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REVIEW ARTICLE

Microbial quality assessment of fermented maize *Ogi* (a cereal product) and options for overcoming constraints in production

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ABSTRACT
Microorganism play important role in the fermentation of foods. Nigeria has several fermentable foods produced from several feedstocks including cereals, legumes, palm tree, tuber (plants) and proteinaceous' animal foods. This study reviews the microbial quality in the fermentation of *ogi*, a Nigerian indigenous maize food drink, the constraints in the preparation and available options in overcoming the hurdles. The study found that the microbial density are mainly aerobic bacterial forms and lactic acid bacteria and to lesser extent fungi (mould and yeasts) and the *Enterobacteriaceae* family. Of all the several microbial diversity found in the fermentation medium of maize ogi, *Lactobacillus* species and *Saccharomyces cerevisiae* are the predominant isolates. The constraints in the fermentation of maize for ogi production are mainly microbiological, absence of quality control, nutritional quality and toxicological problem, storage and environmental factors. The study concluded by suggesting the means of controlling the constraints as options for mitigation.

KEY WORDS: *Cereal, Fermentation, Food, Maize, Microorganisms, Ogi, Public Health*

Introduction

Fermentation technology is as old as man (Ijabadeniyi, 2007), and as such is an integral traditional norm especially in most communities in tropical Africa. Badmos *et al*. (2014) described fermentation of food as age-long culture which has been under documented particularly in West Africa, where absence of writing culture made its origin difficult to trace. Fermentation of food typically involves the application of microorganisms (either from the environment i.e. spontaneous process or inoculated in a controlled environment) that produces certain enzymes which changes the chemical attributes of the food from its original form/state. Kohajdova and Karovicova (2007) defined fermentation as a desirable biochemical modification process of main food matrix brought about by microorganisms and their associated enzymes. The changes that occur during fermentation could either be deleterious (producing toxins) or beneficial (producing food products with superior or distinct attributes). According to Eze *et al*. (2014), traditional food fermentation is a biotechnol*ogi*cal process taking the advantage of the natural microbiota allied with fresh food products in an economical and empirical method to preserve food and enhance its organoleptic and nutritional quality.

Traditional fermented foods are prepared from most common types of cereals (such as corn, wheat or sorghum). They are well known in many parts of the world (Wakil and Daodu, 2011). Oyewole and Isah (2012) reported that fermentation mechanisms are biochemical process that involves lactic acid fermentation to produce products such as organic acids, alcohols, aldehydes and ketones. Kohajdova and Karovicva (2007) listed butyric, succinic, formic, valeric, caproic, lactic, acetic, capric, pyruvic, palmitic, crotonic, itaconic, lauric, heptanoic, isovaleric, propionic, *n*-butyric, isoburyric, caprylic, isocaprilic, pleagronic, mevulinic, myristic, hydrocinnamic and benzylic (organic acids), ethanol, *n*-propanol, isobutanol, amyl alcohol, isoamyl alcohol, 2,3-butandieol and β-phenylethyl alcohol (alcohols), acetaldehyde, formaldehyde, isovaleraldehyde, *n*-valderaldehyde, 2-methyl butanol, *n*-hexaldehyde, acetone, propionaldehyde, isobutyraldehyde, methyl ethyl ketone, butanone, diacetyl and acetoin (aldehydes and ketones) and furfural, methional, glyoxal, 3-methyl butanal, 2-methyl butanal and hydroxymethyl furfural (carbonyl compounds) as compound formed during the fermentation of cereals. Generally, fermented foods are prepared from plant and animal feedstock (Eze *et al*., 2014; Iwuoha and Eke, 1996).

Several processing technologies and techniques have been widely applied in enhancing the nutritional properties of fermentable cereals products. This includes cooking, sprouting, milling and fermentation (Wakil and Daodu, 2011). Also Oyewole and Isah (2012) noted the merits of locally fermented food to include enhancing its organoleptic and preservative properties, provision of nutritional quality, detoxification and production of antibiotics.

Globally several fermented food products abound. Some of these include *Doklu* (a maize based fermented food indigenous to Côte d'Ivoire (Assohoun *et al*., 2013), Kolo and kenkey in Ghana (Halm *et al*., 1993; Kohajdova and Karovicva, 2007) including Nsiho (white kenkey) (Anann *et al*., 2015**)**, Boza (a fermented food from different cereals feedstocks such as maize, rice and wheat flours with high viscosity and are indigenous to Turkey), Togwa (fermented food produced from different feedstocks such as cassava or maize, sorghum or millet and native to Tanzania), Mahewu (magou) in south Africa and Uji in East Africa (Kohajdova and Karovicva, 2007), Masa (mainly from maize, and sometimes from sorghum and rice) in Northern and Southwestern parts of Nigeria (Adegbehingbe, 2014a).

