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

Olakunle David Teniola (olakunleteniola@yahoo.com)
Olusegun Agagu University of Science & Technology (OAUSTECH), Okitipupa,
Wilhelm H. Holzapfel
Handong Global University,
Sunday Ayodele Odunfa
University of Ibadan, Ibadan,

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Abstract

Starter cultures for *'ogi'* production were selected with the aim of improving processing technique, lysine and methionine levels of *'ogi'*, a lactic acid fermented weaning food. Technological features of microorganisms from fermenting raw materials were screened to develop quality starter cultures. *Lactobacillus brevis* XO43 and *Saccharomyces cerevisiae* OY4 were finally selected and used as starter cultures in a pilot plant study. Fermentation with starter cultures showed constant final pH level of 3.35 in modified substrates after fermentation unlike spontaneously fermented; and significantly higher acidity (%TTA) indicative of faster fermentation. Addition of sugar (2%w/w) and soybean flours (1% w/w) also increased the acid levels during fermentation. Fermentation of dehulled maize grains fortified with glucose (2%w/w) alone by starter cultures shows the best quality in all the parameters considered except the available niacin yield. It is 24% higher than oven-dried *'ogi'* flour from the traditional process and 11% higher than unprocessed whole maize grains. The methionine is 92% and 77% higher than the traditionally prepared *'ogi'* and 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 maize grains. Although, the soluble protein level was 23% lesser than the unfermented whole maize grains, it was 12% more than the dehulled maize substrate and *'ogi'* from traditional process. Fermentation of corn into *'ogi'* led to losses in the initial quantity of niacin. Starter cultures 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 starter cultures and dehulled maize guarantee organoleptic qualities, improve *'ogi'* production and create a better nutritional products.

1.0 Introduction

'Ogi' is a common West African lactic acid fermented staple food from maize, sorghum, or millet (Soro-Yao et al., 2014). The popularity and general acceptance of *'ogi'* has encouraged various works on the microbiology (Teniola and Odunfa, 2002; Teniola et al., 2005), economic impact (Bolaji et al., 2015), nutrition (Odunfa et al., 2001; Abioye and Aka, 2015; Makanjuola, 2017; Okafor et al., 2018), mycotoxin safety (Kpodo et al., 1996; Okeke et al., 2015; 2018), the production techniques (Onyekwere et al. 2004; Adegbehingbe, 2013; Akinleye et al., 2014) and spoilage (Teniola and Odunfa, 2002; Asiru *et al*., 2012). Onyekwere et al. (2004) gave a detailed description of cottage and the industrial production techniques presently used. Despite all the attentions, only few works have been carried out on the use of starter cultures (Teniola et al., 2005; Oyedeji et al., 2013) or the impact in *ogi* nutritional improvement (Odunfa et al., 2001; Teniola and Odunfa, 2001, Okoroafor et al., 2019).

The Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria, developed a pilot processing plant for *'ogi'* production based on the traditional procedure that requires spontaneous fermentation (Onyekwere et al., 2004). Although, this has encouraged a better product presentation, packaging, increased shelf life and increased output, a more efficient fermentation requires definite starter culture(s). Products resulting from the present spontaneous fermentation process are not likely to be reproducible worldwide due to varying microflora and the environmental conditions. The spontaneous fermentation been used has discouraged the potential use of modern biotechnology techniques to improve the product quality through the use of define microbial cultures (Teniola, 2021). The application of starter culture(s) during processing can reduce production time, further increase shelf-life and nutritional attributes (Teniola and Odunfa, 2001, Teniola et al., 2005).

Attempts at the nutritional improvement of *'ogi'* in the past has been based on product fortification with legumes such as groundnut, pinto, soybean and cowpea to boost the deficient amino acid levels (Subuola et al., 2012; Olunike, 2014; Abu-Ghannam and Gowen, 2021); while this has been achieved, a different product emerged that is different from *'ogi'* in flavour, aroma, and general acceptability e.g. soy-*ogi* (Onyekwere et al., 2004; Ayo-Omogie and Ogunsakin, 2013). The traditional practice of daily replacement of the sour water on *'ogi'* to prolong the shelf life is cumbersome and may reduce the nutritional value through 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'* and solve various health problems. Olukoya et al. (1994) developed an improved *'ogi'* named *`DogiK´* with potential use in the prevention and treatment of diarrhoea by using *Lactobacillus* starter cultures 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 (Sangwan et al., 2014; Achi and Ukwuru, 2015). Lactic acid bacteria and yeast from *'ogi'* and other related sources have been identified with important features such as production of antimicrobial substances against major pathogens and spoilage microorganisms (Saranraj et al., 2013, Mokoena et al., 2016; Agriopoulou et al., 2020), production of amino acids such as lysine and methionine (Makanjuola, 2017), as well as various enzymes that are capable of degrading anti-nutritional factors like phytate, protease inhibitors and oligosaccharides (Egwim Evans et al., 2013; Tsafrakidou et al., 2020).

