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Microbial Contamination at Different Stages of Production of Ogi in Mowe: A Rural Community, Southwest, Nigeria

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ABSTRACT

The reported cases of outbreaks of communicable diseases and high child mortality in the developing countries have been linked to food and water contamination due to poor sanitary conditions. The microbial assessment at critical points of production of Ogi was aimed at establishing the source(s) of contamination. The water samples, maize grains, paste and filtrate, wet Ogi, body swabs and underneath of nails of the attendants were screened for microbial presence. The organisms were isolated from 10^{-3} and 10^{-7} dilution of water; steep water after soaking of grains, mashed grains, paste and filtrate and fermented wet Ogi, respectively on Potato Dextrose (Fungi), Mueller Hilton (Bacteria) and Sabouraud Dextrose (Yeasts) agar. The enteric organisms were further confirmed on MacConkey and Mannitol salt agar. The isolated organisms included *Aspergillus flavus*, *A. niger*, *Penicillium oxalicum*, *Fusarium oxysporium* and *Rhizopus stolonifer* (Fungi), *Candida albicans* and *Saccharomyces cerevisiae* (Yeast), *Escherichia coli* and *Klebsiella aerogenes* (Enteric bacteria), *Lactobacillus plantarum*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Non enteric bacteria). The non enteric bacteria were contained in all the samples screened while the growth of the enteric bacteria and fungi species was significantly inhibited at the latter stages of fermentation. There was a re-contamination of the paste and fermented Ogi by the enteric bacteria due to poor handling and unhygienic practices associated with the attendants. The water samples, soaking medium, grinding mill and transportation from storage to selling points were the critical points of contamination. Appropriate safety measures and good manufacturing practices will ensure good quality of product.

Key words: Fermentation, ogi, maize porridge, food borne disease, mycotoxins, gastroenteritis

INTRODUCTION

Maize products are the cheapest and readily available fermented foods for infants and young adults in most tropical countries (Torre *et al*., 1991). They are important energy food rich in carbohydrates and with traces of vitamins, proteins and minerals (Achterberg *et al*., 1994; FAO, 2009) and are natural antioxidants (Eaton and Nelson, 1991). The importance of vitamins as antioxidants was aptly discussed by Singh and Sachan (2011).

The wet fermented porridge is prepared and consumed as Ogi, Akamu and Akassa among the Yorubas, Ibos and Hausas in the west, east and northern Nigeria, respectively (Parveen and Hafiz, 2003). These maize products are common in seemingly poor and impoverished communities

across the developing countries (Inyang and Idoko, 2006). These fermented products are largely from *Zea mays*, *Oryza sativa*, *Sorghum valgare* and *Triticum aestivum*. Their production is often by small-scale enterprise undertaken by unskilled female attendants (Aminigo and Akingbala, 2004).

The maize porridge has become part of the stable diets (Adeyemi and Soluade, 1993) for young adults, nursing mothers and a weaning ration for infants between the ages of 1 and 2 years (Adebolu *et al*., 2007). It is a choice meal for patients in need of soft and easily digestible foods (Jay, 2005). The nutritive quality of maize porridge is very low resulting from low quality of maize proteins and the substantial loss of nutrients at the different stages of production (Nkama *et al*., 2000). Consequently, a number of leguminous seeds including Soya beans and Okra seeds are used to fortify and improve their protein, iron, calcium and fibre contents (Osungbaro, 2009; Anigo *et al*., 2009; Olukoya *et al*., 1994) to eliminate the incidences of anaemia and stunted growth often associated with malnutrition (Muhimbula and Issa-Zacharia, 2010).

The inclusion of fumonisin and aflatoxins in maize (Jespersen *et al*., 1994) and other cereal products (Fandohan *et al*., 2005; Shephard *et al*., 2002) has been linked to certain species of fungi including *Aspergillus*, *Penicillium*, *Rhizopus* and *Fusarium* by Omemu *et al*. (2005).