Nigeria is endowed with several fermentable indigenous staple foods that serve as raw materials for many agro-allied cottage industries (Ijabadeniyi, 2007). According to Iwhoha and Eke (1996), Nigeria has about 30 indigenous fermented foods prepared from 7 categories of feedstocks including cereals (*ogi*, burukutu and pito), fruits (agadagidi, cacao wine, Ugba), legumes (iru, daddawa, ogiri-egusi, ogiri-isi, ogiri-ugu or Ogiri-nwan), palm tree (palm wine), cassava tuber (gari, fufu, lafun, Abacha, Elubo, loiloi, kokobele), animal protein (afonnama, Azu-okpo, Nsiko, Uponi or oporo) and milk (maishanu and nono, warankasi). These fermented food which are produced from different feedstocks include *ogi* (maize), burukutu and pito (maize and sorghum), agadagidi (over ripe plantain or banana), cacao wine (cocoa pod palp), Ugba (African oil bean cotyledons), iru (African locus bean), daddawa (soya beans), ogiri-egusi (melon seeds) ogiri-isi (castor oil seed), ogiri-ugu or Ogiri-nwan (fluted pumpkin seeds), palm wine (rapha palm or oil palm tree), gari, fufu, lafun, Abacha, Elubo, loiloi (cassava root), kokobele (cocoyam corms), afonnama (beef tripe), Azu-okpo (fish), Nsiko (crab), Uponi or oporo (crayfish or shrimps), maishanu and nono (cow milk) and warankasi (goat/cow milk) (Iwuoha and Eke, 1996). Similarly, Oyewole and Isah (2012) also updated that locally fermented plant based foods in Nigeria which are grouped into tubers (e.g. gari, and fufu), cereals (e.g. *ogi* and pito), legumes (e.g. dawadawa and iru), milk (e.g. local cheeses) and beverages (e.g. palm wine). Others include masa (Sanni and Adelusi, 2013), kokoro (Oranusi and Dahunsi, 2015), sekete (Onaolapo and Busari, 2014). These fermentable products are found all over Nigeria.. For instance, *ogi* fermented from maize is found to a large extent in the south, west and east and also northern part of the country.

Other fermented foods are mainly from fruits, legumes, tree sap, tuber, animal protein and milk (Iwuoha and Eke, 1996). Blandino *et al*. (2003) reported that some of these traditional foods are used as colorants, spices, beverages and breakfast or light meal foods, while a few of them are used as main menu foods. In addition, locally fermented foods are a source of livelihood to several families in Nigeria.

Like rice and wheat, maize which belongs to the *Poaceae* family is one of the most important cereals in the world. Globally, maize is largely produced in United States, China, Argentina, Mexico, Brazil and to a lesser extent by Nigeria and Hungary. The grains of maize, a cereal can be cooked, roasted, fried, ground, pounded or crushed to prepare various food items like pap, 'tuwo', 'gwate', 'donkunu' and a number of others which are commonly available in various parts of the country among the different ethnic groups, notably among the Yorubas, Hausas, Ibos, Ibiras, Ishas, Binis, Efiks, Yalas etc (Abdulrahaman and Kolawole, 2006). Generally, maize is used to produce about 28 different food dishes; and has 6 medicinal values where it serves an active ingredient (Abdulrahaman and Kolawole, 2006).

Unlike other cereal such as sorghum, millet, rice, maize is widely distributed. For instance in Delta state, maize farming is an integral farming culture of the people where large hectares of land are cultivated for the production of maize grain. Mbata *et al*. (2005) noted that maize processing in West Africa is carried out using traditional indigenous (rudimentary) technology/equipment. Generally, traditional cereal foods play a vital role in the diet of the people of tropical Africa particularly in cereal producing regions (Assohoun *et al*., 2013). Mbata *et al*. (2009) reported that flour made from cereal is a major raw materials/feedstock utilized in the production of some food products with high acceptability, good storage characteristics and cost effective.

One major locally fermented food produced in Nigeria is *Ogi*. *Ogi* is an essential weaning food for infants as well as a dietary staple for adults in West Africa (Wakil and Kazeem, 2012; Bolaji *et al*., 2014; Adegbehingbe, 2013; Abioye and Aka, 2015), prepared from cereals like maize, sorghum and millet (Bolaji *et al*., 2014). Omemu (2011) further reported that *Ogi,* an acid-fermented cereal gruel is a staple food in several parts of Nigeria. *Ogi* is used as a generic name, but in most states of Nigeria it refers to maize *ogi* (Ijabadeniyi, 2007). Though Sorghum *ogi* and millet *ogi* which are known as *ogi* baba and *ogi* gero respectively also exist and also called furah in some parts of Northern Nigeria (Ijabadeniyi, 2007). Hence this paper is aimed at assessing the microorganisms involved in fermentation of maize for *ogi* production, constraints in the production process and the options for overcoming the constraints are also discussed.

Production processes of *Ogi*

Maize porridge or pap is known as *ogi* and *akamu* in Yoruba and Igbo tribes of Nigeria respectively and *akosa* in Ghana. (Adegbehingbe, 2013). *Ogi* is one of the popular fermented food consumed in several part of Nigeria. *Ogi* is among the 30 Nigeria indigenous fermented food as listed by Iwoha and Eke (1996). *Ogi* is produced from several cereal based feedstock including from maize (*Zea mays*), sorghum (*Sorghum sp*), guinea corn or millet (*Pennisetum typhoideum*) (Ohenhen and Ikenebomeh, 2007; Adegbehingbe 2013, 2014b; Adebukunola *et al*., 2015; Abioye and Aka, 2015; Osungbaro, 2009). In general, *Ogi* is mainly fermented in an acidic condition. Wakil and Daodu (2011) reported a sharp decline in pH of fermenting gruel from 5.7 to 3.5 within 24 hours and suddenly increased to 3.8 in 72 hours, while titratable acidity increases from 0.2065 to 0.265 within the first 48 hours and decline to 0.188 in 72 hours. Similarly, Adegbehingbe (2013) reported that the pH values of *ogi* from sprouted and unsprouted maize decreased from 5.8 to 3.2 and 5.7 to 3.7 while their total titratable acidity increased from 1.3% to 4.9% and 1.5% to 4.1% respectively in 24 to 96 hours.

