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Microbiology and Safety of Ogi Fermentation: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author VNE conceptualized and designed the framework of the review article and extensively edited it to its final form. Author AMA prepared the draft and collected the references. Both authors read and approved the final manuscript.

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ABSTRACT

Ogi a widely consumed breakfast cereal in Nigeria and other West African countries plays an important role in the nutrition and economy of many of the populace, especially among the under-privileged as its consumption cut across all age groups. It is significant for its application as a cheap and convenient weaning food for children, breakfast and soft meal for adult, convalescents, pregnant and nursing women. This paper is aimed at reviewing the production of ogi from different cereals, which maize (*Zea mays*), sorghum (*Sorghum bicolor*) and millet (*Penisetum glaucum*). The microflora of ogi is mainly dominated by lactic acid bacteria which are generally regarded as safe with *Lactobacillus plantarum* dominating and certain beneficial fungal species which belong to the genus *Saccharomyces* and *Aspergillus niger*. The safety of the potential microorganisms which are responsible for the fermentation of the product from the various substrates is also of vital importance. The importance of good hygiene practice to reduce post production re- contamination of the product which could possibly lead to food poisoning especially at the grassroot level is also considered. The widespread use of ogi as a weaning food for children in sub-Saharan Africa makes this review very significant and relevant.

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1. INTRODUCTION

Fermentation is an ancient method of preserving food whereby the growth and activities of certain beneficial microorganisms are encouraged. Microbial fermentations have been significantly involved in food processing and preservation for thousands of years. Optimum growth conditions of temperature, pH, water activity, oxygen supply and nutrients are maintained in order to promote the desirable and durable activities of the selected and targeted microorganisms of importance [1].

Fermented foods native to Africa are desirable and receiving lots of attention both in research and economic usage owing to the organoleptic and health benefits they confer apart from the nutritional provision of energy and body maintenance [2]. These health benefits are mediated by the activities of the beneficial natural array of microflora which dominate the fermentation process. Common traditional fermented foods from cereals include kunun-zaki, bushera, fura, mawe, mahewu, injera, burukutu, bussa and ogi amongst others [3,4]. Of these indigenous fermented foods native to Nigeria and West Africa, ogi is ranked high as it serves as a breakfast porridge suitable for almost all age groups and class, a weaning food for infants, soft meal for the convalescents and elderly, stimulant for milk production by nursing mothers and a means of steady income for the producers who mainly are women both in the rural and urban communities across developing countries in sub-Saharan Africa [5,6,7]. The steamed thin porridge is popularly referred to as 'ogi, 'koko'and 'akamu' by the Yorubas' Ibos' and Hausas' respectively in Nigeria. The gel- like product is known as 'eko' by the Yorubas and agidi by the 'Ibos' [8]. The ogi supernatant is taken as a laxative and also administered in the treatment of certain illnesses, a situation which is prevalent among the rural dwellers.

The traditional spontaneous technique of ogi fermentation gives the product its characteristic unique sour taste for which it is loved. However, studies have shown have shown that most of the traditional producers are unskilled and lack adherence to hazard analysis critical control point (HACCP) exposing it to pathogenic contamination and considerable loss of nutrient arising from large amount of water used in sieving and daily changing of water for storing the wet meal [9], this is a major point of concern to public health. Fortification of ogi to improve its nutritional properties especially to reduce protein-vitamin malnutrition had also received extensive research [10] and is still receiving high research attention due to its significant role in thedi et of numerous consumers. However, there is a dearth of literature on the innate microbiological quality of ogi. The aim of this review is to characterise ogi, investigate the microorganisms associated with the fermentation from different substrates and evaluate the safety concerns of this product.

2. CHARACTERISATION AND PRODUC-TION OF OGI

Several cereals can be employed for the production of ogi either independently or in combination. Maize, sorghum and millet are the major cereals used as substrates for the production of ogi; however, emergent cereals for ogi production include fonio grains (*Digitaria spp*), rice (*Oryza sativa*) and amaranth (*Amaranthus spp*). The colour of ogi Fig. 1 on the type of cereal employed for its production. Of the millets, pearl millet (*Penisetum glaucum)* ogi popularly referred to as 'ogi-gero' is the most common. Millet seeds are rich in phytochemical and phytic acid which is believed to lower cholesterol, phytate on the other hand is linked to cancer reduction [3].

