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Determination of the microbiological quality and proximate composition of fermented cassava food products sold in Ilorin-west local government area, Nigeria

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Abstract In the present study, the microbiological safety and the proximate analyses of five urban markets within Ilorin-West Local Government Area, Kwara State, Nigeria were carried out using standard protocols. The bacterial load of fermented staple products from cassava ranged from 0.1 to 10.9×10^5 CFU/g while the fungi and yeast content ranged from 1.1 to 8.2×10^5 CFU/g. The isolates of bacteria from all the markets include the following; *Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermis, Streptococus faecalis, Lactobacillus* species, *Acetobacter* spp.., *Bacillus cereus, Escherichia coli, Bacillus subtilis, Lactobacillus* species while the isolated fungi include *Fusarium oxysporium, Aspergillus niger, A.flavus, A. fumigatus, Saccharomyces cerevisae, Candida albicans, Penicillum spp., Rhizopus stolonifera, Mucor spp.*.The results of the proximate composition showed that moisture content of fermented staple products of cassava ranged from 6.21% (*garri* Ijebu from market A and *lebu* from market C) to 72.25% (*fufu* from market C) while dry matter content ranged between 27.75% (*Fufu* from market C) to 93.79% (*garri* Ijebu market A and *lebu* from market C). Ash content ranged from 0.23% (Tapioca from market A) to 1.96% (*lebu* from market A), crude fibre content ranged between 1.13% (*Fufu* from market C) and 5.28% (*Abacha* from market D), and the carbohydrate content of the fermented staple products from cassava ranged from 18.61% (*Fufu* from market C) to 81.44% (Tapioca from market A). Even though some potential pathogenic bacteria like *E.coli* and *Bacillus* were isolated from cassava fermented products, the minimum microbial load obtained could not impose any health risk.

Keywords: cassava, fermented products, microbial loads, proximate analysis.

1 Introduction

In Africa, cassava has been reported among the most crucial food (FAO, 1999), and Nigeria is the largest producer of cassava in the world (FAO, 2017). Oyewole (1991) stated that cassava root needs to be processed. Moreover, in Nigeria, majority of people prefer to consume cassava in fried, baked or in boiled form after fermenting the raw cassava crop.

Burns *et al.* (2012) stated that cassava root needs to be processed so as to remove available poisonous substances in the tuber. Examples of staple fermented foods obtained from processed cassava tuber include *garri, fufu, lafun, pupuru and tapioca* (Lancaster *et al*., 1982). Previous researchers discovered that diverse microorganisms are important in the process of fermenting the raw cassava root tuber including bacteria, yeasts and moulds (Tamang *et al.* 2016; Capozzi *et al.* 2017). Oyewole and Odunfa (1988) discovered that *Bacillus* spp., *Lactobacillus* spp., *Geotrichum* spp. and *Aspergillus* spp. were present in the fermentation of *lafun*. Moreover, Hahn (1989) discovered that several fungi including *Aspergillus* spp., *Penicillium* spp., *Mucor* spp., *Fusarium* spp., *Curvularia* spp. and *Cladosporium* spp. were isolated from *garri* during storage. Their study, therefore, necessitates the great need in ensuring the microbiological safety of the staple fermented foods obtained from processed cassava tuber. The quality of food defines the amount of available nutrients that could be derived from staple food products. Majorly, most of the fermented staple food obtained from cassava include *garri, fufu and lafun* (Oyewole and Odunfa 1988).

Garri, a dry food is largely consumed by most people from Africa without cooking and can be consumed with the addition of sweeteners (Oyewole *et al.* 2001). The preparation of *garri* includes the detaching of the root, washing, crushing, fermentation, removal of water and, roasting (Oyewole and Sanni 1995). *Fufu* is another major staple fermented food from cassava that is consumed by most people in Africa (Lancaster *et al.* 1982, Okafor *et al.* 1984, Sanni 1989, Longe 1990, Oyewole 1995), and the processing includes peeling, breaking into small sizes, soaking, pulping, screening, sedimentation, removal of water and production of cassava paste (Oyewole *et al.* 2001). The processing of *lafun* is almost similar to the preparation of *fufu* but the fermented cassava needs to be sun-dried and milled before consumption (Oyewole and Sanni 1995)

Therefore, the present study intends to establish the micro flora of these popular cassava products in Nigeria, and to determine their proximate content and microbiological safety to consumers. In addition, the obtained result will assist the policy makers in formulating necessary quality hazard, storage techniques as well as processing line necessary for the production of fermented staple food from cassava in Nigeria and West Africa at large.

2 Material and Methods

2.1 Reagents and test samples

All reagents used were of analytical grade obtained from SIGMA-ALDRICH, Germany and BDH, England. These include; sodium hydroxide pellets, tetraoxosulphate (VI) acid, boric acid, anhydrous sodium tetraoxosulphate (VI), copper tetraoxosulphate (VI) pentahydrate, selenium powder, hydrochloric acid and ethanol (95% v/v). All cassava products displayed in each markets were sampled using simple random sampling techniques, these include; white *garri* (white; cassava flake) yellow *garri* (yellow; cassava flake), '*lebu*' (fine cassava flake), '*garri Ijebu*'(another variety of cassava flake), '*igbodo*' (edible cassava flour, whole root), '*lafun*' (edible cassava flour, pelletized), tapioca (starch extract), '*fufu*' (a dough from cassava) and '*abacha*' (African salad). Five urban markets (designated as A, B, C, D and E) within Ilorin-West Local Government Area, Kwara State in Nigeria were used for sample collection. A total of 256 samples (A=70, B=57, C=50, D=55 and E=24) were collected from all the markets depending on their sizes and numbers of available sellers. Prior to analyses in the laboratory, each product was bulked together to give a representative sample from each market, after which 29 samples were obtained for microbiological and proximate analyses.