Generally the method of *ogi* production has been variously documented by authors (Adebukunola *et al*., 2015; Wakil and Daodu, 2011; Iwuoha and Eke, 1996; Ijabadeniyi, 2007; Farinde *et al*., 2015). During the production of *ogi*, the feedstock (which can either be white maize or red maize, sorghum or millet grains) are typically washed and steeped in clean water for 1-3 days (Wakil and Daodu, 2011; Iwuoha and Eke, 1996; Adebukunola *et al*., 2015; Ijabadeniyi, 2007; Abioye and Aka, 2015; Farinde *et al*., 2015; Badmos *et al*., 2014; Bolaji *et al*., 2015). Though most authors often report ideal fermentation period of 1 -2 days (Wakil and Daodu, 2011). The fermented grain is then wet milled and sieved (using fine sieve) to produce slurry of *ogi* (Wakil and Daodu, 2011; Iwuoha and Eke, 1996; Adebukunola *et al*., 2015). The sievate is allowed to ferment for 2-3 days during which it becomes sour (Wakil and Daodu, 2011). But Iwuoha and Eke (1996) reported that the fermentation for another 1 – 3 days is optional depending on the processor.

Two major product are produced from ferment maize for *ogi* production including pap and *agidi*. Typically, *Ogi* has a distinct aroma and fine texture. The colour of the *ogi* is mainly depending on the type of feedstock used for the processing. Ijabadeniyi (2007), Akinleye *et al*. (2014) and Ikya *et al*. (2013) reported that *ogi* could either be consumed as porridge (pap) or as a gel-like product (*agidi*) in some West African countries. Like *ogi*, *agidi* is becoming popular in different ethnic groups, cutting across different socioeconomic classes (Ogiehor *et al*., 2005). *Agidi* has different names among localities including eko (Yoruba), akasan (Benin), komu (Hausa) and *Agidi* (Ibo) (Ogiehor *et al*., 2005). Hence, the most popular name that it's known as today was derived from the Ibo name. *Agidi* is consumed with soup, stew, akara, moimoi as light meal among hospital patients (Ogiehor *et al*., 2005) and other especially the elderly. Sometimes, coloured *agidi* is prepared with addition ingredient such as oil, pepper, magi, and or fish, egg, meat etc. Colored *Agidi* is sold especially in commercial places like primary and secondary school, and markets. *Agidi* has been variously reported as a major traditional cereal based food consumed in Africa that is processed by natural fermentation (Akobundu and Hoskins, 1982; Umoh and Fields, 1981).

Microbial quality of *ogi* production from fermented maize

Microorganisms play both essential and deleterious roles in food products. In the fermentation industry, the attributes of the food products produced is largely due to the type, age, composition of the microorganism employed. To large extent, both population and diversity play a role in the fermentation of products. Tables 1 and 2 present the microbial population and diversity respectively found in fermented *ogi* produced in Nigeria under laboratory conditions. Typically, the microbial load gradually increases from the first day (0 hours) and attain optimum at 24 – 48 hours of fermentation, before beginning to decline from 72 to 96 hours. The density of the microbes for lactic acid bacteria culture using MRS agar is second to aerobic culture using plate count agar or nutrient agar. This suggests that lactic acid bacteria play a significant role in the fermentation of maize in *ogi* production. The population of microbes of the *Enterobacteriaceae* family is usually least during fermentation of maize used for the preparation of *ogi*. These groups of microorganisms that grow in MacConkey agar (including *E.coli, Klebsiella, Salmonella, Shigella, Citrobacter, Proteus* etc), do not actually participate in fermentation. In a study by Oyelana and Coker (2012), the growth of *E. coli* and *Klebsiella aerogenes* significantly reduces at the end of fermentation. Hence their occurrence in fermentation medium of maize could result from the water used for fermentation or as normal flora of the maize prior to fermentation. Also, the population of fungi (including yeast and mould) ranged between 10^3 to 10^5, being far lesser than the population of lactic acid bacteria and general aerobic viable counts. Again, this suggests that most of the microbes that participate in the fermentation of maize for *ogi* production are mainly bacteria, despite the fact that some yeast also participate actively in the fermentation process. The significant variation in the various classes of microbes (i.e. lactic acid bacteria, aerobic bacteria, family of *Enterobacteriaceae*, and fungi) could be connected to the acidic nature of the medium.

Authors have variously reported that as fermentation proceeds the acidity of the medium increases (pH tending towards 0) and the titratable acidity is enhanced (Wakil and Daodu, 2011; Adegbehingbe, 2013). Adesokan *et al*. (2010) reported that this trend could lead to production of lactic acid bacteria that are responsible for fermentation of *ogi*. Basically, different microbes tolerate acid medium differently, to some it encourages their growth while in others it leads to their death.

Microbes found in food products occur through several means including exposure, handling, use of contaminate utensils for preparation. Several groups of bacteria (coliforms, lactic acid bacteria, aerobic bacteria etc) and fungi (yeast and mould) participate in the fermentation of steeped maize for *ogi* production. The genera of these microorganisms include *Staphylococci*, *Escherichia, Pseudomonas, Enterococcus, Klebsiella, Bacillus, Lactobacilli, Leuconostoc, Clostridium, Corynebacterium, Streptococcus, Micrococcus* and *Citrobacter* (bacteria), *Aspergillus, Saccharomyces, Penicillin, Candida, Rhizopus, Fusarium, Mucor, Geotrichum* and *Rhodotorula* (fungi). *Saccharomyces cerevisiae* and several species of the genus *Lactobacillus* among are found in the fermentation of maize for *ogi* production and to lesser extent the species of the genera; *Enterococcus, Klebsiella, Micrococcus, Clostridium* and *Citrobacter.*

