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Proximate composition, microbiological safety and heavy metal contaminations of garri sold in Benue, North-Central Nigeria

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This study investigated the proximate composition, microbial safety and heavy metal contaminations of garri: a cassava ready-to-eat food product. Garri is prepared from *Manihot esculenta* Crantz tubers by peeling, washing and grating of the tubers and fermentation. Production, storage and selling locations could be necessary predictors of the quality and safety of garri. A total of two hundred and sixteen (n=216) samples of garri were purchased at two-weeks intervals starting from September 2014; from two major garri markets in Benue State, North-central Nigeria. The heavy metals assessed were Cu, Pb, Cd, Ni, Cr and Hg using atomic absorption spectrophotometer (AAS). The moisture, ash contents and titratable acidity were studied alongside some bacterial pathogens that appear frequently in food-borne diseases outbreaks. The moisture, ash contents and titratable acidity were within the permissible limits. The bacteria isolated included *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* and *Shigella* spp. whereas the fungi isolated included *Mucor*, *Aspergillus* and *Fusarium*. The mean total coliform count (TCC), yeast and mould count (YMC) and total viable count (TVC) ranged from minimum values of not detectable (ND) to 1.75, 2.11 and 2.60 log CFU/g, respectively. While cadmium and chromium were not detected in any of the garri samples, lead, nickel, and copper were the most abundant. The values obtained from microbiological assessments indicate potential food safety problems. Heavy metal and the measured physicochemical attributes and the ash content were within the permissible limits.

Key words: Food safety, garri, microorganisms, toxic heavy metals.

INTRODUCTION

Garri is prepared from *Manihot esculenta* Crantz tubers by peeling, washing and grating of the tubers and fermentation. This is followed by pressing, fragmentation, granulation, drying, sifting and suitable heat treatment (frying) (CODEX STAN 151 - 1989). Sometimes, red palm oil is added to improve the quality. Samuel and Ugwuanyi (2014) described garri as a cream coloured, white or yellow starchy food from cassava root. It is a flour of variable granule size. Virtually, all indigenous people eat garri. Millions of people in tropical countries

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worldwide consume it (Edem et al., 2001; Kostinek et al., 2005; Ogiebor et al., 2007; Samuel and Ugwuanyi, 2014). Urban dwellers consume more garri than their rural counterparts (Jekayinfa and Olajide, 2007) probably because of its ease of preparation, storage efficiency or since it could be put into many uses.

Garri consumption cuts across all socio-economic classes. This product is consumed without cooking, soaked in water with sugar or common salt, smoked fish, roasted groundnuts, cooked beans porridge, palm kernel and groundnut cake (kwuli-kwuli). Sometimes, beverages and milk are value additions to the garri for the improvement of flavour, aroma and the nutrient contents during consumption. Sometimes, garri is cooked and eaten as 'foo foo'. Foo foo is a mixture of hot water and garri granules which has been turned into a stiff paste or gelatinized paste (Asegbeloyin and Onyimonyi, 2007) which is eaten with soup or stew.

Consumption of improperly handled, garri could lead to ill health. Some unhygienic practices are associated with the processing of cassava to garri and post-processing operations of garri. Post-processing handling operations include spreading on the floor and mats after frying, display in open containers like basins in the markets during sales. Producers and sellers of garri use none sterilized packaging materials to transport garri from the villages where they were processed to the towns or market. This could be a viable means of carrying infectious agents in the product (Ogiehor and Ikenebomeh, 2005; Ogugbue and Obi, 2011; Ogugbue et al., 2011; Aguoru et al., 2014).

Microorganisms especially moulds have been associated with processed ready-to-eat gari (Aguoru et al., 2014). Processed garri which had been stored for some time before consumption have various fungal species including *Aspergillus*, *Cladosporium, Fusarium*, *Mucor*, *Penicillium* and *Rhizopus* (Ekundayo, 1984; Ogugbue et al., 2011; Aguoru et al., 2014). Some of these organisms are not friendly to human as they produce potent toxins (mycotoxin) leading to some detrimental health effects. Some mycotoxins cause neurological impairment while some have cytocidal effects. When pathogens are in ready-to-eat foods, humans get them through consumption.