2.2 Determination of the proximate composition

Proximate analyses including moisture content, ash, and crude fibre were carried out on the fermented staple products from cassava samples following the AOAC (2000) methods while the total carbohydrates content was analyzed following the method described by Osborn and Vogt (1978). The dry matter content was calculated from moisture content (MC) using the relation;

$$\text{Dry matter (\%)} = 100 - \text{MC}$$

2.3 Microbiological analyses

Isolation of microorganisms

Five gram of the selected fermented staple products from cassava were weighed and mixed with 250 ml of sterilized normal saline followed by serial dilution. Aliquot (1 ml) from the resulting mixture was placed in a sterile petri dish using pour plate method in duplicate. Nutrient agar (Product of Hi MEDIA, Ref. MOO2-5005) was used for the determination of bacteria, incubated at 37^{o}C for 24–48 h while potato dextrose agar (Product of Hi MEDIA, Ref. GM096-500G) was used for the determination of fungus in the

samples, incubated at 27^{o}C for 48–72 h. They were procured from Lab trade Nigeria Ltd, Ilorin, Kwara State, Nigeria. The total number of available colonies obtained after incubation was counted and expressed in CFU/g. The pure cultures of the isolates were acquired by sub-culturing on newly prepared agar plates.

Identification of microbial isolates

The cultural and biochemical characteristics of the pure culture of the isolates obtained were enumerated using the protocol developed by Adetunji and Adejumo, 2017; Adetunji *et al.* (2012) and Uzeh *et al.* (2009). The following cultural, morphological and biochemical features was determined; cellular shape, colonial elevation, colonial edge, colonial opacity, colonial pigmentation, cellular arrangement Gram's staining, motility test, spore staining, capsule staining, catalase test, methyl red test, starch hydrolysis, citrate utilization, and oxygen reaction.

2.4 Statistical analysis of data

Results were expressed as mean ± SD of triplicates (n = 3) determinations. All data generated were analyzed by one-way analysis of variance (ANOVA) using the SPSS statistics for Windows version 20.0.0 (IBM SPSS Statistics, IBM Corporation 2011, Armonk, NY. USA). The means were separated using New Duncan Multiple Range Tests. Significance was accepted at 5% probability level ($p<0.05$).

3 Results and Discussion

The results of proximate composition (Table 1) showed that the moisture contents of fermented cassava food products from Ilorin-West urban markets ranged from 6.21% (*garri Ijebu* from market A and *lebu* from market C) to 72.25% (*fufu* from market C), while dry matter content ranged from 27.75% (*Fufu* from market C) to 93.79% (*Garri Ijebu* from market A and *Lebu* from market C). Ash contents ranged from 0.23% (Tapioca from market A) to 1.96% (*lebu* from market A), crude fibre content ranged from 1.13% (*Fufu* from market C) to 5.28% (*Abacha* from market D), the total available carbohydrate contents of the fermented cassava food products ranged from 18.61% (*Fufu* from market C) to 81.44 (Tapioca from market A).

Table 1: Proximate composition of fermented cassava food products sold in Ilorin-West urban markets, Nigeria (wet basis).