The carcinogenic effects of this contamination were extensively discussed by Shephard *et al*. (2002). Few of these toxins including FB1 are associated with high degree of cancer in rats and humans. Hendricks (1999) and Barug *et al*. (2004) warned of the health implication of consuming mycotoxins contaminated maize products. Fandohan *et al*. (2005) warned of the danger of using the supernatant from Ogi as solvent to extract active ingredients from traditional herbal plants because of probable high level of fumonisin. A positive correlation between the level of aflatoxins and the incidences and severity of kwashiorkor in infants (Adhikari *et al*., 1994) has been established. They also discovered a significantly low haemoglobin level, longer oedema and increased infection rate in children that were positive for aflatoxins.

The death toll as a result of microbial contamination of foods remains ever high in the developing countries. Over 38, 173 cases of cholera outbreaks were reported between January and August, 2010 in Nigeria. This figure was three times the number reported for the year 2009 (WHO, 2010). The incidence was aptly linked to contamination of food and poor hygienic conditions. Osho and Fagade (2000) reported outbreaks of cholera, typhoid fever, infectious hepatitis and gastroenteritis in Ago-Iwoye, Southwest, Nigeria and adduced similar reasons for the high death of infants and young adults. A correlation between high mortality rate in infants and low income families was reported by Uddian and Hossain (2008).

The poor hygienic practices associated with the preparation of Ogi and other cereal products makes it a source of infection when consumed by young adults and infants. Consequently, the study aims at establishing the critical points of contamination during the preparation of Ogi and suggest appropriate control measures.

MATERIALS AND METHODS

The study was conducted at the facilities of Biological Sciences Department, Redeemer's University, Nigeria from September 2010 to March, 2011.

Collection of samples: Three production and storage sites were chosen in Mowe, a border town between Lagos and Ogun States and a fast growing rural community 41 with a population close to 100, 000 people. Samples were collected from water in reservoirs (plastic/metal tanks and drums),

maize grains, steep water from mashed grains, paste, filtrate from paste and fermented slurry (wet pap). Collection of samples was done twice a month, spanning over four months, starting December, 2010 to March, 2011. The samples were collected in sterile bottles and immediately stored at 4°C temperature until ready for use. Swaps from finger nails, clothes and cooking utensils were collected using moist sterile cotton wool.

Production of Ogi (Liquid porridge from maize): The maize grains were sieved to remove pebbles and dirts and subsequently soaked in water for 4 days. The soft grains were mashed, milled and sieved using Muslin cloth. The solid paste was diluted with water and left to ferment for 48-72 h. The surface water was decanted and the sediment (wet slurry) was collected in a bowl and allowed to stand for 8-10 h to sufficiently solidified. The solidified slurry was portioned into small units or cubes and wrapped in leaves or polythene bags ready for sale.

Media preparation: The techniques described by Arora and Arora (2008) and Willey *et al.* (2008) were employed in preparing the Potato Dextrose (PDA) and Mueller Hilton agar to obtain pure cultures of the fungal and bacterial isolates, respectively.

Isolation procedure

Fungi: Serial dilutions of the samples of water (10^{-3}) and steep water, mashed grains, paste, filtrate from paste and fermented wet slurry (10^{-7}) were obtained. The sufficiently diluted samples were mixed with warm agar (PDA) and poured into Petri dishes to obtain sufficient fungal growth. The upper surfaces of fungal colonies were picked and inoculated on fresh PDA to obtain pure cultures using the techniques described by Willey *et al.* (2008).

Yeast: The sufficiently diluted samples were mixed with warm Sabouraud Dextrose (SDA) agar and plated following the techniques described by Marshall (1993).

Bacteria: A small part of the diluted samples was pipette onto the centre of Mueller Hilton agar and spread out evenly over the agar surface with a sterilized spreader and incubated at 37°C for 24 h (Willey *et al.*, 2008). The tip of each colony was picked with a sterilized wire loop and streaked across fresh agar surface to obtain single cell cultures. Estimation of the viable bacteria colonies was done using the Standard plate count agar (Difco lab. Detroit Michigan). The experiment was in duplicate.