The traditional technique of ogi fermentation has been extensively studied and involves spontaneous fermentation of the grains by soaking in water for about 48 hours at 28 ± 2°C and milling into a smooth paste. The slurry obtained is then sieved using a muslin cloth to remove the bran, germ and hull which is high in protein. The filtrate is allowed to undergo a secondary fermentation for about 24–72 h in order to develop its characteristic sour taste. The length of the secondary fermentation depends on the extent to which sourness is desired. In another context, the grains are soaked in hot/warm water for about 12-24 h prior to fermentation to facilitate softening of the cotyledons [11,12,13,14]. This method is usually practised by the traditional unskilled producers who lack adherence to good manufacturing practice and sanitation especially in rural areas where portable water supply is a major concern. These unsanitary practices expose the product to not only contamination from handling and

processing, but water-borne pathogens. The traditional method of ogi fermentation is labour intensive, time consuming [2]. Flow chart for the production of the traditionally fermented ogi is shown in Fig. 2.

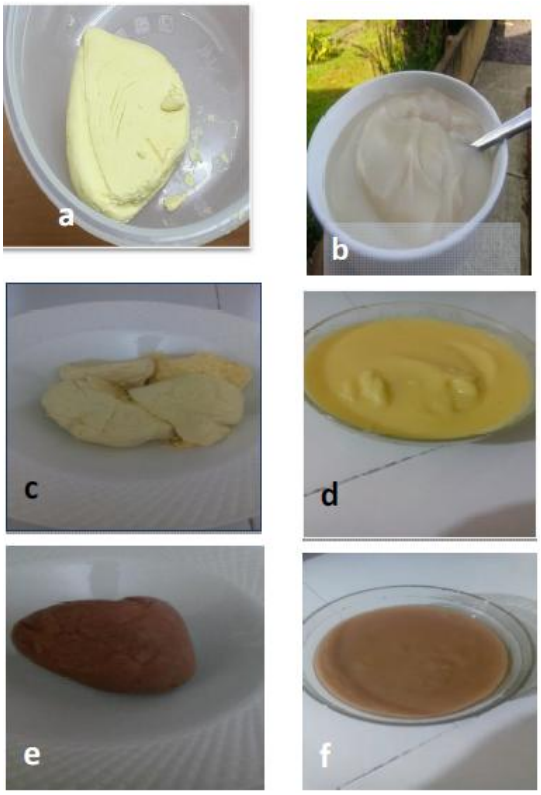

Fig. 1 (a-f). Commonly consumed ogi from different grains

(a) White maize meal; (b) White maize steamed paste (c) Yellow maize meal; (d) Yellow maize steamed paste
(e) Sorghum meal; (f) Sorghum steamed paste

Improvements in the usual traditional process of ogi fermentation have been studied include application of starter culture, dry milling of the grains prior soaking and fermentation, dehulling and milling, sprouting before milling, fortification, boiling of grains before milling, accelerated batch fermentation or backslopping [1,15,16,17]. Ogi produced using lactic acid bacteria (LAB) starter cultures and backslopping methods presents a higher degree of sourness compared to that produced using the traditional method of fermentation [18]. The short period of acidification (24-48 h) must have been responsible for the sourer taste in the LAB fermented ogi. [15]. The flow chart is shown in Fig. 3.