The presence of some heavy metals in the body at certain levels has inimical effects and therefore, calls for concern if allowed to accumulate. Thus, in food, heavy metal contents have strict limits. Some of the most toxic heavy metals are arsenic, cadmium, lead, chromium and nickel. Cadmium, chromium and nickel are carcinogenic. Arsenic and cadmium are teratogenic. Lead causes neurological impairment and central nervous system (CNS) damage by its ability to mimic and inhibit the actions of calcium in its neurotransmission function (Markus and McBratney, 2001; Nadal et al., 2004). Some heavy metals such as cobalt, copper, iron, manganese and zinc are essential micro-elements for living things; however, they are toxic at high concentrations (Nadal et al., 2004; Ani, 2006; Ochieng et al., 2007).

This work investigated proximate compositions, microbial quality and heavy metal contents of garri with a view of establishing its safety for human consumption.

MATERIALS AND METHODS

Samples of garri were bought at two weeks intervals starting from September 2014; from two major garri markets in Benue State, North-central Nigeria (Edumoga Olangbechur along Enugu-Makurdi expressway and Adoka). A total of two hundred and sixteen (n=216) samples representing triplicates of thirty-six yellow and thirty-six white garri were purchased. In every sampling time, six samples each of white and yellow gari were purchased randomly. Thereafter, the purchased garri samples were carried in sterile polyethylene bags to the Research Laboratory, Department of Microbiology of the University where they were analysed. Peeled cassava root tubers used in the preparation of garri were also purchased for analysis. Benue State of Nigeria lies within the area bounded by latitude 6°30' and 8°15'N and longitudes 6°30' and 9°40'E.

Microbiological analyses

Media used for the isolation and identification of the microorganisms were as reported below. Media were sterilized according to the manufacturers' recommendations. Ten grams (10 g) of garri was weighed into a conical flask (250 ml), 90 ml of sterile saline was added, and homogenized by vortex mixing for 5 min. The solubilized garri was, thereafter, diluted further to 10^{-6} and 0.1 ml aliquot of the dilutions spread-plated on agar plates. Colonies that resulted from each plate was counted using Latch colony counter (Latch New Delhi, India) and counts were expressed as log CFU/g. For total viable count (TVC), sterile nutrient agar (Biotechnology Lab. Ipswich, UK) was inoculated and incubated at 37°C for 24 h. Potato dextrose agar -PDA- (Laboratory M Limited, Bury Lancashire BL9 6As, UK) plates were used for yeasts and mould counts. A PDA medium containing chloramphenicol was sterilized by autoclaving at 121°C for 15 min and inoculated as above. Incubation was done at 28°C for 5 days. *E. coli* was isolated and enumerated on Eosin Methylene Blue Agar -EMBA- (Himedia Lab Pot Limited, India) incubated at 37°C overnight, and indole test was conducted on colonies that showed green metallic sheen for test of *E. coli. S. aureus* was isolated on Bair-Parker medium (Laboratory M Limited, Bury Lancashire BL9 6As, UK) as recommended by Macfaddin (1977). *Salmonella* and *Shigella* spp. were isolated and enumerated on deoxycholate citrate agar (DCA) (Park Scientific Ltd, Moultan, Northampton) with tetrathionate and selenite cystine pre-enrichment broths (Macfaddin, 1977).

Bacterial isolates identification using biochemical reaction

Indole test, methyl red test, Voges-Proskauer and citrate utilization (IMVIC) were some of the biochemical tests used in the identification of all the bacterial isolates from the garri. The procedure for the tests was as indicated in Cheesbrough (2006). Additionally, other tests used to identify the isolates included triple sugar iron (TSI) (for *Salmonella* and *Shigella* spp. differentiation), urease test, oxidase, coagulase and catalase (for *S. aureus* differentiation) (Cheesbrough, 2006). Indole test was conducted on colonies that showed green metallic sheen on EMBA. A positive

indole test confirmed *E. coli*.

Identification of the fungal isolates

The procedure of Alexopoulus et al. (1996) was used for the identification of the fungal isolates using morphological and colonial characteristics. All the moulds in the plates were purified by successive sub culturing on sterile PDA medium containing chloramphenicol and were subsequently identified. All morphologically contrasting colonies were checked for purity microscopically and pure cultures were sub-cultured on PDA slants. Mixed colonies were separated by streaking on agar plates before final transfer to agar slants. Storage was at 4°C in the refrigerator pending when these cultures were subjected to final tests for further identification of the organisms. Colonial or morphological appearance of the isolates from the respective cultures were made and recorded taking note of the size, colour and edge of each colony, and the nature of surface.