Air screening: Petri dishes containing PDA and Mueller Hilton agar were sufficiently exposed to air around the production sites for 4 h, incubated at 37°C for 24 h and analysed for fungal and bacterial presence only.

Biochemical tests analysis: The techniques described by Cheesbrough (2002) were employed for the Gram staining while the citrate utilization, Hydrogen sulphide production test and sugar fermentation and oxidase tests were as, respectively described by MacWilliams (2009) and Cowan and Steel (2002). The isolates were later identified using Bergey's manual described by Brenner *et al.* (2005). Confirmation of coliforms was as described by Willey *et al.* (2008) using selective and differential media such as MacConkey and Mannitol salt agar to analyse for *E. coli* and *Klebsiella* sp. and *Staphylococcus aureus*, respectively. The presumptive test in broth was

streaked out on Mueller Hilton agar and incubated at 37°C for 48 h to morphologically characterize the isolates.

RESULTS

The water samples from the three study sites consisted of *Aspergillus niger*, *A. flavus*, *Penicillium oxalicum*, *Fusarium oxysporium* and *Rhizopus stolonifer* (Table 1). These organisms were the principal contaminants and found in water used in the washing and soaking of maize, mashed grains and freshly milled maize pastes. The growth of these fungi pathogens were significantly inhibited at the later stages of fermentation (Table 1). They were found suspended in air around the three study sites and also on clothes and body swabs (Table 2) of the attendants.

The two yeast contaminants which included *Candida albicans* and *Saccharomyces cerevisiae* were equally isolated from maize after soaking and under the nails of attendants and utensils (Table 3). The *Lactobacillus plantarum* and *Staphylococcus aureus* were among the four bacteria species isolated from both water and at the different stages of production (Table 3a, b). They were equally isolated from under nails and clothes of the attendants and cooking utensils (Table 3). The analysis of clothing revealed heavy presence of *Pseudomonas aeruginosa*. The surface of grains was almost sterile while the bacteria growth progressively decline in the steep water, paste and filtrate and fermented Ogi (Table 3a, b).

Table 1: Fungal contamination at stages of production

	Site 1						Site 2						Site 3					
Fungal species	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Aspergillus flavus	+	-	+	-	-	-	+	-	-	-	-	-	+	-	+	-	-	-
Aspergillus niger	+	+	+	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-
Penicillus oxalicum	+	-	+	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
Fusarium oxysporium	+	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-
Rhizopus stolonifer	+	-	+	-	-	-	+	-	-	-	-	-	+	-	+	-	-	-

a: Water in reservoirs, b: Maize grains, c: Steep water, d: Maize, e: Filtrate from paste, f: Wet ogi, -: Absent, +: Present

Table 2: Microbial assay of air, utensils and body swabs of the attendants

		Site 1					Site 2					Site 3				
Group	Microorganism	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Bacteria	*Pseudomonas aeruginosa*	-	-	+	-	+	-	+	+	+	+	-	+	+	+	-
	Lactobacillus plantarum	-	+	-	-	+	-	-	-	-	+	-	-	-	-	+
	Staphylococcus aureus	-	+	-	-	+	-	+	-	+	-	-	+	+	-	+
	Escherichia coli	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+
	Klebsiella aerogenes	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+
Fungi	*Aspergillus flavus*	+	-	-	+	-	+	-	-	-	+	+	-	-	-	+
	Aspergillus niger	+	-	-	+	+	-	-	-	-	-	-	-	-	+	-
	Penicillium oxalicum	+	-	-	-	-	+	-	-	+	-	-	-	-	-	+
	Fusarium oxysporium	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-
	Rhizopus stolonifer	+	-	-	-	+	+	-	-	+	-	-	-	-	-	-
Yeast	*Saccharomyces cerevisiae*	-	+	+	-	+	-	-	-	-	+	-	+	-	-	-
	Candida albicans	-	+	-	-	+	-	+	-	-	+	-	+	-	-	+

a: Air, b: Underneath of nails, c: Boby swabs, d: Clothing, e: Utensils, -: Absent (no growth), +: Present (growth)

