{b}
Dehulled maize grains and glucose (2%w/w)	Spontaneous	3.45^{c}	0.973^{b}
	Starter cultures	3.35^{b}	1.262^{d}
Dehulled maize grains, glucose (2%w/w) and soybean flour (1%w/w)	Spontaneous	3.50^{cd}	1.000^{bc}
	Starter cultures	3.35^{b}	1.297^{d}

$^{a-d}$Values in the same column with different superscripts differ significantly ($p<0.05$). Stated values are means of two trials.
#Results for unprocessed raw material samples.
DMG, Dehulled maize grains

Table 4: Lysine and methionine contents of pilot-plant produced ogi sample

Samples used	Fermentation type	Lysine (mg/g)		Methionine (mg/g)	
		Oven dried	Freeze dried	Oven dried	Freeze dried
Whole maize grains (WMG)	Unfermented	16.26$^{c\#}$	nd	2.19$^{c\#}$	nd
Dehulled maize grains (DMG)	Unfermented	9.07$^{a\#}$	nd	1.56$^{b\#}$	nd
Traditionally produced *ogi* from WMG	Spontaneous	14.54^{b}	26.63^{d}	2.02^{c}	5.8n^{c}
ogi from DMG alone	Spontaneous	7.39^{a}	8.73^{a}	1.54^{b}	3.01^{a}
	Starter cultures	13.27^{b}	20.65^{c}	2.77^{c}	4.12^{b}
Ogi from DMG and glucose (2% w/w)	Spontaneous	7.35^{a}	12.61^{a}	0.96^{a}	3.42^{a}
	Starter cultures	18.08^{c}	29.28^{d}	3.88^{d}	7.38^{d}
Ogi from DMG, glucose (2% w/w) and soybean (1% w/w)	Spontaneous	12.23^{b}	16.74^{b}	2.50^{c}	4.84^{b}
	Starter cultures	15.53^{c}	18.15^{b}	3.76^{d}	5.48^{c}

$^{a-d}$Values in the same column with different superscripts differ significantly ($p<0.05$). Stated values are means of two trials.
#Results for unprocessed raw material samples, nd, not determined

Teniola OD et al., J Food Sci Nutr Res 2023
DOI:10.26502/jfsnr.2642-110000131

Table 5: Total amino acids, soluble protein and niacin contents of pilot-plant produced ogi samples

Samples Used	Fermentation type	Total amino acids content (mg/g)		Soluble protein content (mg/g)*		Niacin content (mg/g)*	
		Oven dried ogi	*Freeze dried ogi*	*Oven dried ogi*	*Freeze dried ogi*	*Oven dried ogi*	*Freeze dried ogi*
Whole maize grains (WMG)	Unfermented	45.87$^{b\#}$	nd	23.04$^{d\#}$	Nd	20.34$^{c\#}$	nd
Dehulled maize grains (DMG)	Unfermented	38.32$^{a\#}$	nd	15.78$^{b\#}$	Nd	12.47$^{b\#}$	nd
Traditionally produced *ogi* from WMG	Spontaneous	53.70^{c}	71.84^{b}	15.72^{b}	20.52^{b}	7.85^{a}	19.50^{c}
Ogi from DMG alone	Spontaneous	48.72^{b}	64.94^{a}	9.18^{a}	14.64^{a}	6.07^{a}	8.27^{a}
	Starter cultures	52.25^{c}	72.95^{b}	13.84^{b}	20.92^{b}	6.37^{a}	13.00^{b}
Ogi from DMG and glucose (2 % w/w)	Spontaneous	45.32^{b}	60.93^{a}	11.22^{a}	18.18^{b}	5.40^{a}	8.07^{a}
	Starter cultures	70.88^{d}	81.79^{c}	17.68^{c}	24.64^{c}	7.38^{a}	12.50^{b}
Ogi from DMG, glucose (2% w/w) and soybean (1%w/w)	Spontaneous	49.46^{b}	65.21^{a}	9.90^{a}	23.04^{c}	7.33^{a}	9.94^{a}
	Starter cultures	53.61^{c}	73.57^{b}	15.76^{b}	25.72^{c}	7.77^{a}	17.27^{c}

$^{a\text{-}d}$ Values in the same column with different superscripts differ significantly ($p<0.05$). Stated values are means of two trials,
$^{\#}$ Results for unprocessed raw material samples, nd, not determined.