Market	Sample name	Moisture content (%)	Ash (%)	Crude fibre (%)	Carbohydrates (%)	Dry matter (%)
A	Yellow *garri*	9.45 ± 0.07 ^{gh}	1.39 ± 0.03 ^{efg}	1.51 ± 0.01 ^{n}	75.65 ± 0.32 ^{fg}	90.55 ± 0.07 ^{hi}
	White *garri*	8.83 ± 0.18 ^{ij}	1.88 ± 0.09 ^{ab}	1.78 ± 0.01 ^{k}	77.17 ± 0.54 ^{de}	91.17 ± 0.18 ^{g}
	Igbodo	8.38 ± 0.23 ^{jk}	1.52 ± 0.40 ^{cdef}	1.48 ± 0.08 ^{no}	76.81 ± 0.31 ^{ef}	91.63 ± 0.23 ^{f}
	Lafun	8.36 ± 0.11 ^{jk}	1.14 ± 0.05 ^{hi}	1.03 ± 0.05 ^{s}	77.27 ± 0.57 ^{de}	91.64 ± 0.11 ^{f}
	Lebu	6.69 ± 0.13 ^{op}	1.96 ± 0.16 ^{a}	1.39 ± 0.10 ^{p}	77.30 ± 0.66 ^{de}	93.31 ± 0.13 ^{b}
	Fufu	69.39 ± 0.59 ^{c}	0.80 ± 0.00 ^{j}	1.57 ± 0.03 ^{m}	23.44 ± 0.03 ^{o}	30.61 ± 0.59 ^{m}
	Gari ijebu	6.21 ± 0.10 ^{p}	1.79 ± 0.05 ^{abc}	1.57 ± 0.03 ^{m}	73.10 ± 0.33 ^{jk}	93.79 ± 0.10 ^{a}
	Tapioca	6.74 ± 0.49 ^{o}	0.25 ± 0.03 ^{m}	nd	81.44 ± 0.32 ^{a}	93.26 ± 0.49 ^{b}
B	Yellow *gari*	13.35 ± 0.06 ^{e}	1.03 ± 0.43 ^{ij}	1.64 ± 0.04 ^{l}	70.93 ± 0.57 ^{l}	86.65 ± 0.06 ^{k}
	White *garri*	9.01 ± 0.20 ^{hi}	1.47 ± 0.10 ^{efg}	3.69 ± 0.01 ^{c}	71.30 ± 0.58 ^{l}	90.99 ± 0.20 ^{gh}
	Igbodo	9.34 ± 0.20 ^{ghi}	1.62 ± 0.04 ^{cde}	2.65 ± 0.03 ^{e}	77.15 ± 0.55 ^{de}	90.66 ± 0.20 ^{hi}
	Lafun	9.76 ± 0.11 ^{g}	1.51 ± 0.06 ^{cdef}	2.09 ± 0.02 ^{h}	73.47 ± 2.50 ^{ijk}	90.24 ± 0.11 ^{i}
	Fufu	70.81 ± 0.57 ^{b}	0.53 ± 0.12 ^{k}	1.25 ± 0.05 ^{q}	21.04 ± 0.41 ^{p}	29.53 ± 0.01 ^{n}
	Tapioca	7.79 ± 0.35 ^{lm}	0.32 ± 0.01 ^{kl}	nd	80.85 ± 0.56 ^{a}	92.21 ± 0.35 ^{de}
C	Yellow *garri*	9.37 ± 0.55 ^{gh}	0.30 ± 0.02 ^{kl}	1.64 ± 0.05 ^{l}	68.75 ± 0.54 ^{m}	90.63 ± 0.55 ^{hi}
	White *garri*	11.40 ± 0.10 ^{f}	0.24 ± 0.05 ^{m}	3.94 ± 0.02 ^{b}	72.66 ± 0.59 ^{k}	88.60 ± 0.10 ^{j}
	Igbodo	8.35 ± 0.14 ^{jk}	1.60 ± 0.01 ^{cde}	2.63 ± 0.03 ^{e}	80.68 ± 0.57 ^{a}	91.65 ± 0.14 ^{f}
	Lafun	9.13 ± 0.36 ^{hi}	1.22 ± 0.04 ^{ghi}	2.43 ± 0.08 ^{g}	75.03 ± 1.14 ^{gh}	90.87 ± 0.36 ^{gh}
	Fufu	72.25 ± 0.40 ^{a}	0.49 ± 0.09 ^{kl}	1.13 ± 0.02 ^{r}	18.61 ± 0.02 ^{q}	27.75 ± 0.40 ^{o}
	Lebu	6.21 ± 0.17 ^{p}	1.59 ± 0.14 ^{cde}	1.83 ± 0.01 ^{jk}	78.07 ± 0.62 ^{cde}	93..79 ± 0.17 ^{a}
D	Yellow *garri*	8.28 ± 0.18 ^{kl}	1.65 ± 0.21 ^{bcde}	1.89 ± 0.01 ^{i}	74.77 ± 0.63 ^{ghi}	91.72 ± 0.18 ^{f}
	White *garri*	8.21± 0.15 ^{klm}	1.54 ± 0.06 ^{cdef}	3.65 ± 0.01 ^{c}	80.37 ± 0.85 ^{ab}	91.79 ± 0.15 ^{ef}
	Igbodo	7.27 ± 0.06 ^{n}	1.75 ± 0.07 ^{abcd}	2.55 ± 0.05 ^{f}	80.74 ± 0.32 ^{a}	92.73 ± 0.06 ^{c}
	Lafun	7.94 ± 0.14 ^{klm}	1.03 ± 0.06 ^{ij}	2.89 ± 0.02 ^{d}	74.46 ± 0.57 ^{ghij}	92.06 ± 0.14 ^{def}
	Abacha	9.00 ± 0.10 ^{hi}	0.32 ± 0.07 ^{kl}	5.28 ± 0.03 ^{a}	78.59 ± 0.33 ^{cd}	91.00 ± 0.10 ^{gh}
	Fufu	67.72 ± 0.29 ^{d}	0.28 ± 0.02 ^{kl}	1.86 ± 0.02 ^{ij}	28.18 ± 2.16 ^{n}	32.28 ± 0.29 ^{i}
E	White *garri*	7.72 ± 0.07 ^{mn}	1.48 ± 0.09 ^{defg}	1.66 ± 0.02 ^{l}	78.45 ± 0.32 ^{cd}	92.28 ± 0.07 ^{d}
	Igbodo	9.15 ± 0.08 ^{hi}	1.60 ± 0.01 ^{cde}	1.61 ± 0.03 ^{lm}	79.14 ± 0.31 ^{bc}	90.85 ± 0.08 ^{gh}
	Lafun	8.22 ± 0.55 ^{klm}	1.32 ± 0.27 ^{fgh}	1.43 ± 0.02 ^{op}	74.05 ± 0.87 ^{hijk}	91.78 ± 0.55 ^{ef}

*Means within the same column with unshared superscript letters are significantly different (P<0.05), nd= not detected.