Elemental analysis

For all the elements analysed, garri sample was oven-dried at 100°C for 3 h. Thereafter, the sample was ground into a fine powder and 0.5 g was weighed into a 100 ml volumetric flask. Thirty millilitres (30 ml) of mixed concentrated acid (650 ml nitric acid + 80 ml perchloric acid + 20 ml H_2SO_4) was added and the mixture was heated at 150°C until dense fumes of nitric acid escaped. Thereafter, it was cooled and brought to a volume of 50 ml using sterile distilled water in a 50 ml volumetric flask. The resulting solution was analysed with an Atomic Absorption Spectrophotometer (AAS, Model Pa990). The spectrophotometer was standardized using the standard solutions of the elements analysed and distilled water was acidified and aspirated to zero using an air-acetylene flame for Cu, Pb, Cd, Ni, Cr and nitrous oxide-acetylene flame for Hg. The absorption radiations of Cu, Pb, Cd, Ni, Cr and Hg produced from the samples at various wavelengths was measured using AAS.

Moisture content

Moisture content was determined by weighing 10 g of garri or cassava tuber (W1), and drying to constant weight in an oven. This was subsequently reweighed (W2). The moisture content calculated in percent was given by the equation previously reported by Manyi et al. (2015).

$$Moisture\ Content\ (MC)(\%) = \frac{Loss\ in\ Weight\ (W2)}{Original\ Weight\ (W1)} \times 100$$

Ash content

Ash content was determined by AOAC (1990) method.

Total acidity

Total acidity was determined by AOAC method (1975) 14.064 – 14.065.

Statistical analysis

Data were analysed using SPSS version 16.0 and results were presented as descriptive statistics.

RESULTS AND DISCUSSION

The moisture contents of the present study ranged from 9.8 ± 1.02 to 14.8 ± 0.29% (Table 1a and b). Similarly, the moisture contents obtained for peeled cassava tubers used in making garri ranged from 64.5 ± 1.40 to 68.2 ± 1.60% (Table 1a and b). There was no statistically significant difference ($p>0.05$) in the moisture contents of garri exposed for sale and that direct from frying. Similarly, the values of the moisture contents recorded for the different cassava tubers are statistically related. The moisture contents of the tubers were significantly higher ($p<0.05$) than that of processed garri. Excessive moisture contents attract high bacterial growth because of increased water activity. However, most of the moisture contents obtained in the present study were within that recommended by Codex Alimentarius Commission for garri. The mean values of the moisture contents in this study support the previous reports of some authors (Adebola et al., 2014; Aguoru et al., 2014; Samuel and Ugwuanyi, 2014). Similarly, the moisture contents of the cassava tubers of the present study supported that reported by Kanim et al. (2009).

The ash content (%) ranges of 1.5 ± 0.06 to 2.4 ± 0.08 and 0.50 ± 0.02 to 0.80 ± 0.02 for garri and peeled cassava tubers respectively were obtained in this study (Table 1). Following the Codex Alimentarius Commission for garri, the ash contents obtained were within the permissible limit (CODEX STAN 151 - 1989). The present ash content values were lower than that previously recorded (Kanim et al., 2009). Even though the ash contents varied from one garri sample to another, the values are statistically homogenous. The ash contents of all the garri samples analysed were consistently higher than the ash contents of the cassava tubers.

Total titratable acidity (%) determined as lactic acid obtained in this study ranged from 0.4 ± 0.07 to 0.8 ± 0.05 (Table 1a and b). The recommended value of total acidity (%) is between 0.6 and maximum of 1.0 (CODEX STAN 151 - 1989). Low acidity presupposes longer fermentation and better quality of garri. Acidity in gari was more than that obtained from the cassava tubers. The results of this study show that there was no statistically significant difference ($p>0.05$) in the titratable acidity. The titratable acidity values reported by Ogiehor and Ikenebomeh (2004, 2005) (0.01 ± 0.00 to 0.4 ± 0.00) were significantly lower than 0.4 ± 0.07 to 0.7 ± 0.05 of the present study. The significance of the determination of some of these physicochemical attributes of food lies in their possibility of inducing microbial spoilage or colonization. For instance, high moisture contents favour bacterial colonization of food, whereas high acidity favours mould growth either of which could predispose the food to microbial invasion.