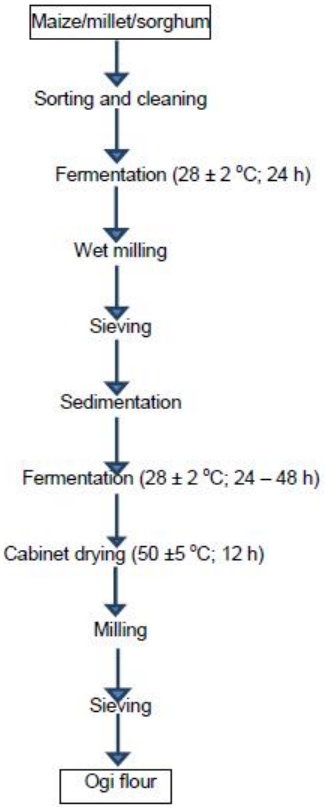

Fig. 2. Flow chart for the production of traditionally fermented ogi flour

Source: [1,18]

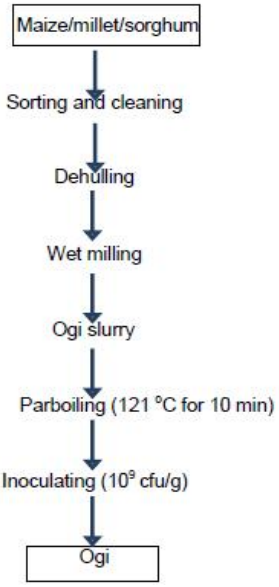

Fig. 3. Flow chart for the production of improved fermented ogi

Source: [15]

3. CHEMICAL PROPERTIES OF OGI

3.1 Physicochemical Properties

Studies on pH and titratable acidity (TTA) of the fermented slurry from different grains revealed that as the TTA increases, pH value decreases [13,19]. This trend was also observable during starter culture fermentation of ogi production [15]). The reason for this decrease in pH is due to the presence and activities of lactic acid bacteria (LAB) which resulted in the production of lactic acid during ogi fermentation [20]. Antimicrobial and bacteriocins which are of great value in bio-preservation and improved product shelf life by eliminating spoilage and pathogenic organisms have also been linked to the low pH of fermented foods [21]. During fermentation of ogi, some of the fermentation organisms produce amylolytic enzymes which are responsible for the disintegration of the starch substrate to reducing sugars, thereby resulting to the decrease in the total sugar content of the ogi [13]. In addition, lowering of the pH is also effected by the ability of yeast and LAB present during fermentation to utilize the free sugars. Another point of note is the increase in bacteria counts which increases as steeping progresses favouring the growth of lactic acid bacteria, thereby increasing the acidity of the steeped water and ogi at the end of fermentation [19].

3.2 Proximate Composition

Several studies have reported considerable variation in the proximate composition of maize, sorghum and millet ogi [5,22,23,24,25] with the agro-climatic condition under which these grains are cultivated showing significant influence on the composition of the grains and the products obtained from them [22]. From the study of [24] as shown in Table 1, sorghum ogi had the highest protein content followed by maize ogi which varied with the result of [22] with millet ogi having the highest protein content (7.92%) followed by sorghum ogi (5.93%). Starter culture fermentation with *Aspergillus niger* and *Lactobacillus plantarum* were able to improve the protein and lipid content of ogi when compared with spontaneous fermentation process [15].

The study conducted by [26] reported that after 72 h of fermentation, the proximate composition showed higher carbohydrate content (19.31%) than the unfermented corn flour (11.14%). However, the protein, fibre, fat and ash content were observed to be higher in the unfermented corn flour (11.90%), (4.73%), (1.30%), (3.45%) respectively compared with the fermented corn slurry (3.33%), (0.15%), (0.13%) and (1.75%) respectively. The loss of protein in the fermented sample is in accordance with the findings of [27] which showed that the stages involve in the production process of grains to ogi resulted in protein loss of about 40% however, it increased the digestibility by about 20%.

3.3 Functional Properties of Ogi

Functional properties of ogi samples from different varieties of grain have been reported to show variation, this trend was observed for water absorption capacity, swelling power, solubility, bulk density and pasting characteristics [23]. This variation has been linked with the ratio of the amylose to amylopectin components of grain, the characteristics of each fraction in terms of molecular weight, distribution, length of branching and conformation [28]. High bulk density is desirable, in order to reduce the paste thickness which is an important factor in convalescent and child feeding [25].