The carbohydrate content obtained from white *garri* from market D had the highest value of 80.37 % among all the *garri* samples tested during this study. However, a higher carbohydrate content of 85.8 % was reported by Okolie *et al.* (2012), from *garri* samples sold in Lagos metropolis, Nigeria. The difference in the carbohydrate content might be due to the preliminary loss of soluble carbohydrate in the previous unit processing of the cassava tubers. The reduction in the carbohydrate content from the *garri* samples might also be due to the fact that the isolated microorganisms have the tendency to utilize the *garri* sample as source of carbon source for their usage and sustainability (Colehour *et al.* 2014, Oyeyiola *et al*. 2014). *Fufu* (market C) was significantly higher ($p<0.05$) in moisture content of 72.25 % than all the other fermented cassava food products. This is expected to be so because *fufu* is a wet product with rapid spoilage in 3 to 4 days. This same product (*fufu* from market C) was significantly ($p<0.05$) lower in crude fibre, total carbohydrates and dry matter contents.

During this study, *fufu* from market C recorded a higher moisture content of 72.25% compared to the moisture content of 58.80% recorded by Omosuli *et al.* (2017), from *fufu* prepared from cassava flour in their study. The different variation recorded in the moisture content of *fufu* from the various studies might be due to the fact that some level of transpiration occurs after the processing of cassava tubers into *fufu* (Ikujenlola and Opawale 2007). The variation in the moisture content observed from the various fermented cassava product might be due to their ability to absorb moisture during storage condition which consequently supports the colonization of these spoilage fungi as well as increases their deteriorative capabilities. The moisture absorbed by the fermented cassava products enhanced the biodegradability potential of these microorganisms (Jonathan *et al.* 2016).

The Nigerian Industrial standards (NIS) 1988, state that the moisture content of *garri* should not exceed 7% (w/w), ash content should not exceed 1.5% (w/w) and crude fibre should not exceed 2% (w/w) (Sanni *et al.* 2015). Only three *garri* products were within the stipulated limit and they are; *lebu* (market A and C) and *garri Ijebu* (market A). The NIS standards for cassava chips stipulate that the moisture content should not exceed 13% (w/w), crude fibre 2.0% maximum and ash content 3.0% maximum. The cassava chips samples in the present project (*lafun* I and II) showed some level of compliance to the NIS standards, except in a few cases where the crude fibre contents were above the maximum content of 2.0%, these are; *lafun* I (market B, C and D), *lafun* II (market B, C and D).

The results of microbiological characteristics of the fermented cassava food samples from Ilorin-West Local Government Urban markets is as shown in Table 2.

Table 2: Microbial load of fermented cassava food products sold from Ilorin-West urban markets (A-E), Nigeria (mean ± SD, n=3 samples; NA= Nutrient agar, PDA = Potato dextrose agar).

Market	Sample name	NA ($\times10^4$ cfu/g)	PDA ($\times10^5$ cfu/g)
A	Yellow *gari*	2.0 ± 0.1^{d}	1.9 ± 0.1^{f}
	White *gari*	1.9 ± 0.1^{de}	1.5 ± 0.8^{g}
	Igbodo	0.5 ± 0.0^{hi}	3.0 ± 0.1^{e}
	Lafun	0.3 ± 0.0^{ijkl}	5.0 ± 0.0^{c}
	Lebu	0.9 ± 0.1^{g}	3.0 ± 0.0^{e}
	Fufu	5.5 ± 0.1^{b}	1.0 ± 0.1^{gh}
	Gari ijebu	0.3 ± 0.0^{ijkl}	0.1 ± 0.0^{m}
	Tapioca	0.4 ± 0.1^{hijk}	1.0 ± 0.1^{gh}
B	Yellow *gari*	0.5 ± 0.1^{hi}	5.9 ± 0.1^{b}
	White *gari*	1.0 ± 0.0^{g}	3.1 ± 0.1^{e}
	Igbodo	0.2 ± 0.0^{lm}	2.0 ± 0.1^{f}
	Lafun	0.3 ± 0.0^{ijkl}	2.1 ± 0.1^{f}
	Fufu	0.8 ± 0.1^{g}	4.1 ± 0.2^{d}
	Tapioca	2.9 ± 0.1^{c}	5.2 ± 0.3^{c}
C	Yellow *gari*	0.9 ± 0.1^{g}	2.0 ± 0.0^{f}
	White *gari*	0.6 ± 0.1^{h}	1.1 ± 0.1^{gh}
	Igbodo	0.3 ± 0.1^{ijkl}	2.9 ± 0.1^{e}
	Lafun	0.2 ± 0.1^{klm}	8.2 ± 0.3^{a}
	Fufu	0.3 ± 0.1^{jklm}	0.9 ± 0.1^{h}
	Lebu gari	0.1 ± 0.0^{m}	2.0 ± 0.1^{f}
D	Yellow *gari*	0.3 ± 0.1^{jklm}	1.1 ± 0.1^{gh}
	White *gari*	2.0 ± 0.1^{d}	4.1 ± 0.1^{d}
	Igbodo	0.6 ± 0.1^{h}	1.2 ± 0.2^{gh}
	Lafun	5.4 ± 0.1^{b}	5.0 ± 0.1^{c}
	Fufu	10.9 ± 0.1^{a}	8.1 ± 0.1^{a}
	Abacha	10.8 ± 0.0^{a}	6.0 ± 0.1^{b}
E	White *gari*	1.8 ± 0.1^{e}	6.1 ± 0.1^{b}
	Igbodo	0.5 ± 0.1^{hij}	4.0 ± 0.1^{d}
	Lafun	1.3 ± 0.1^{f}	6.1 ± 0.1^{b}

*Means within the same column with unshared superscript letters are significantly different ($P<0.05$)

The bacterial load of fermented food samples ranged from $0.1–10.9\times10^4$ CFU/g, while the fungi and yeast ranged $1.1–8.2\times10^5$ CFU/g. The highest bacterial load was observed from market D from *Lafun* with microbial loads of $5.4\pm 0.1\times10^4$ CFU/g, while the lowest was observed from market C from *Lebu garri* with bacterial counts of $0.1\pm0.0\times10^4$ CFU/g (Table 2). The bacterial load observed during this study were of lower value when compared with the findings of Adebayo-Oyetoro *et al.* (2013), who reported a bacterial load of 8.1×10^6 CFU/g from the fermented cassava flour sampled from the different market during their study. Also, the fungi and yeast count found during this study showed a lower value when compared to the value of 3.5×10^6 CFU/g observed by Oyeyiola *et al.* (2014), from fermented cassava food products sold in Oyo town, Oyo State, Nigeria.