The highest number of *E. coli* isolated from garri in this study is 1.80 log CFU/g. Many of the samples had no detectable *E. coli* (Table 2a and b). The presence of an *E. coli* is an indicator of poor hygiene and faecal pollution

Table 1. Moisture content, ash content and total acidity of garri samples (a) and cassava root tuber (b).

S/N	Sample analysed	Moisture content (%)	Ash content (%)	Total acidity (%) (lactic acid)
a				
1	Edu-M1W	13.5 ± 0.16	1.5 ± 0.18	0.6 ± 0.08
2	Edu-M2W	12.2 ± 0.33	1.8 ± 0.13	0.4 ± 0.07
3	Edu-M1Y	12.8 ± 0.54	2.2 ± 0.14	0.5 ± 0.07
4	Edu-M2Y	13.1 ± 0.93	1.5 ± 0.06	0.7 ± 0.05
5	Ado-M1W	12.4 ± 1.00	2.0 ± 0.23	0.5 ± 0.07
6	Ado-M2W	14.8 ± 0.29	1.6 ± 0.04	0.6 ± 0.00
7	Ado-M1Y	10.8 ± 0.38	2.0 ± 0.12	0.7 ± 0.03
8	Ado-M2Y	12.0 ± 0.17	1.7 ± 0.09	0.6 ± 0.06
9	Edu-M1W GDF	11.2 ± 0.44	2.4 ± 0.08	0.7 ± 0.05
10	Edu-M2W GDF	9.8 ± 1.02	1.8 ± 0.17	0.6 ± 0.03
11	Edu-M1Y GDF	10.4 ± 0.50	1.9 ± 0.05	0.6 ± 0.07
12	Edu-M2Y GDF	11.6 ± 0.32	2.1 ± 0.03	0.8 ± 0.05
13	Ado-M1W GDF	11.8 ± 0.21	2.3 ± 0.04	0.7 ± 0.00
14	Ado-M2W GDF	12.8 ± 0.33	2.0 ± 0.07	0.6 ± 0.04
15	Ado-M1Y GDF	12.0 ± 0.60	2.2 ± 0.0 4	0.6 ± 0.08
16	Ado-M2Y GDF	10.5 ± 0.32	2.1 ± 0.07	0.5 ± 0.00
b				
17	Edu-M1	65.5 ± 1.26*	0.50 ± 0.09*	0.4 ± 0.02
18	Edu-M2	68.2 ± 1.60*	0.80 ± 0.0 2*	0.3 ± 0.02
19	Ado-M1	64.5 ± 1.40*	0.60 ± 0.03*	0.5 ± 0.00
20	Ado-M2	66.10 ± 0.47*	0.50 ± 0.02*	0.4 ± 0.06

Figures indicated with the asterisks means that there is statistically significant difference ($p<0.05$) between them and the non-asterisked column. Results are mean of six samples. Edu-M1 = Edumoga Market 1, Edu-M2 = Edumoga Market 2; Ado-M1 = Adoka Market 1, Ado-M2 = Adoka Market 1; GDF = garri direct from frying; W = white garri; Y = yellow garri.

Table 2. Mean values of microorganisms isolated from the garri samples (a) and peeled cassava root tubers (b) (expressed as log CFU/g of garri).