According to [29] water and oil absorption capacities increases with increase in steeping period. Water absorption capacity gives a good indication of possibilities of protein incorporation with aqueous food formulations and finds application in the development of ready to eat foods and a high water absorption capacity may also enhance product effectiveness.

Pasting is the phenomenon that follows gelatinisation in the fractionalization or breaking up of starch. It is a property which involves rapid

Table 1. Proximate composition (g/100 g) of ogi flour produced from different grain

Substrate	Carbohydrate	Crude protein	Crude fibre	Fat content	Moisture	Ash
Maize	75.78	6.13	4.71	4.6	8.43	0.34
Millet	78.96	4.73	2.81	5.17	7.93	0.41
Sorghum	77.1	8.90	3.52	3.1	8.90	0.54

Source: [24]

swelling of the granules, exudation of molecular components, leaching out of amylose from starch granules and total disruption of the granules. It is a property essential in ogi in order to predict the behavioural pattern of the cooked pap as it is consumed as a cooked paste [30]. It also represents a degree of intactness of product, granule size, concentration and amylose/ amylopectin ratio with changes observed in final viscosity and setback linked to the degree of re-ordering leached amylose chains [28].

In a report, ogi from yellow maize stored at -10± 3°C and -20± °C presented a better gelling ability throughout the 12 weeks of storage period. Furthermore, the study reported that ogi stored at refrigerated temperatures of -10± 3°C and -20±°C maintained its peak viscosity and viscous load of the fresh fermented ogi while the peak viscosity of the samples stored at ambient temperatures of 27±3°C and 5± 2°C decreased throughout the period of storage with the viscous load decreasing as storage period increases. The authors explained the decrease in the peak viscosity, final viscosity and setback observed at the ambient temperature as probably due to the alteration in the chemical structure mediated by the activities of the microorganisms present which have tendency to modify the chemical structure of starch with time [28].

The setback viscosity is an index of retrogradation and entrapping water thus promoting syneresis [29], however, retrogradation may have some nutritional benefit in producing nutrient dense product that will not require the addition of water during infant feeding [31]. Osungbaro [32] also found out that maize of different varieties exhibited different pasting viscosities on the amylograph and that the difference was due to the fact that the maize varieties contain varying amounts of amylose with values ranging from 29- 34%.

Pasting temperature gives an indication of the minimum temperature required for cooking the ogi. It has been shown that degree of fermentation influences swelling property of ogi. In terms of pasting viscosities and consistencies 48 h fermentation of maize is appropriate for the manufacture of ogi [33]. The author established that fermentation of ogi extending beyond 96 h resulted in the paste exhibiting poor quality, gelling tendency and consistency. In a similar trend, Apotiola [29] observed the pasting characteristics of sorghum ogi powder decreased with increased soaking period. Values of peak viscosity observed in his study were lower compared with values obtained by Fasasi et al. [31]. Likewise, a related reduction in viscosities on fermentation of samples of sorghum flour [34]. This trend of variation of viscosities of ogi samples among different varieties of grain have been reported by other studies for sorghum, maize, pearl millet [35,36].

3.4 Nutritional Quality of Ogi

Quite a lot of nutrient loss is experienced during the processing of cereal for the production of ogi. These losses occur as a result of steeping, discarding of steeping water, sifting to remove the bran and germ which contains much of the protein and also discarding of the ogi supernatant thereby resulting in loss of minerals, fibre, protein, iron, phosphorus, calcium, vitamins such as riboflavin, thiamine, niacin, folic, pantothenic acid and other nutrients. This therefore results in reduction of net protein utilization, protein energy ratio and biological values [37,38]. In developing countries where consumption of this resultant low nutritional product is high, deficiency of protein and energy usually results in negative clinical manifestations such as kwashiorkor and marasmus in children, with severe cases leading to death. In order to improve the nutritional quality of ogi several fortification with protein rich substrates have been studied which include, functional and pasting characteristics of fermented maize with nile tilapia (*Oreochromis nicoliticus*) [31]; protein enriched soy-ogi [39]; enrichment of sorghum ogi flour with cocoa [40]; instant ogi from blends of fermented maize, conophor nuts and melon seeds [25]; co-fermentation of maize/cowpea and sorghum/cowpea ogi as instant complimentary food [22]; nutritive value of sorghum ogi fortified with groundnut seed (*Arachis hypogaea L.*) [17]; dietary fortification of sorghum-ogi using crayfish (*Paranephrops planifrons)* as supplements in infancy [41]; fortification of maize ogi with okra seed meal [37]; fortification of ogi with okra seed flour [42].