Table 3a: Estimation (c.f.u. $mL^{-1} \times 10^6$) of bacteria and yeast population in samples from different stages of production

		A			B			C			D			E			F		
Sampling	Microorganism	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
I	*Pseudomonas aeruginosa*	4.42	4.15	-	-	-	-	1.80	3.02	1.64	2.79	3.12	-	2.79	3.12	-	5.94	2.94	1.93
	Lactobacillus plantarum	3.80	3.14	2.81	-	-	-	1.77	2.89	2.01	2.66	3.15	-	-	2.63	2.17	4.78	4.77	1.89
	Staphylococcus aureus	4.36	4.11	-	-	-	-	1.23	1.38	1.60	2.00	1.38	1.01	2.60	2.33	1.68	-	2.88	-
	Escherichia coli	4.38	4.13	4.14	-	-	-	-	-	-	-	-	-	-	-	-	-	1.22	-
II	*Pseudomonas aeruginosa*	4.37	4.58	3.82	-	-	-	2.46	1.88	1.81	-	2.33	-	4.83	2.36	-	-	-	-
	Lactobacillus plantarum	-	3.58	-	-	-	-	1.34	2.38	-	1.22	2.22	2.31	2.78	2.86	2.82	-	-	-
	Staphylococcus aureus	4.35	4.49	-	1.02	-	-	1.23	3.00	-	2.68	3.61	3.63	3.47	-	2.86	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	*Pseudomonas aeruginosa*	3.88	3.11	2.89	-	2.01	-	1.59	1.01	1.89	1.47	2.34	3.24	2.41	2.83	3.11	-	-	-
	Lactobacillus plantarum	-	-	3.84	-	-	-	1.34	1.83	2.82	2.78	2.74	2.68	3.62	1.08	2.36	2.11	1.91	1.33
	Staphylococcus aureus	3.91	3.34	2.79	-	-	-	2.81	2.88	2.02	2.61	-	-	-	-	3.02	-	-	-
	Escherichia coli	2.84	-	-	-	-	-	-	-	-	-	-	-	1.06	-	-	-	-	-
IV	*Pseudomonas aeruginosa*	3.14	3.89	2.88	1.02	-	-	3.04	2.85	1.86	2.84	2.18	2.36	2.21	1.89	-	-	-	-
	Lactobacillus plantarum	2.53	3.37	3.66	-	-	-	3.68	2.93	2.90	3.09	2.22	2.69	2.53	1.96	1.23	1.03	1.11	0.36
	Staphylococcus aureus	1.63	3.28	-	-	-	-	2.63	3.13	-	-	3.87	2.73	-	-	-	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	*Pseudomonas aeruginosa*	3.88	3.71	3.74	1.03	-	1.07	2.36	3.60	3.06	3.12	2.93	-	2.97	2.61	2.53	-	-	1.86
	Lactobacillus plantarum	2.37	2.99	2.88	-	-	-	-	2.61	2.16	2.02	2.48	2.34	2.06	-	-	-	-	2.37
	Staphylococcus aureus	4.12	3.81	-	-	-	-	2.61	1.88	-	2.66	2.31	-	-	-	-	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	1.52	-	-	-	-	-	-	-	-	-	0.14
VI	*Pseudomonas aeruginosa*	3.92	3.28	-	-	-	-	2.93	2.91	3.22	2.13	3.68	2.58	-	-	-	1.00	-	-
	Lactobacillus plantarum	2.89	3.13	3.12	-	-	-	2.78	3.10	1.22	1.83	1.98	2.65	2.67	1.09	2.38	1.36	1.38	2.38
	Staphylococcus aureus	2.36	2.18	-	-	-	-	3.10	0.12	2.23	2.14	-	-	-	1.06	-	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	-	-	-	1.02	-	-	-	-	-	-	-
VII	*Pseudomonas aeruginosa*	3.36	3.67	3.14	1.61	-	-	3.30	3.11	5.61	2.69	2.27	-	2.38	-	-	1.04	-	-
	Lactobacillus plantarum	2.89	3.13	3.42	-	-	-	2.78	3.17	1.22	2.01	1.83	1.88	2.65	2.67	1.09	2.38	1.36	1.07
	Staphylococcus aureus	2.48	2.10	-	-	-	-	3.61	3.33	-	2.81	-	-	-	-	-	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	-	-	0.39	-	-	-	-	-	-	-	-
VIII	*Pseudomonas aeruginosa*	4.23	3.15	2.66	-	0.97	-	-	2.53	2.55	3.16	3.91	-	-	1.89	1.83	-	-	-
	Lactobacillus plantarum	3.70	3.43	2.87	-	-	-	1.33	2.89	2.73	2.32	3.94	2.58	1.86	1.78	1.93	-	2.88	1.66
	Staphylococcus aureus	-	-	-	-	-	-	1.21	-	-	1.36	1.29	-	-	-	-	-	-	-
	Escherichia coli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-

