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The Effect of Processing Conditions on the Quality Characteristics of 'Garri' Produced from Cassava (*Manihot esculenta*)

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Abstract. The effect of processing conditions, such as fermentation period, pH, and frying time and temperature on the microbiological, biochemical, physicochemical and organoleptic quality characteristics of 'garri' produced from cassava (*Manihot esculenta*) were evaluated. Results showed that the total bacterial count increased with the increase in fermentation period to 96 h up to 1.03 x 10^8, and thereafter decreased when the fermentation period was ended after 120 h. Mixed microbial populations of *Bacillus*, *Streptococcus, Staphylococcus* and *Corynebacterium* species dominated the early phase, while *Leuconostoc, Lactobacillus, Candida, Geotrichun* and *Pichia* species dominated the later phase of fermentation. The pH decreased from 5.04 ± 0.01 to 3.47 ± 0.02, while the titratable acidity at the end of the fermentation period increased from 0.01 ± 0.001 to 0.04 ± 0.001. With the exception of lipids, moisture and hydrocyanic acid contents, which decreased with fermentation period, the increase recorded in the carbohydrates, proteins, ash, and fibre contents were significant at $p < 0.05$. Frying at 75.5 ± 0.5 °C for 20 min drastically reduced the bioload by several folds. Sharp reductions, which were significant at $p < 0.001$, 0.01, 0.05, were recorded in the moisture and hydrocyanic acid contents. Different stages of processing impacted significant effects on the sensory attributes evaluated. The recorded observations are likely to be useful for developing viable indices for the production, processing and handling of 'garri'.

Keywords: *Manihot esculenta*, cassava fermentation, cassava processing, cassava 'garri'

Introduction

A roasted granular product popularly known as 'garri', produced from peeled, grated and fermented cassava roots (*Manihot esculenta*), is consumed by millions of people in the rain forest belt of West Africa, especially Nigeria. Its acceptability cuts across the multiethnic and socioeconomic classes of the populations, making it the commonest meal amongst the rich and the poor. 'Garri' is principally consumed as the main meal, with vegetable and meat dishes, and is sometimes eaten as snacks soaked in cold water or milk with roasted peanuts, coconuts or smoked fish. It contributes up to 60% of the total calories intake in West Africa, where its average consumption is 150 g per person per day (Cock, 1985). 'Garri' is currently produced, processed and handled as a domestically produced fermented food on a cottage industry scale, which varies from one ethnic group and locality to another. This has resulted in variable processing conditions, leading to variability in the quality of 'garri' produced by the various ethnic groups of different sub-localities (Ogiehor *et al.,* 2004). Thus, the microbiological, physicochemical and organoleptic quality criteria, which determine its acceptability and consumption, lack uniformity (Agbonlahor *et al.,* 1997). The acceptability of each variant of the locally produced 'garri' is therefore limited to its immediate environment. This is a matter of serious concern for the standardized branded marketing of the product, as the 'garri' acceptability and popularity is now on the increase, especially at the international level.

The 'garri' after processing is spread on the floor, or on a mat, to allow it to cool before final sieving and packaging for marketing. In the open market, 'garri' is displayed in open basins, bowls, bags and mats. These practices are a potential cause of contamination by various groups of microorganisms, which may predispose the product to public health hazards (Ogiehor, 2002). Data and suggestions for safe handling and extension of shelf-life of 'garri' for up to 12 months have been documented (Ogiehor and Ikenebomeh, 2005). These informations are useful as a base for industrialization of the product and for international acceptability. The present study was therefore designed to investigate the effects of some processing conditions, such as fermentation period, and frying temperature and time, on the microbiological load, and physiochemical, biochemical and organoleptic quality characteristics of 'garri', with the principal objective of developing measurable and reproducible indices for 'garri' production, processing and handling procedures.

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Materials and Methods

Source of cassava and garri processing. Cassava root tubers were obtained from open market and processed at the Supply and Transport Military Barracks, 'Garri' Processing Centre, Benin City, Nigeria. The processing of cassava tubers into 'garri' was done according to the scheme described by Adeyemi and Balogh (1985). Briefly, the tubers were peeled, washed with clean tap water and grated in a commercial grating machine. The grated cassava pulp was packed into Hessian bags and allowed to ferment while dewatering gradually under impaired pressure. Six batches were produced and allowed to ferment for 24, 48, 72, 96, and 120 h. The starting unfermented raw material served as the reference control (zero h fermentation). Thereafter, the fermented pulps were sieved through raphia palm net sieves, fried at 75.3 ± 0.5 °C, allowed to cool to ambient temperature (30 ± 2 °C) followed by resieving into finer grains.