Oyarekua and Eleyinmi [22] in their study on the nutritional quality of corn, sorghum and millet ogi reported the amino acid (AA) composition of ogi prepared from these grains with leucine and proline as the most abundant amino acids in corn and millet while for sorghum ogi, phenylalanine, glycine, arginine and valine were the most abundant. As a result, in the choice of weaning foods and for children, sorghum ogi would be preferable because of its high value of arginine

91.5 compared to 33.2 and 43.1 of millet and corn ogi which is an essential amino acid for children. Considering the total essential amino acid of ogi flours from the three varieties of cereals as reported by [22], millet ogi (275.2 mg g^{-1} crude protein), corn ogi (373.2 mg g^{-1} CP), and sorghum (721.9 mg g^{-1} CP), comparatively, only the ogi from sorghum had values that can be compared with the egg reference protein (566 mg g^{-1} CP). Therefore, since sorghum had values that have been shown to satisfy the amino acid requirement of all age groups it can be regarded as a high quality protein.

Although, generally lysine is reported to be low for all the cereals, however, sorghum ogi has a higher content than the other cereals. In order to improve their nutritional quality as weaning foods, ogi from these cereals could be supplemented with milk or legume high in lysine [43].

4. MICROBIOLOGICAL PROPERTIES OF OGI

The microbiology of ogi is quite complex. The traditional fermentation is initiated as a result of chanced inoculation by uncontrolled microorganisms from the environment involving a build-up of bacteria and fungi. Some of these microorganisms may participate in parallel, while others act in succession with a changing dominant biota during the course of fermentation. Different studies [12, 44,45, 46, 47] have been able to isolate and enumerate possible microorganisms associated with the fermentation of ogi. The following genera predominates the bacterial fermentation, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Pediococcus, Streptococcus, Micrococcus and Bacillus* The fungal genera are include representatives of *Saccharomyces, Candida, Aspergillus, Fusarium, Cladosporium and Penicillium amongst others* Lactic acid bacteria (LAB) are one the most common microorganisms responsible for cereal fermentations, they are notable for the beneficial role of preservation, enhanced nutritional value, detoxification, lactic acid, flavour and aroma production with *Lactobacillus plantarum* reported as the most dominant specie [12]. These organisms have been studied to competitively eliminate other organisms especially pathogens from the fermentation process. The synergy between LAB and yeast is common in food and beverage fermentations with LAB creating the acidic environment for yeast growth and yeast providing the vitamins and other growth factors necessary for the survival of Lab [48,49]. Studies of ogi fermentation revealed similar microorganisms as shown in Table 2.