A: Water from tanks (reservoirs), B: Maize grains prior to soaking, C: Steep wate, D: Miaze paste, E: Filtrate from paste, F: Wet ogi , 1-3: Sites of collection, I-VIII: Number of sampling-absence of organisms (No growth)

Table 3b: Estimation (c.f.u. $mL^{-1} \times 10^6$) of bacteria and yeast population in samples from different stages of production

		A			B			C			D			E			F		
Sampling	Microorganism	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
I	*Klebsiella aerogenes*	-	-	-	-	-	-	1.23	-	-	2.00	-	-	-	-	-	-	-	-
	Saccharomyces cerevisiae	7.17	6.13	5.82	-	-	-	3.23	-	-	2.89	2.73	-	-	-	-	-	-	-
	Candida albicans	4.83	-	3.26	-	-	-	3.88	2.91	-	-	-	-	-	-	3.11	-	-	-
II	*Klebsiella aerogenes*	4.39	4.52	-	-	-	-	1.83	-	-	-	-	-	-	-	-	2.83	-	-
	Saccharomyces cerevisiae	6.23	5.89	4.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Candida albicans	-	-	5.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	*Klebsiella aerogenes*	3.10	-	-	-	-	-	-	-	2.46	-	-	-	-	-	-	-	-	3.06
	Saccharomyces cerevisiae	4.93	3.37	-	-	-	-	3.28	3.49	2.84	-	3.57	4.53	-	-	-	-	-	-
	Candida albicans	3.69	3.28	3.11	-	-	-	4.72	4.14	-	-	-	-	1.02	-	-	-	-	-
IV	*Klebsiella aerogenes*	2.98	-	-	-	-	-	-	-	2.83	-	-	-	-	-	-	-	-	-
	Saccharomyces cerevisiae	3.66	2.91	2.79	-	-	-	3.23	3.65	3.46	-	3.28	-	-	-	-	-	-	-
	Candida albicans	-	-	3.81	-	-	-	-	-	-	-	-	2.62	-	-	-	-	-	-
V	*Klebsiella aerogenes*	2.11	-	-	-	-	-	1.89	-	-	-	-	-	-	-	-	-	-	-
	Saccharomyces cerevisiae	3.09	3.38	3.22	-	-	-	1.91	2.26	1.38	-	1.81	-	-	-	-	-	-	-
	Candida albicans	3.83	3.44	-	-	-	-	-	-	1.97	-	-	-	-	1.78	-	-	-	-
VI	*Klebsiella aerogenes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.27	-
	Saccharomyces cerevisiae	-	4.35	-	-	-	-	3.23	2.42	2.56	-	-	-	-	-	-	-	-	-
	Candida albicans	2.68	-	-	-	-	-	-	2.63	2.51	-	-	-	-	-	-	-	-	-
VII	*Klebsiella aerogenes*	1.06	-	-	-	-	-	1.25	-	-	-	-	-	-	-	-	-	-	-
	Saccharomyces cerevisiae	-	-	2.94	-	-	-	-	2.37	-	-	-	-	-	-	-	-	-	1.22
	Candida albicans	-	2.93	2.29	-	-	-	-	2.85	2.57	-	-	-	-	-	-	-	-	
VIII	*Klebsiella aerogenes*	-	-	-	-	-	-	-	-	1.02	-	-	-	-	-	-	-	-	-
	Saccharomyces cerevisiae	3.63	-	-	-	-	-	3.12	2.89	2.38	-	3.17	-	-	-	-	-	-	-
	Candida albicans	2.37	-	2.61	-	-	-	-	-	2.67	-	-	-	-	-	-	-	-	-