Microbiological analyses. Twenty five gram proportions of each sample (fermented, unfried, 0-120 h; and fermented, fried, 0-120 h) were aseptically taken and soaked in 125 ml of 0.1% sterile peptone water (w/v) for 2-3 min with occasional stirring using sterile glass rod. Ten-fold serial dilutions were subsequently prepared by transferring 1 ml aliquot of the supernatant into 9 ml of aqueous sterile peptone water as the diluent. Further serial dilutions were carried out and thereafter 1 ml of the appropriate dilution was aseptically plated for total aerobic bacterial count on nutrient agar (Biotech), fungi count on malt extract agar (Oxiod) for fermented unfried samples, and potato dextrose agar (Biotech) supplemented with chloramphenicol for fried samples. Isolation, characterization and identifications of bacterial groups and fungi were carried out, respectively, using the guidlines of Vanderzannt and Splitt stoesser (1992) and Samson and Reenen-Hoekstra (1988).

Biochemical and physicochemical analyses. The pH values of the various samples were determined. The titratable acidity (as lactic acid, %) was determined by titrating 0.1 N sodium hydroxide against 10 ml of the supernatant of 10 g of the various samples, previously soaked in 100 ml of water in a beaker (AOAC, 1990). The available carbohydrates, proteins, lipids, ash, fibre, moisture, and hydrocyanic acid contents were determined (AOAC, 1990).

Sensory evaluation. The sensory quality was assessed on such parameters as taste, colour/appearance, aroma/flavour, mouthfeel, texture and swelling index to determine the organoleptic quality of ready to eat 'garri'. Using a nine point hedonic scale, a ten member panel scored the various attributes of 'garri' for overall acceptability (Larmond, 1977).

Data analyses. The data obtained were subjected to statistical analyses of mean, standard deviation and analysis of variance (ANOVA); the significant difference was determined using the student distribution test.

Results and Discussion

The effects of of the studied processing conditions on the microbiological, biochemical, physicochemical and organoleptic quality characteristics of 'garri' are shown in Tables 1-5. It was observed that the total viable count increased steadily with the increase in fermentation time from 6.7 x 10^1 at 0 h (control, starting time) to 1.03 x 10^8 on 96 h fermentation, which decreased on further fermentation (Table 1). Mixed

Table 1. Changes in microbiological, biochemical and physicochemical characteristics during fermentation of cassava for different periods for the production of 'garri'

Parameters	Fermentation period (h)					
	0	24	48	72	96	120
Microbes (TVC)	$6.7x10^1$	$1.05x10^3$	$1.54x10^5$	$1.65x10^7$	$1.03x10^8$	$1.30x10^6$
pH	5.04 ± 0.01	4.07 ± 0.02	3.83 ± 0.01	3.69 ± 0.00	3.55 ± 0.01	3.47 ± 0.02
TA (%)	0.01 ± 0.01	0.02 ± 0.00	0.03 ± 0.01	0.03 ± 0.00	0.04 ± 0.01	0.04 ± 0.00
Moisture (%)	43.10 ± 1.0	40.80 ± 1.5	38.30 ± 0.8	36.60 ± 0.9	34.65 ± 1.4	34.20 ± 0.7
Proteins (%)	0.60 ± 0.01	0.82 ± 0.02	1.08 ± 0.02	1.54 ± 0.05	1.66 ± 0.02	1.58 ± 0.01
Lipids (%)	0.43 ± 0.01	0.64 ± 0.01	0.95 ± 0.02	1.18 ± 0.02	1.30 ± 0.01	1.20 ± 0.02
Ash (%)	2.02 ± 0.02	2.00 ± 0.01	1.97 ± 0.01	1.53 ± 0.02	1.44 ± 0.02	1.40 ± 0.01
CHO (%)	39.10 ± 1.2	41.30 ± 1.5	42.50 ± 1.6	43.6 ± 0.9	44.05 ± 1.5	43.66 ± 1.6
Fibre (%)	0.57 ± 0.01	1.87 ± 0.02	2.08 ± 0.02	2.08 ± 0.02	3.2 ± 0.02	3.78 ± 0.03
HCN (mg/kg)	31.90 ± 0.6	24.30 ± 0.5	17.00 ± 0.6	11.80 ± 0.3	9.50 ± 0.5	3.07 ± 0.1

TVC = total viable count of both fungi and bacteria; TA = titratable acidity; CHO = carbohydrates; HCN = hydrocyanic acid

microbial population was isolated. In all, eight bacterial genera (*Bacillus, Staphylococcus, Streptococcus, Corynebacterium, Leuconostoc, Lactobacillus, Salmonella* and *E. coli*) and three fungal genera (*Candida, Geotrichum* and *Pichia*) were detected and isolated (Table 2). Ecological succession was observed amongst the various groups of microorganisms detected. The early phase of the fermentation period was dominated by *Bacillus, Staphylococcus, Streptococcus* and *Corynebacterium* species. While the later phase was dominated by acid tolerant microorganisms, such as *Leuconostoc, Lactobacillus, Candida, Geotrichum* species and yeast species (Tables 1-2). However, *Salmonella* and *E. coli* disappeared, after 24 h of fermentation.