This work is aimed at selection and demonstrating the ability of the selected lysine- and methionine- producing starter cultures to improve the amino acid levels of *'ogi'* in a pilot plant study. The implication of certain steps employed during processing and their effects on the final product will also be investigated.

2.0 Materials And Methods

2.1 Screening of starter culture

Isolates of yeasts and lactic acid bacteria (LAB) cultures obtained during *'ogi'* processing as previously described (Odunfa et al., 2001) were screened to obtain *'ogi'* starter cultures (Teniola and Odunfa, 2001). Isolates were screened for such important features as pH reduction ability (Adesulu-Dahunsi et al., 2018; Olatunde et al., 2018), acid production from oligosaccharides (Ajayeoba et al., 2019), lysine and methionine production ((Odunfa et al., 2001; Teniola and Odunfa, 2001; Okoroafor et al., 2019), phytate degradation (Onipede et al., 2020), bacteriocin production (Onwuakor et al., 2014; Ohenhen et al., 2015) and biogenic amine production (Ukwuru, 2014). Promising isolates were further tested and selected for use as *'ogi'* starter cultures.

2.2 Selected starter cultures

Saccharomyces cerevisiae OY4 and a hetero-fermentative *Lactobacillus brevis* XO43 identified as *'ogi'* starter cultures with lysine and methionine producing capabilities (Teniola and Odunfa, 2001) isolated in an earlier work, were used for the fermentation.

2.3 Inoculum production for fermentation

Twenty-four hours cultures of *S. cerevisiae* OY4 and *L. brevis* XO43 on agar slants were prepared according to the method of Teniola and Odunfa (2001).

2.4 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 dehulled maize grains was used for each fermentation. The substrates were made up of substrates: (A) Dehulled maize grains alone; (B) Dehulled maize grains and glucose (2%w/w); (C) Dehulled maize 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 SDA (Oxoid CM 41)]. An uninoculated spontaneously fermented sets from the substrates described above were used as the control; while whole maize grains spontaneously steeped and fermented as done traditionally was used as a reference control (Onyekwere et al., 2004). 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 48 h. The traditionally prepared reference control from whole maize grains was wet-sieved before further fermentation. After fermentation, the pH and percentage total titratable acidity of the fermented mash samples were measured (Okoroafor et al., 2019). *Lactobacillus brevis* XO43 and *Saccharomyces cerevisiae* OY4 used as starter cultures 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^{o}C temperature using a Labconco freeze-dryer (Lyph-Lock 6, Labconco Co., Kansas City, USA) (Teniola and Odunfa,;2001). The water of the fermented mash samples were removed and the water extract kept at -20^{o}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^{o}C to obtain *'ogi'* flakes. These flakes were milled into powder in a disk mill (Apex-Mill, Apex Construction Ltd., England) and packaged in polyethene bags. The final samples were stored at -20^{o}C temperature prior to analyses. The experiments were set-up in duplicates.

2.5 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. (2019). Total amino acids assessment was according to Rosen (1957) while the method of Lowry et al. (1951) was used for the total soluble protein determination.

2.6 Determination of lysine, methionine and niacin

Test materials were prepared according to A.O.A.C. methods. The samples were analysed for availability of lysine, methionine, and niacin by microbiological assays (AOAC, 1980; Wright and Orman, 1995).

2.7 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 considering the colour or appearance, aroma, taste, sourness after taste, mouth feel consistency and overall acceptability as reported by Teniola and Odunfa (2001). This was then analysed statistically as described by Cass (1980).

2.8 Statistical analysis

This was done by analysis of variance (ANOVA) using the Duncan`s Multiple Range Test (0.05 level) as described by Cass (1980).

2.9 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 "Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria".

3.0 Results

Natural lysine and methionine production study of *Lactobacillus* and yeast in batch fermentation of *'ogi'* showed that 43% of the *Lactobacillus* and 83% of the yeast isolates tested were capable of lysine production while 25% of the *Lactobacillus* and 88% of the yeast isolates produced methionine (Odunfa et al., 2001). Other important characteristics of the screened LAB isolates vary depending on LAB groups as shown in Tables 1. It was observed that *Pediococcus* has the highest percentage population (96.92%,) to be able to reduce the pH of MRS broth. 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 isolate screened produce a biogenic amines.

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*	*Bacteriocin production*	*Acid from oligosaccharides*	
						Stachyose	*Raffinose*
Homo-fermentative *Lactobacillus*	35	Rods	32	20	0	16	33
Hetero-fermentative *Lactobacillus*	25	Rods	2	4	0	4	12
Pediococcus	65	Cocci	6	24	0	29	59
Lactococccus	24	Ovoids	1	9	3	6	8
Leuconostoc	1	Ovoids	0	0	0	0	0
Enterococcus	20	Ovoids	4	1	0	9	13

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 2. Fermentation substrates pre-inoculated with starter cultures showed 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 whole maize grains. Fermentation with starter cultures gave products with higher acidity (%TTA) than the spontaneous fermentations (Table 2). Addition of sugar and soybean flours also increased the acid levels during fermentation. Nutrients such as lysine, methionine, total amino acids, soluble