A: Water from tanks (reservoirs), B: Maize grains prior to soaking, C: Steep wate, D: Miaze paste, E: Filtrate from paste, F: Wet ogi , 1-3: Sites of collection, I-VIII: Number of sampling-absence of organisms (No growth)

There was no significant difference (p = 0.005-ANOVA) in the number of colonies found in all the water sources from the three sites. The growth of *E. coli* and *K. aerogenes* declined significantly at complete fermentation stages. These organisms were re-introduced into the preparation at later stages of production as fresh contaminants. The growth of *P. aeruginosa*, *L. plantarum* and *S. aureus* was unaffected (4.00-5.76 cfu mL^{-1}×106) at terminal stages of fermentation.

DISCUSSION

The outbreak of infectious and communicable diseases in tropical parts of the world is primarily as a result of food poisoning due to microbial contamination (Jay, 2005). They are often responsible for acute gastroenteritis, abdominal discomfort and pain and diarrhoea in infants and young adults (WHO, 2010; Kimmons *et al.*, 1999).

The maize grains were almost surfaced sterile prior to soaking. The isolated *Staphylococcus aureus* in few maize samples could have arisen from contaminated sacks used for storage and transportation of produce. Onovo and Ogaraku (2007) discovered some bacteria and fungi on exposed Tigernut (*Cyperus esculentus* L.) before processing. The presence of *Aspergillus flavus, A. niger, Penicillium oxalicum, Fusarium oxysporium, Rhizopus stolonifer, Saccharomyces cerevisia Candida albicans Escherichia coli Klebsiella aerogenes* and *Staphylococcus aureus* in water from the reservoirs suggests an extremely poor storage system, deplorable sanitary conditions available at the three sites and multiple sources of contamination due to open access to the reservoirs. Similar and related organisms were implicated in food and canned products by Gadaga *et al.* (2008), Taulo *et al.*(2009) and Oladipo and Omo-Adua (2011).

The exposure of water tanks to direct rays from the sun provided the required warmth and physical condition for growth of these organisms. Ozoh and Kuyanbana (1995) and Osho and Fagade (2000) equally affirmed water as the source of *Shigella* spp. and *E. coli* in maize and other cereal porridge. Contaminated water was linked as the main source of *Vibrio cholera* infection (Shahcheraghi *et al.*, 2009) in some population in Iran. Oranusi *et al.* (2007) estimated 2-3 Log10 coliforms per 100 g mL^{-1} of cooked maize porridge and linked contamination to the water used during washing and soaking of maize grains. Heavy presence of *E. coli, Klebsiella pneumonia* and *Streptococcus* sp. was reported (Yeboah-Manu *et al.*, 2010) in some foods sold around the University of Ghana campus. The introduction *Salmonella* sp. *Rhizopus* sp. and *Staphylococcus* aureus in some food products have been linked to the presence of phytotoxin by Okafor and Omodamiro (2006).