Table 2. Distribution of microorganisms and their ecological succession during different periods of fermentation of cassava for 'garri' production

	Fermentation period (h)					
	0	24	48	72	96	120
Bacteria						
Bacillus	+	+	+	+	+	+
Staphylococcus	+	+	+	+	+	-
Streptococcus	+	+	+	+	+	+
Corynebacterium	-	+	+	+	-	-
Leuconostoc	-	-	+	+	+	+
Lactobacillus	-	-	+	+	+	+
Salmonella	+	-	-	-	-	-
E. coli	+	-	-	-	-	-
Fungi						
Candida	-	-	+	+	+	+
Geotrichum	-	-	+	+	+	+
Pichia	-	-	+	+	+	+

+ = present; - = absent

The pH was noted to decrease with increase in the fermentation time, from 5.04 ± 0.01at 0 h to 3.47 ± 0.02 at the end of the fermentation period of 120 h (Table 1). Conversely, the titratable acidity increased all through the fermentation period from 0.01 ± 0.001 to 0.04 ± 0.01. With the exception of lipids, hydrocyanic acid and moisture contents, which decreased as fermentation progressed, other components such as proteins, available carbohydrates, fibres and ash contents increased up to the 96 h of fermentation, which thereafter decreased on 120 h fermentation.

The effects of frying at 75.5 ± 0.5 °C on the various quality characteristics of 'garri' are shown in Table 3. The total viable count decreased by several folds while no fungus was detected. Slight increase was recorded in the pH values, with a corresponding decrease in the titratable acidity. A decrease in moisture content was recorded from 18.2% to 11.65% at the start of fermentation to 120 h fermentation (Table 3). Similarly, a decrease in the production of hydrocyanic acid was noted from 12.5 mg/kg at zero fermentation to 3.96 mg/kg at 12 h fermentation. With the exception of lipids, the changes in the contents of available carbohydrates, proteins, ash and fibre were significant at various levels (Table 3).

The effects of various processing conditions on the sensory attributes, such as colour/appearance, aroma/flavour, texture, swelling index, and taste were evaluated (Table 4). The overall acceptability scores showed that the various attributes were significant at different levels, which were in the order of 48 h > 72 h > 96 h > 24 > 120 h > 0 h fermentation period (Table 5).

Table 3. Changes in microbiological, biochemical and physicochemical quality characteristics of 'garri' fermented after frying at 75.3 ± 0.5 °C

	Fermentation period (h)					
Parameters	0	24	48	72	96	120
Bacteria (TVC)*	$0.9x10^1$	$0.5x10^1$	$0.5x10^1$	$0.5x10^1$	$0.03x10^1$	$0.2x10^1$
pH	4.43 ± 0.05	4.20 ± 0.02	4.12 ± 0.01	4.01 ± 0.01	3.98 ± 0.01	3.96 ± 0.01
TA (%)	0.02 ± 0.001	0.02 ± 0.001	0.03 ± 0.00	0.03 ± 0.001	0.03 ± 0.00	0.04 ± 0.001
Moisture (%)	18.20 ± 1.2	16.31 ± 0.7	14.10 ± 0.8	12.88 ± 0.8	12.10 ± 0.6	11.65 ± 0.5
Proteins (%)	0.84 ± 0.01	1.36 ± 0.05	2.41 ± 0.06	2.58 ± 0.03	2.86 ± 0.02	2.63 ± 0.03
Lipids (%)	1.07 ± 0.01	0.6 ± 0.02	0.71 ± 0.02	0.63 ± 0.02	0.58 ± 0.03	0.59 ± 0.01
Ash (%)	0.86 ± 0.01	1.01 ± 0.01	1.54 ± 0.02	1.66 ± 0.03	1.90 ± 0.02	2.02 ± 0.02
CHO (%)	56.30 ± 1.3	59.10 ± 2.1	63.25 ± 1.6	66.42 ± 1.7	67.56 ± 2.1	65.20 ± 1.4
Fibre (%)	1.96 ± 0.02	2.21 ± 0.03	2.46 ± 0.05	2.83 ± 0.02	3.65 ± 0.02	4.0 ± 0.02
HCN (mg/kg)	12.50 ± 0.5	9.50 ± 0.3	5.50 ± 0.5	4.35 ± 0.4	4.05 ± 0.2	3.96 ± 0.3