Table 3:

Market	Samples	Cellular shape (R: Rod, C: Cocci)	Colonial elevation (R: Raised, F: Flat)	Colonial edge (E: Entire, L: Lobate)	Colonial opacity (T: Translucent, O: Opaque)	Colonial surface (S: Smooth, R: Rough, D: Dull)	Colonial pigmentation (Y: Yellow, C: Cream, CW: Creamy white, YC: yellowish cream, W: White)	Cellular arrangement (C: Chain, CL: Clusters, S: Single)	Gram's staining	Motility test	Spore staining	Capsule staining	Catalase test	Methyl red test	Starch hydrolysis	Citrate utilization	Oxygen reaction	Action on simple carbohydrates					probable microorganism
																		Lactose	Glucose	Sucrose	Maltose	Fructose	
A	Yellow *garri*	R	R	E	T	S	YC	C	-	+	-	-	-	+	-	-	AE	-	A	A	A	AG	*Pseudomonas aeruginosa*
	White *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*Staphylococcus aureus*
	Igbodo	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Lafun	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Lebu	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
	Fufu	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*Streptococcus faecalis*
	Garri ijebu	R	R	L	O	S	CW	CL	+	-	-	-	-	-	-	-	FAN	A	A	A	A	AG	*Lactobacillus sp*
	Tapioca	R	R	L	T	R	C	S	-	-	-	-	-	-	-	-	AN	A	A	-	-	-	*Acetobacter sp*
B	Yellow *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	White *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
	Igbodo	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Lafun	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
	Fufu	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*Streptococcus faecalis*
	Tapioca	R	R	L	T	D	C	C	+	+	+	+	+	+	+	-	AE	-	AG	A	AG	AG	*Bacillus cereus*

Continued..

Table 3 Continued.

Market	Samples	Cellular shape (R: Rod, C: Cocci)	Colonial elevation (R: Raised, F: Flat)	Colonial edge (E: Entire, L: Lobate)	Colonial opacity (T: Translucent, O: Opaque)	Colonial surface (S: Smooth, R: Rough, D: Dull)	Colonial pigmentation (Y: Yellow, C: Cream, CW: Creamy white, YC: yellowish cream, W: White)	Cellular arrangement (C: Chain, CL: Clusters, S: Single)	Gram's staining	Motility test	Spore staining	Capsule staining	Catalase test	Methyl red test	Starch hydrolysis	Citrate utilization	Oxygen reaction	Action on simple carbohydrates					probable microorganism
																		Lactose	Glucose	Sucrose	Maltose	Fructose	
C	Yellow *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	White *garri*	R	R	E	T	S	C	C	-	-	-	+	-	-	+	+	FAN	-	-	AG	AG	AG	*E.coli*
	Igbodo	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Lafun	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
	Fufu	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Lebu garri	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
D	Yellow *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	White *garri*	R	F	L	O	D	W	CL	+	+	+	+	+	+	-	-	FAN	AG	A	A	A	A	*Bacillus subtilis*
	Igbodo	R	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*Streptococus faecalis*
	Lafun	R	R	E	T	S	C	C	-	-	-	+	-	-	+	+	FAN	-	-	AG	AG	AG	*E.coli*
	Fufu	R	R	L	O	S	CW	CL	+	-	-	-	-	-	-	-	FAN	A	A	A	A	AG	*Lactobacillus* sp
	Abacha	R	R	E	O	S	Y	S	-	+	-	-	-	-	-	-	FAN	-	A	A	A	A	*Salmonella spp.*
E	White *garri*	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*
	Igbodo	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. epidermis*
	Lafun	C	R	E	O	S	CW	CL	+	-	-	-	+	-	+	+	FAN	AG	A	A	A	-	*S. aureus*

The isolates of bacteria from all the market included *Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermis, Streptococcus faecalis, Lactobacillus* species, *Acetobacter* spp., *Bacillus cereus, E. coli, Bacillus subtilis, Lactobacillus* spp. (Table 3). The isolated microorganisms present in the fermented cassava food product have also been observed by Ogiehor and Ikenebomeh (2005). This might be resulting from processing and poor handling practices where these products are sold and can further increase microbial hazards from food products from cassava (Oyeyiola *et al.* 2014). It was observed that *Staphylococcus* spp. was isolated from all the markets, and similar trends have been reported earlier by researchers that had worked on different varieties of *Garri* from Nigeria (Ogiehor *et al.* 2007, Adetunji *et al.* 2012, Olopade *et al.* 2014). They are normally associated with individual hygiene of the people who handle them in market places. *(*Aboloma 2008, Oyeyi and Lum-nwi 2008, Shamsuddeen and Ameh 2008, Wada-kura *et al.* 2009). Kim *et al.* (2009) also discovered that *P. aeruginosa*, an opportunistic pathogen, which is responsible for bacteremia and gastrointestinal infections in affected individuals. *E. coli* has been documented to be responsible for diarrhoea in human being (Nweze 2010). Some *Bacillus* spp. are known to be accountable for food poisoning and their presence as a biological hazard in *garri* products which are consumed raw have raised many concerns with cassava products (Aboloma 2008).