Sample analysed	*E. coli*	*S. aureus*	*Salmonella* sp	*Shigella* sp	TCC	YMC	TVC
a							
Edu-M1W	1.00 ± 0.02	0.90 ± 0.01	0.30 ± 0.06	1.20 ± 0.03	1.00 ± 0.00	1.85 ± 1.01	2.00 ± 1.04
Edu-M2W	1.08 ± 0.09	1.15 ± 0.05	ND	ND	1.25 ± 0.03	1.79 ± 1.02.	2.15 ± 0.36
Edu-M1Y	ND	1.30 ± 0.40	ND	ND	1.38 ± 0.67	2.11 ± 0.8	2.18 ± 0.96
Edu-M2Y	ND	1.36 ± 0.06	1.00 ± 0.10	0.60 ± 0.00	1.46 ± 0.7	2.06 ± 1.00	2.20 ± 0.90
Ado-M1W	ND	1.00 ± 0.01	ND	ND	0.30 ± 0.01	1.92 ± 1.01	2.57 ± 1.16
Ado-M2W	1.04 ± 0.40	1.08 ± 0.86	0.30 ± 0.03	ND	1.75 ± 0.36	1.66 ± 0.64	2.60 ± 0.42
Ado-M1Y	ND	0.31 ± 0.00	ND	ND	1.04 ± 0.72	1.97 ± 0.60	2.23 ± 0.43
Ado-M2Y	0.90 ± 0.26	0.47 ± 0.30	ND	ND	1.36 ± 0.33	2.09 ± 0.72	2.56 ± 1.01
Edu-M1W GDF	ND	ND	ND	ND	ND	ND	ND
Edu-M2W GDF	0.70 ± 0.02	ND	ND	ND	1.38 ± 1.01	1.69 ± 1.06	1.78 ± 0.90
Edu-M1Y GDF	ND	ND	ND	ND	0.70 ± 0.60	0.30 ± 0.00	1.23 ± 1.06
Edu-M2Y GDF	ND	ND	ND	ND	ND	ND	1.65 ± 0.60
Ado-M1WGDF	ND	ND	ND	ND	1.18 ± 0.50	ND	1.47 ± 0.66
Ado-M2WGDF	ND	ND	ND	ND	1.56 ± 0.40	0.60 ± 0.05	1.83 ± 0.82
Ado-M1Y GDF	0.90 ± 0.00	ND	ND	ND	1.08 ± 0.22	ND	2.07 ± 0.18
Ado-M2Y GDF	ND	ND	ND	ND	ND	ND	ND

Table 2. Contd.

b							
Edu-M1	2.13 ± 1.01	1.98 ± 0.66	1.70 ± 0.80	2.33 ± 1.16	3.33 ± 1.07	3.10 ± 0.86	3.86 ± 0.40
Edu-M2	2.47 ± 0.10	2.38 ± 0.50	1.88 ± 0.45	ND	2.98 ± 1.23	3.56 ± 1.41	3.78 ± 1.61
Ado-M1	2.75 ± 0.22	1.36 ± 0.54	ND	2.88 ± 0.77	3.51 ± 1.04	2.82 ± 1.00	4.03 ± 0.86
Ado-M2	2.60 ± 0.60	2.51 ± 1.10	2.03 ± 0.77	2.75 ± 1.06	2.81 ± 1.04	1.64 ± 0.90	3.97 ± 1.16

TCC, Total coliform counts; YMC, yeast and mould counts; TVC, total viable counts. Edu-M1= Edumoga Market 1, Edu-M2 = Edumoga Market 2; Ado-M1 = Adoka Market 1, Ado-M2 = Adoka Market 1, ND = not detected in 1 g of gari or peeled cassava tuber, GDF = garri direct from frying; W = white garri; Y = yellow garri.

of a material. The low level of the organism is a pointer to its good quality and hygiene standard across the processing and distribution line. However, the recommended level of *E. coli* in a ready-to-eat food of this nature is <3 CFU/g for the food to be satisfactory (Millard and Rockliff, 2005).

In the present study, maximum *Staphylococcus aureus* isolated from garri of 1.85 log CFU/g and mean 1.36 (Table 2a and b) were significant enough to cause a health concern. *S. aureus* is a normal flora of human skin and nose horizontally transferred to the garri by processors and vendors. *S. aureus* is an important and major food-borne pathogen worldwide producing enterotoxins not digested by a protease, can withstand high heat treatments and a major contaminant of foodstuffs (Wu et al., 2016). Besides, toxigenic *S. aureus* contamination in ready-to-eat foods is the leading cause of food-borne illness in some countries of the world (Oh et al., 2007).

The levels of *Salmonella* and *Shigella* spp. isolated from garri in the present study were relatively low as compared to *E. coli* and *S. aureus*. Both *Salmonella* sp. and *Shigella* were not isolated in many of the samples (Table 2a and b). They were however isolated from peeled cassava root tubers used in garri production. Food safety guideline considers most ready-to-eat foods satisfactory if *Salmonella* and *Shigella* spp. are not detectable in 25 g of the food.