Table 1: Microbial load during fermentation of maize for *ogi* production

Period, hours / **Medium**	**Hours** 0	24	48	72	96	**Laboratory study, Nigeria**	**References**
Plate count agar	1.0 x 10^{8}	1.89 x10^{14}	2.48 x10^{14}	1.72 x10^{14}	-	-	Wakil and Daodu, 2011
MRS	6.5 x10^{7}	1.7 x10^{14}	1.73 x10^{14}	2.90 x10^{14}	-	-	
Nutrient agar	9.8 x10^{7}	1.75 x10^{14}	1.2 x10^{14}	9.5 x10^{13}	-	-	
MacConkey agar	5.8 x10^{7}	1.0 x10^{13}	-	-	-	-	
Malt extract agar	3.0 x10^{7}	1.2 x10^{13}	1.5 x10^{13}	2.7 x10^{13}	-	-	
Plate count agar	2.5 x 10^{9}	4.0 x 10^{9}	7.9 x 10^{8}	4.2 x 10^{8}	-	-	Nwokoro and Chukwu, 2012
de Mann Rogosa Sharpe	1.6 x 10^{7}	3.2 x 10^{7}	4.0 x 10^{7}	7.1 x 10^{8}	-	-	
MacConkey agar	6.3 x 10^{3}	1.6 x 10^{3}	3.8 x 10^{2}	2.5 x 10^{2}	-	-	
Nutrient agar	(5.0) [4.0] {2.0} x10^{5}	(9.0) [5] {3}x10^{5}	(1.6) [1.6] {1.2} x10^{6}	(1.8) [1.7]{1.6} x10^{6}	-	Steeped maize	Ijabadeniyi 2007
	(1.8) [1.7] {1.6} x10^{6}	(3.6) [2.8] {2.2}x10^{6}	(4.0) [4.0] {3.4} x10^{6}	-	-	Secondary fermented maize	
Mueller Hinton	(6.5) [4.0] <2.0> x10^{5}	(8.0) [6.0] <4.0> x10^{5}	(1.5) [1.4] <1.1> x10^{6}	(1.7) [1.6] <1.5> x10^{6}	-	-	Akinleye *et al.*, 2014
Nutrient agar	-	2.5 x x10^{5}	3.3x10^{7}	4.5 x10^{8}	2.3 x10^{9}	Sprouted	Adegbehingbe, 2013
	-	2.5 x10^{6}	3.1 x10^{6}	4.3x10^{7}	2.3 x10^{8}	unsprouted	
Saboraud dextrose agar	-	1.8 x10^{3}	1.7 x10^{4}	2.1 x10^{4}	4.6 x10^{4}	Sprouted	
	-	3.1 x10^{3}	5.3 x10^{3}	1.6 x10^{4}	2.6 x10^{4}	unsprouted	
Potato dextrose agar	(2.) [1.0] {1.0} x10^{3}	(3.0) [3.0] {2.0}x10^{3}	(3.5) [3.5] {3.0} x10^{3}	(4.0) [4.0]{3.0} x10^{3}	-	Steeped maize	Ijabadeniyi, 2007
	(0.4) [0.4] {0.3} x10^{4}	(2.8) [2.5] {2.0}x10^{4}	(4.8) [4.0] {3.6} x10^{4}	-	-	Secondary fermented maize	
Saboraud dextrose agar *	2.0 x10^{4}	8.0 x10^{4}	1.6 x10^{5}	6.8 x10^{8}	-	-	Nwokoro and Chukwu, 2012
Potato dextrose agar	(2.0) [1.0] <1.0> x10^{3}	(3.5) [2.5] <2.0> x10^{3}	(4.0) [3.5] <3.0> x10^{3}	(4.5) [4.0] <3.0> x10^{3}	-	-	Akinleye *et al.*, 2014

( )= white maize, [ ] yellow maize, { } Quality protein maize; < > brown maize * = yeast counts only

Nwokoro and Chukwu (2012) reported that *Lactobacillus delbrueckii, Lactobacillus plantarum, Lactobacillus fermentum, Lactobacillus amylovorus, Pseudomonas aeruginosa, Pseudomonas alkaligenes, Bacillus cereus, Bacillus licheniformis, Bacillus subtilis, Candida utilis, Candida tropicalis, Saccharomyces cerevisiae, Aspergillus oryzae, Aspergillus niger, Penicillium citrinum, Rhizopus microsporus* and *Rhizopus oligosporus* are microflora of maize, since it was only *Mucor circinelloides* and *Rhodotorula glutinis* that was isolated from fermentation of maize for *akamu/ogi* production after 48 hours. Adegbehingbe (2014a) reported *Aspergillus niger, Rhizopus stolonifer, Mucor mucedo*, *Fusarium* species, *Saccharomyces cerevisiae, Candida utilis* and *Penicillium citrinum, Lactobacillus plantarum, Lactobacillus fermentum, Staphylococcus aureus, Corynebacterium* spp., *Leuconostoc mesenteroides* and *Micrococcus luteus* as the microbial isolated from *musa* (a sorghum-maize blend).

Of these, the author reported that lactic acid bacteria mainly *L. Plantarum* and yeast *S. cerevisiae* are the predominant microbial species. Similarly, Ijabadeniyi (2007) reported that during secondary fermentation (after wet milling of the fermented maize) of *ogi Lactobacillus plantarum, Lactobacillus fermentum,* and *Saccharomyces cerevisiae* were the predominant isolates. This suggested that they are main microbes that play essential role in fermentation *ogi*. Majority of the microbes in fermented steeped maize for *ogi* production have been variously reported to participate in fermentation of some other local food. Oyewole and Isah (2012) reported that *Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus, Penicillium* and *Saccharomyces* are important in fermentation of local foods.