TVC = total viable count; TA = titratable acidity; CHO = carbohydrates; HCN = hydrocyanic acid; *no fungus was detected at any stage of fermentation

Table 4. Sensory quality of 'garri' fermented for various periods after frying the raw material at 75.3 °C

Fermentation period (h)	Attributes					
	Taste	Appearance	Aroma	Texture	Swelling index	Mouthfeel
0	sweet	whitish	fine sweet aroma	coarse grains	+++	+
24	slightly soured/sweet	glassy/white	sweet aroma	coarse grains	++	+
48	soured-sweet	glassy/opaque	slightly fermenting	slightly smooth	+++	+++
		aroma	coarse grains			
72	soured	opaque white	fermenting aroma	smooth-coarse	++	+++
			grains			
96	very soured	opaque	fermenting odour	smooth-powdery	++	+
120	highly soured	opaque	fermenting odour	smooth-powdery	+	+

+ = fair; ++ = good; +++ = very good

Table 5. Overall acceptability scores of 'garri' produced on fermentation for various periods

Period of fermentation (h)	Taste	Colour	Attributes	Swelling index	Mouthfeel	Texture	Overall
0	3.3 ± 0.3	4.2 ± 0.2	2.7 ± 0.4	7.1 ± 0.2	3.1 ± 0.5	3.2 ± 0.2	3.93 ± 0.3*
24	4.8 ± 0.4	4.4 ± 0.1	4.2 ± 0.5	6.4 ± 0.2	4.2 ± 0.3	4.3 ± 0.1	4.71 ± 0.3**
48	6.8 ± 0.2	6.6 ± 0.2	5.9 ± 0.1	5.8 ± 0.1	6.1 ± 0.2	6.3 ± 0.1	6.25 ± 0.1*****
72	5.8 ± 0.5	5.6 ± 0.3	5.2 ± 0.2	5.7 ± 0.2	5.4 ± 0.1	5.3 ± 0.2	5.4 ± 0.3****
96	5.5 ± 0.5	4.9 ± 0.2	4.7 ± 0.1	4.8 ± 0.2	4.6 ± 0.2	4.8 ± 0.2	4.88 ± 0.2***
120	3.8 ± 0.2	4.6 ± 0.1	3.8 ± 0.2	4.5 ± 0.3	3.6 ± 0.1	4.3 ± 0.1	4.10 ± 0.2*

± standard deviation for duplicate determinations; ***** = most preferred; **** = highly acceptable; *** = acceptable; ** = poorly acceptable; * = not acceptable

The initial increase in the bioload of the fermenting cassava pulp may be associated with favourable environmental conditions, nutrient availability and uninterrupted physiological status. However, the decrease thereafter could be traced to slight nutrient depletion, negative effects of end-products of metabolism, which also potentiate unfavourable environmental conditions, and the effects of these on the physiological status leading to altered homeostasis. The ecological succession observed amongst the fermenting microorganisms may be partly attributed to the presence of organic acids due to starch hydrolysis by *Corynebacterium manihotti*, which favours acid tolerating microorganisms as the fermentation progresses. Similar explanation may account for the gradual decrease in the pH values and the relative increase in the titratable acidity. Furthermore, the disappearance of *E. coli* and *Salmonella* after 24 h of fermentation may be due to their inability to tolerate the changes in the ecological status characterized by increasing acidity (their presence may have been potentiated by contamination from water used for washing and rinsing of peeled cassava). The observations obtained during the present investigation, and the conclusions drawn from these, were in general agreement with those reported earlier (Tyllesker *et al.,* 1992; Oyewole and Odunfa, 1989; Ejiofor and Okafor, 1988; Eka, 1986; Okafor, 1977).

The slight increase recorded in the pH after frying may be associated with volatalization and evaporation of some of the organic acids, organic compounds and other substances during frying, which subsequently reduced the titratable acidity levels. During fermentation, some of the organic compounds are converted to esters and aldehydes, which further enhance the taste and contribute immensely to the characteristic flavour/aroma of 'garri'. In addition, frying at high temperature releases the esters and aldehydes, which determine the final characteristic taste and aroma. The changes from raw white state to glassy white and dull white to various textural presentations such as coarse, grain, smooth or powdery, may also be associated with the combined effects of fermentation and frying. These agree with previous reports (Ogiehor, 2002). The overall acceptability score of the various attributes shows that these were significantly different at various levels amongst the various samples evaluated.

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