Table 6: Organoleptic (sensory) assessment of ready to eat pap from pilot-plant produced ogi flour samples[a]

Substrate used	Fermentation Type	Organoleptic (sensory) characteristics								
		Colour/ Appearance	Aroma	Taste	Sourness	After taste	Flavour	Mouth feel	Consis-tency	Overall Acceptability
Traditionally produced *ogi* from whole maize grains (control)	Spontaneous	3.33 ± 0.49	3.17±0.17	3.17±0.17	2.33±0.56	3.17±2.67	2.67±0.42	3.83±0.17	4.00±0.37	3.67±0.33
Ogi from dehulled maize grains alone	Spontaneous	3.66 ± 0.49	2.5±0.43	2.67±0.42	2.50±0.43	2.33±0.33*	2.50±0.22	2.67±0.33*	3.33±0.21	3.17±0.31
	Starter cultures	4.00 ± 0.26	3.50±0.34	3.17±0.17	2.67±0.42	3.33±0.21	3.00±0.26	3.17±0.31	3.83±0.31	3.67±0.21
Ogi from dehulled maize grains and glucose (2% w/w)	Spontaneous	4.00 ± 0.26	2.83±0.60	3.17±0.48	2.17±0.40	3.50±0.22	2.83±0.31	3.33±0.33	3.33±0.21	3.00±0.37
	Starter cultures	3.83 ± 0.31	3.33±0.49	3.50±0.22	3.33±0.21	3.17±0.17	3.00±0.26	3.33±0.42	3.00±0.26	3.33±0.33
Ogi from dehulled maize grains glucose (2% w/w) and soya bean (1%w/w)	Spontaneous	2.33 ± 0.33	2.50±0.50	2.17±0.40	1.33±0.33	2.17±0.31*	2.33±0.33	2.83±0.48	2.67±0.21*	2.17±0.31*
	Starter cultures	2.50 ± 0.56	2.83±0.60	2.33±0.21	3.17±0.48	2.67±0.49	2.50±0.50	3.00±0.37	2.67±0.33*	2.67±0.33

[a] Values are means of the seven-man taste panel ± S.D.
*Values are significantly different ($P>0.01$) from the traditionally fermented sample from whole maize grains (control).

show lesser quantities of niacin than the unprocessed WMG. There were higher levels of available lysine, methionine, total amino acids, soluble proteins, and niacin in the freeze-dried than in the oven-dried samples (tables 4 and 5). Organoleptic or sensory study of the products of the pilot-plant produced *ogi* as shown in table 6 confirmed that good quality *ogi* product were obtained from dehulled maize grain substrate and SCS, which are improved processing techniques confirmed by the elimination of traditional cumbersome wet-sieving stage. There is no significant difference between the traditionally

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Teniola OD et al., J Food Sci Nutr Res 2023
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produced *ogi* and all other prepared samples considering the appearance, aroma, taste and sourness (table 6).