Constrains associated with fermentable food/drink from maize

Fermentation of cereals including maize enhances the shelf life, texture, taste and aroma, bioavailability of digestibility and minerals including amino acids and significantly reduces the antinutrients of cereal products (Kohajdova and Karovicva, 2007; Wakil and Daodu, 2011; Wakil and Oriola, 2012). Sharma *et al*. (2013) also reported that fermentation enhances the nutritional attributes of any product by improving the amount of soluble vitamins and proteins. Hence fermented food products act as nutraceutical agents to improve beneficial health effects . To a large extent, lactic acid bacteria play a significant role in the fermentation of cereals including maize into different products. Typically, the nutritional effects of lactic acid fermentation include degradation of anti-nutritional factors and increased mineral bio-availability, improvement of protein digestibility of tannin-rich cereals, and degradation of flatulence-causing oligosaccharides (Kohajdova and Karovicva, 2007). Nevertheless the nutrient composition (such as proteins and minerals) could be lost from the grain during fermentation (Aminigo and Akingbala, 2004). Other challenges could emanate from processing environment, microbiology of the fermentation processes, absence of quality control and storage effects. This is aggravated due to the fact that most individuals involved in the production processes have inadequate knowledge of food science and associated parameters or factors that could affects the final products.

Processing environment

The processing of maize fermentable foods is typically carried out by smallholders, who process it for subsistence and to a larger extent for commercial purpose (source of livelihood). The processing of *ogi* is carried out using rudimentary equipment and often in an un-hygienic environment especially during processing and handling. Microbes are known to be ubiquitous, therefore the products could be prone to unintentional contamination by microbes found in the environment. Oyelana and Coker (2012) listed *Pseudomonas aeruginosa, Lactobacillus plantarum, Staphylococcus aureus, E. coli, Klebsiella aerogenes, Aspergillus flavus, Aspergillus niger, Penicillin oxalicum, Fusarium oxysporium, Rhizopus stolonifer, Saccharomyces cerevisiae* and *Candida albicans* as microbes found in air, utensils and body swabs of attendants of *ogi* production. Apart from *Pseudomonas aeruginosa* and *Lactobacillus plantarum,* the authors have reported that the organisms are also found in the water used for fermentation. In a review study, Izah and Ineyougha (2015) reported *Staphylococcus aureus*, *E.* coli, *Alcaligenes faecalis, Proteus, Pseudomonas, Enterobacter, Salmonella, Klebsiella, Bacillus*, *Aeromonas, Micrococcus, Citrobacter, Streptococcus, Vibrio, Shigella, Enterococcus, Flavobacterium, and Chromobacterium* species as bacteria diversity found in different potable water sources in Nigeria. The potable water sources such as lake,.

Table 2: Microbial diversity that participate in the fermentation of maize for *ogi* production

Microbial class	**References**							
	Nwokoro, and Chukwu, 2012	Akinleye *et al*., 2014	Wakil and Daodu, 2011	Omemu, 2011	Oyedeji *et al*., 2013	Adegbehingbe 2013		Ijabadeniyi, 2007
	-	-	-	-	-	Unsprouted	Sprouted	-
Bacteria	*Lactobacillus delbrueckii, L. plantarum, L. fermentum, L. amylovorus*	*Lactobacillus fermentum, L. plantarum* .	*Lactobacillus plantarum, L. brevis, L. fermentum*	-	*L. plantarum, L. cellobiosus, Lc lactis, Lc. Paramesenteroides, L. acidophilus, L. cellobiosus*	*Lactobacillus plantarum, L. fermentum,*	*Lactobacillus plantarum, L. fermentum, L. brevis*	*Lactobacillus plantarum, L. fermentum*
	-	-	*Streptococcus lactis*	-	-	-	*Leuconostoc mesenteroides*	*Leuconostoc mesenteroides*
	-	*Corynebacterium sp*	*Enterococcus feacalis*	-	-	-	-	*Clostridium bifermentans*
	Pseudomonas aeruginosa, P. alkaligenes	*Pseudomonas aeruginosa*	*Escherichia coli*	-	-	*Micrococcus luteus,*	*Micrococcus luteus,*	
	-	*Staphylococcus aureus*	*Staphylococcus aureus*	-	-	*Staphylococcus aureus*	*Staphylococcus aureus*	*Staphylococcus aureus*
	-	*Escherichia coli*	*Enterobacter sp.*	-	-	*Pediococcus acidilactici*	-	-
	-	*Klebsiella spp*	*Citrobacter sp.*	-	-	-	-	-
	-	-	*Klebseilla sp.*	-	-	-	-	-
	Bacillus cereus, B. licheniformis, B. subtilis,	-	*Bacillus Subtilis. B. cereus, B. licheniformis*	-	-	-	-	-
	-	-	*Aerobacter sp*	-	-	-	-	-
	-	-	*Corynebacteria sp.*	-	-	*Corynebacterium spp*	*Corynebacterium spp*	*Corynebacterium sp.*
Fungi (Yeasts and Molds)	*Saccharomyces cerevisiae*	*Saccharomyces cerevisae*	*Saccharomyces cerevisiae*	*Saccharomyces cerevisiae*	-	*Saccharomyces cerevisiae*	*Saccharomyces cerevisiae, S. pastorianus*	*Saccharomyces cerevisiae*
	Candida tropicalis, C. utilis,	*Candida albicans*	*Candida sp.*	*C. krusei, C. tropicalis,*	-	*Candida crusei*		*Mucor mucedo*
	Rhodotorula glutinis	-	*Rhodotorula sp*	*Rhodotorula graminis*	-	*Rhizopus nigricans*	*Rhizopus nigricans*	*Rhizopus stolonifer*
	Aspergillus oryzae, A. niger	*Aspergillus niger, A. flavus*	*Aspergillus niger*	*Aspergillus niger, Aspergillus flavus*	-	*Aspergillus niger*	*Aspergillus niger*	*Aspergillus niger*
	Penicillium citrinum	*Penicillium species*	*Penicillium sp*	*Penicilium citrinum*	-	-	-	*Penicillium sp.*
	Rhizopus microsporus R. oligosporus.	*Rhizopus stolonifer*	-	*Rhizopus nigricans, Rhizopus stolonifer*	-	-	-	-
	-	-	-	*Geotrichum candidum, G. fermentum*	-	-	-	-
	Mucor circinelloides	*Mucor mucedo*	-	*Mucor circinelloides*	-	-	-	-
	-	*Fusarium oxysporium*	-	*Fusarium subglutinans*	-	-	-	-

pond, stream, hand dug well, borehole, rain water etc (Izah *et al*., 2016) are also source of domestic water. Most of the microbes found in the fermentation medium are pathogenic, while few others are non-hazardous.