The mean total coliform count (TCC), mean yeast and mould count (YMC) and mean total viable count (TVC) indicate the mean levels of coliform, fungi and bacteria respectively in the product. These means as presented in Table 2a and b, ranging from minimum values of not detectable (in 1 g of garri or peeled cassava tuber) to 1.75, 2.11 and 2.60 log, CFU/g, respectively for processed ready-to-eat garri. The mean values of these organisms for cassava root tubers were 2.81 to 3.51, 1.64 to 3.56 and 3.78 to 4.03 log CFU/g, respectively. These values indicate that the food products are potentially problematic considering the recommended food safety limits. The use of TVC, TCC, and YMC as indices of measurement of food quality is a useful quantitative assay of microbial load and contamination.

The fungi isolated in this study included *Mucor*, *Aspergillus* and *Fusarium* spp. (results not shown). While *Mucor*, *Aspergillus* and *Fusarium* spp. can cause spoilage of the food and great economic loss, some *Aspergillus* spp. can produce mycotoxins. Mycotoxins are threats to global food security as well as to human health. Fungal species including *Aspergillus*, *Cladosporium, Fusarium*, *Mucor*, *Penicillium* and *Rhizopus* (Ekundayo, 1984; Ogugbue et al., 2011; Aguoru et al., 2014) had been isolated previously from garri. *Cladosporium, Penicillium* and *Rhizopus* were however not isolated in this study.

The presence of some selected heavy metals were investigated in this study and the presence of cadmium and chromium was not detect in any of the garri samples while lead, nickel and copper were the most abundant (Table 3). The highest values of lead, nickel and copper in the garri samples were 1.300 ± 0.0004, 0.448 ± 0.0021 and 0.274 ± 0.0002 mg/kg, respectively. These values were within the Codex Alimentarius Commission (2011) tolerable limits of some heavy metals (Table 4) in some food items. Mercury was detected in three gari samples with the highest value of 0.082 ± 0.0001 mg/kg. The mean values of lead, cadmium and chromium obtained from garri direct from frying in the present study, are similar to that reported by Dibofori-Orji and Edori (2015). The range of the permissible quantity of these metals in food items is as presented in Table 4.

Even though, heavy metals are naturally occurring in soils, heavy vehicular traffic accounts for a significant source of heavy metals in most of the roadside soils (Zakir et al., 2014; Dibofori-Orji and Edori, 2015). Similarly, Dibofori-Orji and Edori (2015) reported that lead and some heavy metals are emitted through the exhaust of motor vehicles. These metals are retained from the refining process of the crude oil (Dibofori-Orji and Edori, 2015). The argument is that since heavy vehicular traffic can deposit a significant amount of heavy metals on the roadside soils, ready-to-eat garri displayed uncovered and exposed for sale along busy roads could also have significant deposits. Other factors leading to heavy metals contamination could arise from the implements used in the processing of garri. Similarly, the increased use of fertilizers and other agrochemicals like insecticides and pesticides to increase crop production could also

Table 3. Heavy metal concentration in garri and cassava root tubers (mg/kg).