Table 2. Microorganisms involved in fermentation of ogi

Substrate	Organisms involved	References
Sorghum	*Lactobacillus plantarum*, *Corynebacterium, aerobic bacteria, Streptococcus lactis, aerobacter, Candida mycoderma, Rhodotorula sp., Saccharomyces cerevisiae, Penicillium sp., Aspergillus niger, Fusarium sp., Cephalosporium, Debaryomyces hansenii, Candida krusei*	[12,48]
Maize	*Lactobacillus sp., Lactobacillus brevis, Leuconostoc sp., Streptococcus lactis, Bacillus megaterium, Micrococcus reseus, Aeromonas aerogenes, Corynebacterium fermentum, Staphylococcus aureus, Saccharomyces cerevisiae, Pediococcus sp., Candida stellalata, Penicillium italicum, Penicillium notatum Aspergillus flavus, Aspergillus niger, Rhizopus stolonifer and Fusarium sp. and Yeast*	[26,50,51,52]
Millet	*Pediococcus pentosaceous, Lactobacillus plantarum, Saccharomyces cerevisiae, Candida krusei, Rhizopus sp, Aspergillus flavus, Aspergillus niger, Fusarium sp, Penicillium sp.*	[44,53]
Maize (fermented sprouted and unsprouted	*Lactobacillus plantarum*, *Lactobacillus fermentum*, *Leuconostoc mesenteroides*, *Lactobacillus brevis*, *Pediococcus acidilactici*, *Saccharomyces sp.*, *Candida krusei, Aspergillus niger, Micrococcus luteus.*	[54]

4.1 Safety Assessment of Ogi

Microbial food safety is a public health concern and fresh ogi is known to house an array of lactic acid bacteria such as *Lactobacillus plantarum*, *Lactobacillus fermentum* and *Streptococcus lactis* which are health promoting food grade organisms usually common with fermented foods [55]. However, during spontaneous fermentation, the presence of undesirable microorganisms such as *Bacillus subtilis*, *Bacillus cereus*, *Salmonella spp*., *Streptococcus pyogenes*, *Escherichia coli, Staphylococcus aureus*, *Pseudomonas aeruginosa, Aspergillus flavus* and other enterobacteriaceae complicates the control of the fermentation process and raises concern about its reliability and safety [56]. These associated microorganisms indicates possible processing and post processing contamination and have been implicated in food poisoning [57]. One of the major sources of bacterial contamination of ogi is water coupled with unhygienic conditions of processing and handling associated with the indigenous processes. This is particular to communities where portable water is not available leading to frequent heavy contamination of the product with pathogens and may be a major factor in causing food borne illness such as diarrhoea and associated malnutrition in children [57].

Processing contamination of ogi often results from the use of untreated water. Surface water (wells, river, streams) which are not completely free of microbial contamination serve as the main source of water for most rural processors, municipal water supplies are not also spared of microbial contamination. The presence of *E. coli* in water is an indication of direct or indirect faecal contamination. Therefore, the isolation of *E. coli* from wet milled ogi is probably an indication of the likely presence of other enterobacteriaceae which are known to be causative agents of foodborne gastroenteritis and bacterial diarrhoeal [58]. This becomes more threatening especially when ogi is either consumed raw or not properly cooked before consumption. Selected strains of the bacterium have been noted to cause a wide range of infections such as diarrheal, urinary tract infection, dysentery.

The occurrence of *Bacillus subtilis* and *Pseudomonas spp* in the raw ogi is probably responsible for the development of rancidity and ropiness associated with the fermented ogi. The presence of *Aspergillus spp*. in processed ogi poses a severe health risk when it is consumed. Strains of *A. flavus* have been reported to secrete aflatoxins which have been implicated in hepatoxin and cancer related diseases [58]. Infectious diseases such as cholera were associated with ogi due to contamination from handling and poor hygiene during preparation. Mould growth, mycotoxins production and certain yeast infections and allergies have also been associated with storage of ogi and are indications of contamination by spoilage organisms common to carbohydrate foods [58,59].

Contamination of the processed product can be prevented through the use of latex gloves to reduce excessive human hand contact, use of clean non-infected grains for processing, regular treatment of municipal water or conscious utilisation of clean surface water during milling and sieving, proper packaging and storage of both the wet and dry ogi to avoid microbial contamination [57,60].

In order to reduce the microbial load, the processing water could first be boiled (100°C) and allowed to cool. The muslin cloth used in sieving could also be thoroughly washed and properly sterilized, regular cleaning of the inner and outer parts of the milling machine could also be effective [61]. Okoronkwo et al. [1] isolated *Staphylococcus aureus* from white and yellow maize which is as a result of contamination of the grain from handling at the market and can produce enterotoxins which are highly resistant to heat in food stuffs. Furthermore, street vending and sales in the open market could lead to a possible re- contamination of ogi and serve as a reservoir for pathogens.