If such microbes have a virulent strain, it could lead to disease condition such as gastroenteritis. Generally, this could have been happening but it often goes unreported especially in rural areas. Gabriel-Ajobiewe *et al*. (2014) reported that fermentation is widespread in tropical regions with relative high temperature and humidity, with unsanitary conditions that enhance food spoilage.

Storage condition

Fermentation of maize medium into variety of food products is carried out by microorganisms either through inoculation or spontaneous fermentation. Fermentation of maize products such as *agidi* deteriorates easily during storage (2 – 3 days) leading to loss of essential constituents of the product (Ogiehor *et al*., 2005). Also during storage the pasting properties of ogi are altered. The dynamics of growth, survival and biochemical activity of microorganisms in foods and its products is due to stress reactions in response to the changes on the physical and chemical setting into the food micro-environment (including pH, oxygen, water activity, salt concentration, and temperature) and the ability to colonize the food matrix and to grow with spatial heterogeneity (e.g., microcolonies and bio-films) (Wakil and Daodu, 2011). Bolaji *et al.* (2011) reported that storage temperature affects ogi characteristics.

However the storage process of fermented maize food is often carried out in environment lacking quality control. The food could get contaminated by the storage materials. For instance, after wet milling of fermented maize for *Ogi* production, the bagged milled maize is further fermented in water prior to use. During this process, it could get contaminated by microbes in the water, thereby putting prospective consumers of maize fermented food at risk of food borne diseases.

Microbiology

Food microbiology has evolved as a means of regulating changes that could occur in the fermentation of food and its related products. Typically, changes in the chemical quality of a food are mainly caused by enzymes which are produced by microorganisms in the medium. According to Sharma *et al*. (2013), microorganisms involved in natural fermentation, assist in establishing the genetic resources of fermentation processes. The use of unrelated microorganisms in the fermentation medium often leads to production of products with different organoleptic properties. Sometimes the output could be preferred but in most cases, they are detrimental. Again, the microorganisms employed during fermentation are mainly from the environment, fermentation materials including water used.

The traditional fermented food producers lack the basis means of identifying the organisms, its constituents, age and purity. The microorganisms that affects food products is a function of intrinsic and extrinsic factors. Iwuoha and Eke (1996), Oyedeji *et al*. (2013) listed pH (acidity), temperature, ions (such as hydrogen ions), as optimal conditions that favor microbial performance in fermentation. Also, processors of these food products do carry out fermentation at ambient temperature and without pH regulation.

Quality control

Fermented food such as *ogi* by smallholder lack quality control measures. No laid down procedure for processing stating the quantity of water that could be added to a particular amount/weight of maize during fermentation. Also the fermentation period depends mainly on individuals and locality. For instance, in the production of *ogi* (a fermented cereal gruel with smooth texture with sour taste), fermentation is mainly carried out from 0 – 72 hours, but some individuals also ferment for up to 96 -120 hours. There is a distinct change in quality of product fermented for 24 hours and that of 48 hours.

The only quality control frequently carried out by processors is the organoleptic characteristics, and to a large extent, this depends on the individual. No control in environmental factors such as relative humidity, pH and temperature is carried out during fermentation of the product.

Nutritional and toxicological effects

Foods are typically consumed for its nutritional benefits including provision of energy, vitamin, amino acids, nutrients (potassium, sodium, calcium, magnesium, manganese, zinc, iron etc). Fermentation leads to loss of some nutrient from the maize used for fermentation. According to Osungbaro (2009), the extent of nutrient losses depends significantly on the method of *ogi* preparation. When undesirable microbes dominate the fermentation medium, it could produce products with different organoleptic properties. For instance, Osungbaro (2009) reported that nutritional quality of *Agidi* (a gel-like *Ogi*) is a reflection of the chemical composition of the *ogi*. Therefore, deficiency in some area is also a function of the raw material. Generally cereals including maize have little protein content. Protein in addition to other non-starch components such as fat and crude fibre, reduces the tendency of cereal starches to form gels, limits the inclusion of non-starch nutrients into cereal starches intended for *agidi* production (Osungbaro, 2009). Specifically, maize is deficient in lysine and tryptophan (Osungbaro, 2009). During the processing of maize into different products such as agidi, its protein content is lost. Again, the sieving activities reduce the quality (proximate composition and nutrients) of the *ogi* (Farinde, 2015).

Options for overcoming the problems

Process control

Since fermented foods are influenced by temperature, water activity, hydrogen ion concentration (pH), oxygen availability and substrate used for food fermentation process (Oyewole and Isah, 2012) which to large extent are influenced by the environment. Therefore this could be controlled by manipulation of the environmental factors (thus controlling of temperature, pH, water activity, ionic strength and oxygen availability).

Microorganisms control

Several microorganisms are found in the fermentation medium and some may result from the water used for fermentation, therefore the need to use of starter culture in a confined environment. The use of starter culture for *Ogi* production has been documented by Teniola *et al*. (2005). Also Omemu (2011) reported that fermentation dynamics of *ogi* is boosted by the use of starter culture and this assists in optimizing the process for improved *ogi.* The choice of a particular starter culture may be considered for the following roles; sugar fermentation potential, organic acids, produced desirable effect at optimum temperature (mainly room temperature) and production of flavor. Also the use of sprouted maize has been demonstrated to have a higher microbial density in a fermentation medium between 24 – 72 hours compared to the unsprounted maize (Adegbehingbe, 2013). The density of the microbes in fermentation medium also facilities the process provided all environmental condition are optimum.