The isolated fungi included *Fusarium oxysporium, Aspergillus niger, A. flavus, A. fumigatus, Saccharomyces cerevisae, Candida albicans, Penicillum* spp., *Rhizopus stolonifera* and *Mucor* spp. (Table 4 and 5). Some of the isolated fungi were identified to be spoilage inducing on foods during storage (Homer *et al.* 1994). The microbiological attributes of the raw cassava to be processed should be clean and of good quality. The usage of starter cultures that have antimicrobial properties with the capability to detoxify, in addition to sustaining adequate and clean surrounding is recommended. Also, sterilised packaging material should be used in packing the processed fermented food from cassava (Ikujenlola and Opawale 2007).

The presence of fungi on various fermented cassava food products examined during this study might be due to the fact that the environmental condition favors their rate of sporulation (Olopade *et al.* 2014). Also, Oranusi and Braide (2012), reported in their study that some fungus species like *Penicillium, Fusarium,* and *Aspergillus* isolated from different samples during this study could produce poisonous substances which may be toxigenic when exposed to a favorable environmental condition. The occurrence of *Aspergillus* species found in most of the fermented cassava food products from all the markets during this study might be due to the various methods used in the cassava processing. The same observations was reported by

Jonathan *et al.* (2017) who discovered the presence of *Aspergillus* species from cassava products.

Table 4: Distribution of different isolated fungus from fermented cassava food products sold from Ilorin-West urban markets, Nigeria.

Market	Sample name	Distribution of fungus from different market
A	Yellow *garri*	*Fusarium spp., Mucor spp., A. niger, Saccharomyces spp., A. fumigatus*
	White *garri*	*Rhizopus spp., Penicillum spp., Aspergillus spp.*
	Igbodo	*Aspergillus niger, A. fumigatus, Fusarium spp., Mucor spp.*
	Lafun	*Aspergillus niger, A. flavus, Rhizopus spp., Penicillum spp., Mucor spp.*
	Lebu	*Fusarium spp., Rhizopus spp., Penicillum spp., Aspergillus spp.*
	Fufu	*Saccharomyces spp., Candida spp.*
	Garri ijebu	*A. niger, Saccharomyces spp., A. fumigatus, Mucor spp.*
	Tapioca	*Rhizopus spp., Penicillum spp., Aspergillus spp., Fusarium spp.*
B	Yellow *garri*	*Aspergillus niger, A. fumigatus, Penicillum spp., Fusarium spp.*
	White *garri*	*Penicillum spp., Aspergillus spp., Mucor spp.*
	Igbodo	*Aspergillus niger, A. flavus, Rhizopus spp., Penicillum spp.*
	Lafun	*Penicillum spp., Aspergillus spp., Fusarium spp.*
	Fufu	*Saccharomyces spp., Candida spp., Aspergillus niger*
	Tapioca	*Penicillum spp., Aspergillus spp., Fusarium spp., Saccharomyces spp.*
C	Yellow *garri*	*Mucor spp., Saccharomyces spp., Aspergillus fumigatus*
	White *garri*	*Rhizopus spp., Penicillum spp., Aspergillus spp.*
	Igbodo	*Mucor spp., Aspergillus niger, A. fumigatus, Fusarium spp.,*
	Lafun	*Aspergillus flavus, Rhizopus spp., Penicillum spp., Mucor spp.*
	Fufu	*Saccharomyces spp., Candida spp.*
	Lebu garri	*Rhizopus spp., Penicillum spp., Aspergillus spp.*
D	Yellow *garri*	*Aspergillus fumigatus, Mucor spp., A. niger*
	White *garri*	*Fusarium spp., Penicillum spp., Aspergillus spp., Mucor spp.*
	Igbodo	*Aspergillus niger, A. fumigatus, Fusarium spp., Mucor spp.*
	Lafun	*Rhizopus spp., Penicillum spp.*
	Fufu	*Saccharomyces spp., Candida spp.*
	Abacha	*Aspergillus fumigatus, A. niger, Saccharomyces spp., Mucor spp.*
E	White *garri*	*Rhizopus spp., Penicillum spp., Aspergillus spp.*
	Igbodo	*Aspergillus flavus, Rhizopus spp., Penicillum spp.*
	Lafun	*Aspergillus flavus, Rhizopus spp., Penicillum spp.*

4 Conclusions

This study has established the microbiological quality and proximate composition of fermented cassava food products sold in Ilorin-west local government area, Nigeria. During this study, various pathogenic microorganisms constituting biological hazards were highlighted from different markets where fermented cassava food products were surveyed. Therefore, there is a need to prevent these foods from contaminants especially the biological hazards from air and during processing stages. The seller should wear gloves during production and sales. More studies with applications of modern techniques that involve utilization of nanotechnology and irradiation for preservation of fermented foods are required to ensure food safety further.

Table 5: Cultural and morphological characterization of the isolated fungi from fermented cassava food products sold from Ilorin-West urban markets, Nigeria.