Discussion

The selection of lysine-producing and methionine-producing SCS as reported is a cheap and safe way of improving *ogi* value without changing the sensory features and product acceptability [18,55]. Other features such as phytase production, reduction of pH below 4.0, degradation of oligosaccharides, no biogenic amine production are meant to further enhance the product nutritional qualities and the safety [40,56]. Isolated screened may not contain any biogenic amine producers because the environment from where they are isolated naturally contains very low protein levels hence there will be poor levels of precursors for producing biogenic amines [39]. Bacteriocinogenic isolates have been linked with *ogi* products safety [16,57]. The isolation of three *Lactococcus* strains producing bacteriocin in table 1 as in other studies, showed that future beneficial products may be generated to secure product safety and probable treat infectious pathogen if bacteriocin producers are included in the SCS composition [17,58]. SCS application in this study, has also demonstrated a unique ability to stabilize fermentation by bringing about homogeneity within fermented batches. A stable pH 3.35 was regular in three SCS fermented substrates, even with varying composition, when compared with varying pH in spontaneous fermentation. The varying pH levels observed in the spontaneously fermented controls may be attributed to the different modifications in the substrate compositions and the various types of the microorganisms that are active in spontaneous fermentations [59]. Dominant *L. brevis* activity in the fermenting mash enhanced by the presence of *S. cerevisiae* when they were both used as SCS for *ogi* may be responsible for the stable final pH and high acid production during SCS fermentation (Table 2) [36]. This indicate a better product shelf life since organic acids produced by lactic acid bacteria has inhibitory effect against many spoilage and pathogenic organisms [35].

Lysine and methionine producing capabilities of the starter cultures used conform to the results of Teniola & Odunfa [60] as well as Okoroafor *et al.* [18] on the possibility of improving food nutrients by microbial fermentation with nutrient hyper-producing microorganisms. The result confirm the presence of lysine and methionine producing *Lactobacillus* and yeast as well as their potential for ogi nutritional improvement [38]. Chung and Fields [61] reported a decrease in the available lysine level of cornmeal fermented with *Bacillus megaterium* ATCC 13639 and *Enterobacter aerogenes*, although a significant increase in the available methionine and tryptophan were observed. The fermentation liquor removal prior to drying and the heat applied during oven drying are major factor responsible for nutritional losses during *ogi* processing. Although low, the various quantities of the nutrients observed in the discarded fermentation liquor gives credence to this view (data not shown) as well as the differences observed between the nutritional status of oven- and freeze- dried samples (tables 4 and 5).

Different after taste observed in the two spontaneously fermented samples from DM alone and that from substrate fortification with glucose and soybean may indicate that more strange metabolites is been produced by other microorganisms in the spontaneous fermentation that are different from that from *ogi* SCS. Bacteria such as *Bacillus subtilis, B. licheniformis* and *Staphylococcus* spp. with unknown contributions during *ogi* fermentation have been largely isolated in various soybean-related products [62]. The lower acceptability of *ogi* produced from soybean-fortified raw materials agreed with past reports [63]. Better improvement in the product quality as reflected by the overall acceptability when *ogi* is fermented with selected microorganisms confirmed the ability to impact good features on the final products by the SCS selected (table 5).

Conclusion

The present result shows that the current pilot plant process can be improved nutritionally and the final product pH stabilized with higher acidity and fermentation rate by the use of well-selected cultures. The modification of the traditional fermentation substrate, WMG into dehulled maize, effectively remove the wet-sieving stage of *ogi* traditional production and its associated challenges. It also allows substantial reduction or control of water usage during production, which reduces nutritional losses from prolong period of final product recovery by the discarding of the excess fermentation liquor and or heat drying to obtain *ogi* flour. Solid-state fermentation use during *ogi* production will help to reduce the cost of space and water as observed in *Kenkey*, a related Ghanaian fermented product from maize [8,20,64]. Although, grain dehulling reduces the substrate nutrient (table 3 and 4), the use of well-selected SCS with valuable nutrient-yielding capability will remove the disadvantage during fermentation. The use of SCS for the pilot-plant production of *ogi* and product nutritional enhancement is a good foundation for future *ogi* product improvement by modern microbial biotechnological techniques. The removed hull and germs from the WMG will find good value in the livestock industry as feed and feed supplements.

Declaration of competing interest

The authors declare no conflict of interest.

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