Microorganisms are main cause of spoilage in food products. The use of botanicals and chemical preservatives has been used to enhance the shelf life of *ogi*. Adesokan *et al*. (2010) reported that coliform population and total viable count in with ginger blend *ogi* when compared with no ginger blend supplement. The authors further reported that the density of lactic acid bacteria and yeast increased significantly as fermentation proceeds (Wakil and Daodu, 2011; Nwokoro and Chukwu, 2012). Ogiehor *et al*. (2005) also reported that 0.15% sodium benzoate hinder the growth of total viable bacteria and fungi in *Agidi* for a period of 21 days.

Control of processing environment

Since processing environment of *ogi* lacks hazards control, and most of processor carry out their activities under unhygienic conditions, there is the need to improve on the environmental condition (including personal hygiene, use of clean utensils and for fermentation, initial washing of the maize with clean water prior to fermentation). This process could reduce unwanted microbes such as the coliforms that are likely faecal contaminations and do not play roles in fermentation of *ogi*. Also, the processing and storage temperature could adversely affect storage. Ogiehor *et al*. (2005) reported that when *agidi* supplemented with 0.15% sodium benzoate are stored at 12 - 14ºC, there was no growth up till 28 days of storage as compared to 21 days before microbes began to grow when preserved at ambient temperature 30ºC. The authors further reported that pH of *agidi* blended with 0.15% sodium benzoate in higher (with respect to alkalinity) when compared to the *agidi* without blend.

Enhancing the shelf life

Fermentation process for ogi involves the use of naturally occurring microorganisms to produce new product. However fermentation could be a functional approach for reducing microbial contamination of food products (Kohajdova and Karovicova, 2007). In recent times, food processing industry has been shown to rely on a wide range of preservation technol*ogi*es to sustain the food at an acceptable level of quality from the time of manufacture through to the time of consumption (Kohajdova and Karovicova, 2007). This is because most fermented food are threatened by short shelf life (1 – 7 days). Studies have been conducted on the improvement on the shelf life of *ogi* (Adesokan *et al*., 2010).

Improving its nutritional quality

Studies have been variously carried out to fortified *ogi* so as to improve the protein content using botanicals such as Moringa (Abioye and Aka, 2015; Arise et al., 2014),*Carica papaya* (Ajanaku *et al*., 2010), mango mesocarp (Badifu *et al*., 2000), ginger and clove (Farinde 2015), bambara nut (Mbata *et al*., 2005, 2007), Okra seed (Aminigo and Akingbala, 2004) (Table 3) and co-fermentation with legumes such as Millet *(Pennistum vulgare),* Sorghum, (*Sorghum bicolor L. moench*) and Cowpea (*Vigna unguiculata* (L) Walp.) (Oyarekua, 2011). *Ogi* with supplement usually have higher nutritional effects and lower viscosity. For instance Aminigo and Akingbala (2004) reported that *ogi* supplement with okra reduces the viscosity, carbohydrate content and moisture content and increased the protein content and percentage ash, but the crude fibre did not show any significant difference between the medium with supplement and un-supplemented.

Similarly Badifu *et al* (2000) reported that mango mesocarp increases the protein, fat, ash, fibre, beta carotene, energy content and reduces the moisture, carbohydrate and viscosity of *akamu*. Abioye and Aka (2015) reported that protein, fat, ash, crude fiber, beta carotene content, moisture increases, while carbohydrate decreases with addition of moringa. Also, Arise et al. (2014) reported that *ogi* from fermented yellow maize supplemented with *Moringa oleifera* flower powder showed an increase in crude protein, crude fibre, ash and fat with increase in the levels of *Moringa oleifera* flower powder and decrease in carbohydrate and moisture content. Mbata *et al*. (2005) reported that protein, fat, ash and moisture increases with addition of bambara nut to *ogi*. In Sorghum based *Ogi*, Ajanaku *et al*. (2010) reported that fat, ash, protein content, ascorbic acid content, total sugar, reducing sugar and non reducing sugar increased and moisture and carbohydrate content also decreased.

The supplementation of *ogi* with botanicals enhances its nutritional quality. Badifu *et al*. (2000) reported that addition of soybean and mango mesocarp to maize based *ogi* improves its amino acid constituents (arginine, lysine, histidine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, aspartic, serine, glutamic, proline, glyine, alanine, cysteine and tyrosine) and it is a pro-vitamin A booster. Again, studies have shown that nutrients (such as iron, zinc, magnesium, sodium, calcium, potassium, phosphorous, iodine and copper) composition of *ogi* increases with addition of botanicals. There was an increase of nutrients with moringa leaves (Abioye and Aka, 2015), soya bean and mango mesocarp (Badifu *et al*., 2000), with soy bean spices such as ginger and clove (Farinde, 2015) was supplement to *ogi* as shown in Table 4. Similarly, Oyarekua and Adeyeye (2009) reported that co-fermented maize/cowpea and sorghum/cowpea improves the nutritional quality, functional properties and amino acid profile of *ogi*.

Based on the study of Farinde (2015) on the organleptic characteristics of *ogi* supplemented with spice (ginger and clove), colour, appearance, texture, taste and overall acceptability were preferred for sieved *ogi* with spice while the flavor of sieved *ogi* without spice were preferred. Similarly, Abioye and Aka (2015) reported that *ogi* supplemented with 10% moringa leave showed apparent difference (less level of sensory acceptability) with plain *ogi* with regard to taste, mouth fee and flavor but showed no significant difference.