Description	Probable fungus
Colonies have aerial mycelium with whitish or peach colour; Conidiophores are usually short branched on phialides.	*Fusarium oxysporium*
The colony usually contains black conidiophore. Conidial heads, radiate. Conidiophore stipe smooth-walled, hyaline but often in brown colour. Vesicles globose to sub-globose.	*Aspergillus niger*
Colonies have yellow-green conidiophores. Conidiophores have stipes with smooth-walled hyaline but often in brown colour.	*Aspergillus flavus*
Colonies have dense felt of yellow-green conidiophores. Conidia heads typically radiate latter splitting in several loose columns, yellow-green becoming dark yellow-green. Sclerotia are brown to black.	*Aspergillus fumigatus*
Colonies extent quickly and developed within three days. They have flat, moist, glittering or dull, and cream in color. Blastoconidia are present.	*Saccharomyces cerevisae*
Colonies are whitish-cream in color, smooth, glabrous and yeast-like in appearance. Presence of spherical to sub spherical blastoconidia.	*Candida albicans*
Colonies grow and sporulate with yellow or brown-green conidiophores with 3-6 phalides. Phalides often solitary, cylindrical with a short neck.	*Penicillum spp.*
Colonies have whitish color becoming grayish-brownish. Sporangiophores are colourless to dark brown, rough-walled stolons opposite the branched rhizoids. It has sporangia with sub-globose, ovoid, with blackish-brown color at maturity.	*Rhizopus stolonifera*
The colony was white and woolly. The hypha were thick and non-septate, columella were round. The sporagiopores departs laterally from mycelium, the sporangia were filled with spores.	*Mucor spp.*

Good agricultural and manufacturing practices should be encouraged during post-harvest, processing, and marketing of raw cassava crop. The food processor should adopt good and general hygiene and apply HACCP during production of fermented cassava food products. The local cassava processing centers should encourage the usage of standard operating procedure (SOP) to minimize the level of biological hazards and any available contamination from the raw material and the environment.

References

AOAC. 2000. Official Methods of Analysis of AOAC International, 17th ed. Published by the Association of Official of Analytical Chemists International Suite 400 2200, Wilson Boulevard, Arlington, Virginia 22201-3301 USA.

Aboloma RI. 2008. Microbiological analysis of bread samples from bakery to sale points in Ado-Ekiti, Ekiti State, Nigeria. *Biological and environmental sciences journal for the tropics* 5(3): 77 – 81.

Adetunji CO, Adejumo IO. 2017. Nutritional assessment of mycomeat produced from different agricultural substrates using wild and mutant strains from *Pleurotus sajor-caju* during solid state Fermentation. *Animal Feed Science and Technology* 224:14-19. 10.1016/j.anifeedsci.2016.12.004

Adetunji CO, Olaleye OO, Fawole OB, Williams JO, Oloke JK, Adetunji JB, Kazeem MO. 2012. Microbiology and moisture content studies of Gari stored in two different packaging materials. *Science Focus* 17(1):110-115.

Adebayo-Oyetoro AO, Oyewole OB, Obadina AO, Omemu MA. 2013. Microbiological safety assessment of fermented cassava flour ''*lafun*'' available in Ogun and Oyo States of Nigeria. *International Journal of Food Science* http://dx.doi.org/10.1155/2013/845324

Burns AE, Gleadow RM, Zacarias AM, Cuambe CE, Miller RE, Cavagnaro TR. 2012. Variations in the chemical composition of cassava (*Manihot esculenta Crantz*) leaves and roots as affected by genotypic and environmental variation. *Journal of Agricultural and Food Chemistry* 60: 4946−4956. dx.doi.org/10.1021/jf2047288.

Capozzi V, Fragasso M, Romaniello R, Berbegal C, Russo P, Spano G. 2017. Spontaneous Food Fermentations and Potential Risks for Human Health. *Fermentation* 3(49): 1-19. doi: 10.3390/fermentation3040049

Colehour AM, Meadow JF, Liebert MA, Cepon-Robins TJ, Gildner TE, Urlacher SS, Bohannan BJM, Snodgrass JJ, Lawrence SS. 2014. Local domestication of lactic acid bacteria via cassava beer fermentation. *Peer J* 2: e479; 1-18. DOI 10.7717/peerj.479.

FAO. 1999. FAO world book. Food and Agricultural Organization of the United Nations, Rome.

FAO. 2017. FAO in Nigeria, Nigeria at a glance. Accessed on November 17, 2017. http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/

Hahn SK. 1989. An overview of Africa traditional cassava processing utilization. *Outlook on Agriculture* 18: 110 – 118.

Homer WE, Lehrer SB, Salvaggio JE, Banks DE, Weissmmanb DN. 1994. 'Fungi'. Indoor air pollution: an allergy perspective. *Immunology and Allergy Clinics of North America* 14: 551 – 566.

Ikujenlola AV, Opawale BO. 2007. Effects of processing on the yield and physico-chemical properties of cassava products. *Advanced Material Research*, 18: 165 -170.

Jonathan SG, Adeniyi MA, Asemoloye MD. 2016. Nutrient value, fungal biodeterioration and aflatoxin contamination of suya spices a novel Nigerian indigenous snack. Hindawi - Scientifica 2016: ID 4602036.

Jonathan SG, Bello TS, Asemoloye MD. 2017. Food values, spoilage moulds and aflatoxin detection in 'Attiéké' (A Cassava Fermented Product*). Journal of Microbial* and *Biochemical Technology* 9:244-248. doi: 10.4172/1948-5948. 1000372.