In a related study, isolation of *Escherichia coli* and *Staphylococcus aureus* during fermentation stages of ogi, however, the organisms were unable to grow but could only survive for a short time owing to the fact that although prepared under poor hygienic conditions there was presence of lactic acid (low pH) [10]. Fermentation has been linked with the potential of inhibiting growth of most pathogenic organisms due to the low pH and high TTA associated with spontaneous fermentation of ogi which results in drastic decrease for competing microorganisms [61]. The critical control points do not support the growth of pathogenic microorganisms, which gives ogi a good safety record, however, good hygiene practices and HACCP measures should be adopted to minimize the presence of pathogens in the food.
Studies revealed that factors such as poor hygiene, infrequent cleaning of milling machine

and frequent exposures of raw and cooked products may contribute to contamination of ogi. The presence of coliform is an indication of faecal contamination associated with unhygienic practices and poor environmental sanitation [57]. Although food handlers and environment could serve as possible and important reservoirs for pathogens, studies have shown that the pathogens investigated could not grow but only survive in the antimicrobial environment of ogi for a short period at room temperature [10].

4.2 Probiotic Attributes of Ogi

Probiotics have been associated with fermentation as beneficial living microorganisms which when consumed in adequate amounts 10^6 cfu/ml confer health benefits to the host [4]. Probiotics bacteria characteristics include resistant to acid and bile, ability to produce antimicrobial substances, adherence to epithelial tissue, colonization of the gastrointestinal tracts, stimulation of host immune response, lowering of cholesterol and lactose activity [50,62]. From the study conducted by [63] the probiotic strain of *Lactobacillus plantarum* isolated from fermenting corn slurry (ogi) displayed a good antagonistic action against selected pathogenic bacteria (*Bacillus cereus* NCIB 6349, *E. coli* Type 1 NCIB 14070, *Klebsiella pneumoniae* NCIB 950, *Staphlococcus aureus* NCIB 8588, *Shigella dysentariae*clinical isolate) with inhibition zones between 1- 4 mm*. Lb. plantarum* was also able to adhere to the epithelial cell (IEC) of experimental albino rats, lower aminotransferases levels and reduction of serum cholesterol makes it a good probiotic agent.

Adebolu et al. [64] investigated the effect of uncooked ogi liquor from five varieties of grains; white maize, yellow maize, white guinea corn, red guinea corn and millet on some diarrhoeal bacteria; *Staphylococcus aureus, Shigella dysenteriae, Escherichia coli, Salmonella typhimurium* and *Enterobacter* species and concluded almost all the test organisms were inhibited by the raw ogi liquor with zones of inhibition ranging from 4.0-14.0 mm. The possibility of which is due to ability of LAB isolated from the raw ogi liquor to produce various bioactive compounds such as organic acids, diacetyl, lactic acid, hydrogen peroxide and bacteriocin during lactic acid fermentation. In addition, low pH of liquors could also be partly responsible for the antibacterial activity against common bacteria that cause diarrhoea. As a result of this therapeutic benefit, raw ogi is therefore effective in the treatment and prevention of diarrhoeal a major health hazard and a principal cause of morbidity and mortality especially among infants in rural communities of sub-Saharan Africa where access to primary healthcare care is not readily available before they are transported to hospital for proper medical care [57].

5. CONCLUSION

The microbial fermentation of ogi is mainly dominated by lactic acid bacteria which have been proven to provide certain health benefits and are generally regarded as safe (GRAS) and through the activities of some beneficial yeast, which have the potential to eliminate pathogenic organisms from the product under controlled conditions when applied as starter cultures. However, the occurrence of pathogens in ogi is mainly due to post production re- contamination during handling, poor hygiene of the processors, storage and retail contamination thereby increasing the risk of contracting food borne illnesses. Sanitary measures such as regular supply of portable water at the rural level and proper packaging of ogi can help reduce rate of contamination from water- borne sources and retailing outlets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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