The attendants at the three study sites admitted collecting water from streams and lakes whenever the public water supply failed and often time untreated water was used during preparation. Good and hygienic water supply has been the bane of many communities in the developing countries (Ehiri *et al.*, 2001) including Nigeria where the needed social and infrastructural facilities are grossly inadequate.

The unlimited and open access to the water tanks allowed cross contamination of the cooking utensils and bowls and subsequent re-contamination of products at the later stages of production. The body swabs and underneath of nails contained substantial counts of *Staphylococcus aureus* and *Lactobacillus plantarum* and also, *E. coli, Klebsiella aerogenes* and *Saccharomyces cerevisiae*. The Muslin clothes used in sieving the shaft were stained and soiled and often reused without thorough washing. The wrapping leaves and polythene were not sufficiently rinsed or sterilized before use. Omemu and Adeosun (2010) observed similar unhygienic practices among attendants and vendors at some production sites in Abeokuta, Nigeria.

The air was laden with *Aspergillus flavus, Penicillium oxalicum* and *Rhizopus stolonifer* and served as source of re-contamination of the finished products. Wacher *et al.* (1993) linked the contamination of freshly prepared pozol, traditional Mexican fermented maize dough to the surrounding air. The growth of bacteria (*Escherichia coli* and *Klebsiella aerogenes*) declined significantly in fully fermented wet paste as rightly observed by Byaruhanga *et al.* (1999) for *Bacillus cereus* after 24 h fermentation. Also, Mensah *et al.* (1990, 1991) observed a significant inhibition in the growth of some gram-negative bacteria. Chukeatirote *et al.* (2010) observed an exponential increase in the population of bacteria and fungi with increased pH and fermentation time of Thua nao (Soybean).

However, a re-contamination at latter stages of production by these enteric bacteria as observed could be linked to water as it was used repeatedly during preparation. Odugbemi *et al.* (1993) reported an increase in the level of faecal coliforms in cooked Ogi under 9 h storage conditions and suggested a probable re-introduction during storage. A similar conclusion was held by Sanni *et al.* (2002) for the rise in the population of yeast from 1.0 cfu g^{-1} to 5.36 cfu g^{-1} after 12 h fermentation. Alalade and Adeneye (2007) observed a significant correlation between pH and coliform bacterial count in wara cheese during fermentation process.

We observed few counts of *Escherichia coli* and *Klebsiella aerogenes* in fully fermented products (wrapped wet Ogi). Poor handling by vendors was rightly suggested by Wacher *et al.* (1993) for the significant increase in enteric bacteria in freshly prepared pozol. On the other hand, the growth of *Lactobacillus plantarum* was unhindered at the different stages of production, even after 48 h fermentation. Relatedly, an exponential increase in growth of some lactic acid bacteria was earlier reported by Kunene *et al.* (1999) in both fermented and cooked maize porridge. The critical contamination points during the preparation of Ogi included the point of soaking of grains, mill and wrapping materials. Effective GMP as recommended by Amoa-Awua *et al.* (2007) would help eliminate contaminants for improved table quality and assure the health of consumers.

CONCLUSION

The water samples were the major sources of microbial contamination of products at all the stages of production. The unhygienic practices by attendants were linked to the heavy presence and repeated contamination by *A. flavus, A. niger, F. oxysporium, P. oxalicum* and *R. stolonifer, S. cerevisiae, C. albicans, E. coli, K. aerogenes, P. aeruginosa, L. plantarum* and *S. aureus*. The enteric bacteria and all the fungi species were eliminated at full fermentation while the growth of others was unaffected. The wrapping leaves and surfaces of bowls provided secondary sources of contamination of product. Appropriate training to expose attendants and vendors to safety standards and good manufacturing practices is essential to maintaining quality of products.

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