Kim KY, Kimb HT, Kim D, Nakajimad J, Higuchi T. 2009. Distribution characteristics of airborne bacteria and fungi in the feedstuff manufacturing factories. *Journal of Hazardous Materials* 169: 1054 – 1060 pp.

Lancaster PA, Ingram JS, Lim MY, Coursey DG. 1982. Traditional fermented staple products from cassava foods; survey of processing techniques. *Economic Botany* 36(1): 12 – 48 pp.

Longe OG. 1990. Effects of processing on the chemical composition and energy value of cassava. *Nutrition Reports International* 21(6): 819 – 828 pp.

Nigerian Industrial Standard. 1988. Standard for *garri*. Standard Organization of Nigeria. Federal Ministry of Industries, Lagos 10.

Nweze EI. 2010. Aetiology of Diarrhoea and Virulence Properties of Diarrhoea genic *Escherichia coli* among Patients and Healthy Subjects in Southeast Nigeria. *Journal* of *Health*, *Population* and *Nutrition* 28 (3): 245 – 252 pp.

Ogiehor IS, Ikenebomeh MJ. 2005. Extension of shelf life of gari by hygienic handling and sodium benzoate treatment. *African Journal of Biotechnology* 4(7): 744 – 748 pp.

Ogiehor IS, Ikenebomeh MJ, Ekundayo AO. 2007. The bioload and aflatoxin content of market *garri* from some selected states in southern Nigeria: public health significance. *African Health Sciences* 7(4): 223–227.

Okafor N, Ijioma B, Oyolu C. 1984. Studies of Microbiology of cassava retting for foo-foo production. *Journal of Applied Bacteriology* 56(1): 1 – 13.

Okolie NP, Brai M, Natoyebi OM. 2012. Comparative study on some selected *garri* samples sold in Lagos metropolis. *Journal of Food Studies* 1(1):1-10.

Olopade BK, Oranusi S, Ajala R, Olorunsola SJ. 2014. Microbiological quality of fermented Cassava (Gari) sold in Ota Ogun State Nigeria. *International Journal of Current Microbiology* and *Applied* Sciences 3(3): 888-895.

Omosuli SV, Ikujenlola AV, Abisuwa AT. 2017. Quality assessment of stored fresh Cassava Roots and '*fufu*' flour produced from stored roots. *Journal of Food Science and Nutrition Therapy* 3(1): 9-13.

Oranusi US, Braide W. 2012. A study of microbial safety of ready-to eat foods vended on highways: Onitsha-Owerri, south east Nigeria. *International Research Journal of Microbiology* 32: 66-71.

Oyewole OB, Odunfa SA. 1988. Microbiological studies on Cassava fermentation for *lafun* Production. *Food Microbiology* 5: 125 – 133.

Oyewole OB, Sanni O, Dipeolu AO, Adebayo K, Ayinde IA, Pearce DM, White JL, Tomlins K, Westby A. 2001. Improved processing technology for the fermentation of cassava to *fufu*. 11th World Congress of Food Technologists. Seoul, Korea. April 23-27.

Oyewole OB, Sanni LO. 1995. Constraints in traditional cassava processing: A case of 'fufu' production. *In*: Transformation Alimentaire Du Manioc (Cassava Food Processing). Editors: Tom Agbor Egbe, AlainBrauman, Dany Griffon, Serge Treche. Institut Francais de Recherche Scientifique Pour le Development en Cooperation (ORSTOM), Paris, France. ISBN 2-7099-1279-1. pp. 523-529.

Sanni MO. 1989. The mycoflora of gari. *Journal of Applied Bacteriology* 67: 239 – 242.

Sanni LA, Odukogbe OO, Faborode MO, Ibrahim RO. 2015. Optimization of process parameters of a conductive rotary dryer for *garri* production. *In*: Proceedings of International Conference on National Capacity Building Strategy for Sustainable Development and Poverty Alleviation. 26 – 28 May 2015. Cr1006, Block 10, The American University in the Emirates, Dubai, UAE. 527-532.

Oyeyi TI, Lum-nwi MEF. 2008. Bacteriological quality of some street ended foods in Bayero University campuses, Kano, Nigeria. *Biological and environmental sciences journal for the tropics* 5(4): 239 – 243.

Oyeyiola GP, Oyeniyi OR, Arekemase MO, Ahmed RN. 2014. A comparative study on the microbiological and nutritional properties of stored chips and flours. *World Journal of Biological Research* 6(2):1-6.

Shamsuddeen U, Ameh JB. 2008. Survey on the possible critical control points during the production of 'balangu' in Kano. *Bayero Journal of Pure and Applied* Sciences, 1(1): 76 – 79.

Tamang JP, Watanabe K and Holzapfel WH .2016. Review: Diversity of Microorganisms in Global Fermented Foods and Beverages. *Frontiers in microbiology* 7:377. doi: 10.3389/fmicb.2016.00377.

Uzeh RE, Alade FA, Bankole M. 2009. The microbial quality of pre-packed mixed vegetable salad in some retail outlets in Lagos, Nigeria. African Journal of Food Science 3(9): 270 – 272.

Wada-kura A, Maxwell RG, Sadiq H-Y, Tijjani MB, Abdullahi IO, Aliyu MS, Adetunji OA. 2009. Microbiological quality of some ready-to-eat foods and fomites in some cafeterias in Ahmadu Bello University, Zaria. *Biological and environmental sciences journal for the tropics* 6(1): 6 – 9 pp.