Sample analysed	Cu	Pb	Cd	Ni	Cr	Hg
Edu-M1W	0.274 ± 0.0002	1.057 ± 0.0007	ND	0.448 ± 0.0021	ND	ND
Edu-M2	0.225 ± 0.0005	0.772 ± 0.0006	ND	0.379 ± 0.0001	ND	ND
Edu-M1Y	0.219 ± 0.0032	1.223 ± 0.0007	ND	0.378 ± 0.0009	ND	0.002 ± 0.0001
Edu-M2Y	0.252 ± 0.0021	1.300 ± 0.0004	ND	0.404 ± 0.0005	ND	0.082 ± 0.0001
Ado-M1W	0.228 ± 0.0022	0.921 ± 0.0014	ND	0.382 ± 0.0005	ND	ND
Ado-M2W	0.207 ± 0.0003	0.889 ± 0.0014	ND	0.243 ± 0.0076	ND	ND
Ado-M1Y	0.335 ± 0.0002	0.214 ± 0.0008	ND	0.127 ± 0.0055	ND	ND
Ado-M2Y	0.054 ± 0.0001	0.192 ± 0.0010	ND	0.221 ± 0.0001	ND	0.004 ± 0.0001
Edu-M1W GDF	0.031 ± 0.0001	0.004 ± 0.0001	ND	ND	ND	ND
Edu-M2W GDF	0.012 ± 0.0003	ND	ND	ND	ND	ND
Edu-M1Y GDF	0.032 ± 0.0001	0.028 ± 0.0001	ND	0.153 ± 0.0032	ND	ND
Edu-M2Y GDF	ND	0.013 ± 0.0001	ND	0.042 ± 0.0001	ND	ND
Ado-M1W GDF	ND	0.007 ± 0.0001	ND	0.115 ± 0.0001	ND	ND
Ado-M2W GDF	0.093 ± 0.0001	ND	ND	ND	ND	ND
Ado-M1Y GDF	ND	ND	ND	ND	ND	ND
Ado-M2Y GDF	ND	ND	ND	ND	ND	ND
Edu-M1 Cassava root tubers	0.454 ± 0.0004	1.322 ± 0.0071	1.03 ± 0.0063	0.248 ± 0.0009	0.13 ± 0.0003	ND
Edu-M2 Cassava root tubers	1.200 ± 0.0009	2.781 ± 0.0027	0.42 ± 0.0008	0.544 ± 0.0009	ND	0.012 ± 0.0001
Ado-M1 Cassava root tubers	0.028 ± 0.0001	1.244 ± 0.0009	0. 27 ± 0.0003	0.192 ± 0.0005	ND	0.081 ± 0.0001
Ado-M2 Cassava root tubers	0.990 ± 0.0001	0.490 ±	0.55 ± 0.0002	0.562 ± 0.0008	0.012 ± 0.0001	ND

Edu-M1 = Edumoga Market 1, Edu-M2 = Edumoga Market 2; Ado-M1 = Adoka Market 1, Ado-M2 = Adoka Market 1, ND = not detected in 1 g of garri or peeled cassava tuber, GDF = garri direct from frying; W = white garri; Y = yellow garri.

Table 4. Tolerable limits of some heavy metals (mg/kg).

Heavy metal	Tolerable limits	Reference	Daily allowance	Reference
Pb	0.1 – 1.5	Codex Alimentarius Commission (2011)	0.30 mg/day	Dibofori-Orji and Edori (2015)
Cd	0.05 – 1.0	Codex Alimentarius Commission (2011)	1.59 µg/day	Dibofori-Orji and Edori (2015)
Cr	-	-	1.50 µg/day	Dibofori-Orji and Edori (2015)
Cu	0.1 – 1.0	Codex Alimentarius Commission (2011)	-	-
Ni	-	-	-	-
Hg	0.001 – 1.0	Codex Alimentarius Commission (2011).	-	-

release some heavy metals to the atmosphere and increase the health risks (Khan et al., 2009). In the same way, Khan et al. (2009) reported that industrial effluents and other anthropogenic activities contribute heavy metals to the environments.

Perhaps, one assumes that once the recommended levels of these metals are exceeded, they automatically cause a health hazard to man. However, health risk index (HRI) or the hazard quotient (HQ) needs to be quantified as the tolerable limit and the exposure quantity should be ascertained (Khan et al., 2009). Information on the quantity of the heavy metals transferred to a consumer is necessary. As garri is a ready-to-eat food product, the quantity of the heavy metal transferred to a consumer is directly proportional to both the quantity of garri consumed and that of the heavy metals therein. The present study is a quantitative approach and did not assess health risk due to the consumption of the product. However, using the health risk index formula adapted from Khan et al. (2009):

$$\text{Health Risk Index (HRI)} = \frac{\text{Daily intake of metals}}{\text{Reference oral dose}}$$

one extrapolates the risk assessment.

The safe limits by Codex Alimentarius Commission (2011) for Pb, Cd and Cu are 124 µg, 60 µg, and 3 mg, respectively. Sales of garri in properly packaged bags or plastic containers and preferably not along roadsides is recommended.

Conclusions

The measured physicochemical attributes, the ash

content and the concentrations of the heavy metals of garri were within the permissible limits. The values of the microorganisms indicate potential food safety problems which could be reduced by increased hygiene and food safety consciousness.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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