The authors showed that colour, appeal and general acceptability of 100% maize *ogi* is preferred showing significant variation. However, in all cases of sensory quality, it range from slight likeness to very much likeness. Badifu *et al*. (2000) reported that blended with mango mesocarp and soybean has significant acceptability with regard to texture, colour, flavor and general acceptability compared to un-blended akamu.

Amingo and Akingbala (2004) reported that *ogi* without okra seed meal or roasted okra seed meal had superior organoleptic properties (aroma, colour, taste, texture and general acceptability). Adesokan *et al*. (2010) reported that 5% ginger blend to cooked *ogi* improved the appearance, taste, texture colour and aroma.

Table 3: Proximate composition of *Ogi* supplemented with botanicals

Blends	Moisture	Protein, %	Fat %	Ash %	Fibre %	Carbohydrate, %	β-Carotenes (µg/100g)	Energy (kcal/100g)	Viscosity	References
100% *ogi*	8.63	9.10	3.57	1.67	2.47	74.57	121.67	-	-	Abioye and Aka 2015
90% *ogi* + 10% Moringa	8.67	13.23	3.63	2.30	2.83	69.33	838.33	-	-	
85% *ogi* + 15 moringa	8.90	17.63	3.73	3.10	3.37	63.57	1058.33	-	-	
Raw maize ogi	9.3	10.3	6.7	0.24	3.04	70.42	-	-	-	Akanbi et al., 2010
Maize and soya blend	10.24	15.3	8.23	1.76	3.20	61.76	-	-	-	
Raw *akamu*	19.8	5.7	3.9	0.3	1.2	78.9	67.0	373.5	3436	Badifu *et al*., 2000
70% Maize + 30 soya bean	9.5	18.7	8.9	2.3	2.0	58.6	158.0	389.3	2350	
55% Maize + 25 soya bean + 20% mango mesocarp	8.7	17.4	8.7	2.6	2.3	60.3	233.2	389.1	2208	
60 % Maize + 25 soya bean + 15% mango mesocarp	9.3	17.6	8.5	2.4	2.3	59.9	199.2	386.5	2217	
Seived *ogi* % spices	8.07	10.23	-	1.09	5.15	68.89	-	-	-	Farinde, 2015
Unseived *ogi* +spice	7.94	12.13	-	1.43	6.84	63.53	-	-	-	
Seived *ogi* +no spice	8.29	9.22	-	0.83	3.39	72.35	-	-	-	
Unseived +no spice	8.26	11.45	-	1.13	6.24	66.77	-	-	-	

Table 4: Mineral composition of *Ogi* supplemented with botanicals

Blends	Minerals									References
	Iron mg/100g	Zinc, mg/100g	Mg, mg/100g	Na, mg/100g	Ca, mg/100g	K, mg/100g	P, mg/100g	I, µg/kg	Cu, mg/100g	
100% *ogi*	4.67	0.23	36.67	-	125.01	21.67	-	-	0.37	Abioye and Aka 2015
90% *ogi* + 10% moringa	7.37	0.43	95.05	-	360.02	183.33	-	-	0.53	
85% *ogi* + 15 moringa	12.77	0.63	135.01	-	445.10	233.33	-	-	0.53	
Raw maize ogi	21.6	18.3	271.5	-	73.5	-	-	-	14.6	Akanbi *et al*., 2010
Maize and soya blend	24.3	19.2	340.6	-	98.2	-	-	-	15.8	
Raw akamu	2	4	3	2	6	10	110	1	-	Badifu *et al*., 2000
70%maize + 30 soya bean	10	13	19	21	36	24	380	3	-	
55% maize + 25 soy bean + 20% mango mesocarp	12	15	26	14	39	31	270	10	-	
60 % maize + 25 soya bean + 15% mango mesocarp	11	14	20	13	37	29	269	4	-	
Seived *ogi* % spices	19.60	12.64	89.04	45.66	59.84	-	-	-	-	Farinde, 2015
Unseived *ogi* +spice	23.76	15.60	144.56	43.88	68.44	-	-	-	-	
Seived *ogi* +no spice	17.44	9.96	76.56	35.96	34.24	-	-	-	-	
Unseived +no spice	19.60	12.60	99.04	59.84	45.68	-	-	-	-	

Conclusion

Food is essential for the survival of man and other living organisms. Nigeria has several staple food including plantain, cassava, maize, yam, etc. Majority of these food items are processed prior to consumption. Some also undergo fermentation processing via spontaneous process or with microorganisms found in the environment. Ogi is a typical fermented food largely produced from the fermentation of maize in Nigeria. Ogi is a major diet for the elderly and a weaning food in infants. During the fermentation of maize, several microbes are found in the medium including bacteria (of the *Enterobacteriaceae* family, lactic acid bacteria, obligate and facultative bacteria), fungi (yeast and mould). Majority of the microbes are mainly from the environment and processing utensils. Typical microbes that enhance fermentation of the maize medium for ogi production are yeast such as *Saccharamyces cerevisiae* and lactic acid bacteria such as *Lactobacillus* species. As fermentation proceeds, the microbial density also increases. There are a number of constraints encountered during the fermentation of maize viz from environmental factors, microbiological sources, quality control, nutritional and toxicological effects and storage problem. These challenges can be regulated by enhancing the hygienic condition of processors, using un-contaminated water for fermentation and processing, blending the ogi with botanicals (paw-paw, ginger, clove, soy bean etc) with antimicrobial properties and rich in protein and amino acids, vitamins and nutrient such calcium, magnesium, iron, copper, potassium, sodium and manganese, and also optimize environmental factors such as temperature and pH.

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