Table 2
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 (traditional method)	3.40[bc]	0.934[a]
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.

protein and niacin reduced when whole maize grains were dehulled (Tables 3 and 4). Freeze-dried *'ogi'* analyses indicated that the use of starter cultures 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 dehulled maize grains used as the substrates (Tables 4). Fermentation of dehulled maize grains fortified with glucose (2%w/w) alone by starter cultures shows the best quality in all the parameters considered except the available niacin (Tables 3 and 4). It is 24% higher than oven-dried *'ogi'* flour from the traditional fermentation and 11% higher than unprocessed whole maize grains. The methionine level of the sample from this fermentation fortified with added glucose and fermented with starter cultures 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 maize grains. Although, the soluble proteins level was 23% lesser than the unfermented

Table 3
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.

Table 4
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 (µg/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}

$^{a-d}$ 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.

whole maize grains, it was still 12% more than the dehulled maize 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 3–4). 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 show lesser quantities of niacin than the unprocessed whole maize grains. There were higher levels of available lysine, methionine, total amino acids, soluble proteins and niacin in the freeze dried than the oven dried samples (Tables 3 and 4).

Organoleptic or sensory study of the products of the pilot-plant produced *'ogi'* as shown in Table 5 confirmed that good quality *'ogi'* product were obtained from dehulled maize grain substrate and starter cultures. There is no significant difference between the traditionally produced *'ogi'* and all other prepared samples considering the appearance, aroma, taste and sourness (Table 5).

Table 5

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

Substrate used	Fermentation type	Organoleptic (sensory) characteristics								
		Colour/ Appea-rance	Aroma	Taste	Sour-ness	After taste	Flavour	Mouth feel	Consis-tency	Overall Accep-tability
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).*

4.0 Discussion

The selection of lysine and methionine producing starter cultures as reported is a cheap and safe way of improving *'ogi'* value without changing the sensory features and product acceptability (Teniola and Odunfa, 2001). Other features such as no biogenic amine production further confirms the safety (Adesulu-Dahunsi et al., 2018; 2021). Bacteriocinogenic isolates have been linked with *'ogi'* products (Teniola et al., 2005; Omemu and Faniran, 2011), the isolation of three *Lactococcus* isolates producing bacteriocin as demonstrated by Teniola et al. (2005) emphasised the potential of the product hygiene improvement by using starter cultures. Starter cultures application has also demonstrated a unique ability to stabilize fermentation bringing about homogeneity within fermented batches (pH 3.35) when compared with 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 micro-organisms present in these fermentations (Adebo et al., 2018). Dominant *L. brevis* activity in the fermenting mash enhanced by the presence of *S. cerevisiae* when they were both used as starter cultures for *ogi* may be responsible for the stable final pH and high acid production during starter culture fermentation (Table 2) (Egwim Evans et al., 2013). This indicate a better product shelf life since organic acids produced by lactic acid bacteria has inhibitory effect against many spoilage and pathogenic organisms (Agriopoulou et al., 2020).

Lysine and methionine producing capabilities of the starter cultures used conform to the results of Teniola and Odunfa (2001) and Okoroafor et al. (2019) 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 (Odunfa et al., 2001). Chung and Fields (1986) 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 was not 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 difference observer between the nutritional status of oven- and freeze- dried samples.

Different after taste observed in the two spontaneously fermented samples from dehulled maize 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'* starter cultures. 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 (Uguayin and Okpara, 2019). The lower acceptability of *'ogi'* produced from soybean fortified raw materials agreed with past reports (Onoja et al., 2014). Better improvement in the product quality as reflected by the overall acceptability when *'ogi'* is fermented with selected microoganisms confirmed the ability to impact good feature on the final products as starter cultures (Table 5).

4.1 Conclusion

In conclusion, the present result shows that:

- The current pilot plant process can be improved nutritionally by the use of a well-selected cultures and the modification of the traditional whole maize grains used as the fermentation substrate.
- Dehulling of whole maize grains prior to use as fermentation substrate will effectively replace the wet-sieving stage of *ogi* traditional production and its associated challenges.
- Dehulling also allows substantial reduction or easy regulation/control of water usage during fermentation and reduces nutritional losses from longer period of final product heat drying to flour or the discarding of the excess fermentation liquor prior to drying.
- Possible solid-state fermentation used during *ogi* production will help to reduce the cost of space and water as observed in *kenkey*, a related Ghanaian fermented product from maize (Nyako, 1977; Halm et al., 1993; Kpodo et al., 1996).

- Although, grain dehulling reduces the substrate nutrient (Tables 3 and 4), the use of well-selected starter cultures with valuable nutrient yielding capability will remove the disadvantage during fermentation.
- The use of starter cultures for the pilot plant production of *'ogi'* and product nutritional enhancement is a good foundation for the future *'ogi'* product improvement by modern biotechnological techniques.
- The removed hull and germs from the grains will have a good value in the livestock industry as a food supplement.

Declarations

Declaration of competing interest

The authors declare no conflict of interest.

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