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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Received: 19th September 2017, Revised: 21st November 2017, Accepted: 25th December 2017

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 $10.9 \times 10^5$ CFU/g while the fungi and yeast content ranged from 1.1 to $8.2 \times 10^5$ CFU/g. The isolates of bacteria from all the markets include the following: Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermis, Streptococcus 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, Penicillium 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 from 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;

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\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°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°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      | 1.39 ± 0.03 | 1.51 ± 0.01 | 75.65 ± 0.32 | 90.55 ± 0.07 |
|         | White garri | 8.83 ± 0.18      | 1.88 ± 0.09 | 1.78 ± 0.01 | 77.17 ± 0.54 | 91.17 ± 0.18 |
|         | Igbodo      | 8.38 ± 0.23      | 1.52 ± 0.40 | 1.48 ± 0.08 | 76.81 ± 0.31 | 91.63 ± 0.23 |
|         | Lafun       | 8.36 ± 0.11      | 1.14 ± 0.05 | 1.03 ± 0.05 | 77.27 ± 0.57 | 91.64 ± 0.11 |
|         | Igbodo      | 6.69 ± 0.13      | 1.96 ± 0.16 | 1.39 ± 0.10 | 77.30 ± 0.66 | 93.31 ± 0.13 |
|         | Fufu        | 69.39 ± 0.59     | 0.80 ± 0.00 | 1.57 ± 0.03 | 23.44 ± 0.03 | 30.61 ± 0.59 |
|         | Gari ijobo  | 6.21 ± 0.10      | 1.79 ± 0.05 | 1.57 ± 0.03 | 73.10 ± 0.33 | 93.79 ± 0.10 |
|         | Tapiaoca    | 6.74 ± 0.49      | 0.25 ± 0.03 | 0.25 ± 0.03 | 74.44 ± 0.32 | 93.26 ± 0.49 |
| B       | Yellow garri | 13.35 ± 0.06     | 1.03 ± 0.43 | 1.64 ± 0.04 | 70.93 ± 0.57 | 86.65 ± 0.06 |
|         | White garri | 9.01 ± 0.20      | 1.47 ± 0.10 | 3.69 ± 0.01 | 71.30 ± 0.58 | 90.99 ± 0.20 |
|         | Igbodo      | 9.34 ± 0.20      | 1.62 ± 0.04 | 2.65 ± 0.03 | 77.15 ± 0.55 | 90.66 ± 0.20 |
|         | Lafun       | 9.76 ± 0.11      | 1.51 ± 0.06 | 2.09 ± 0.02 | 73.47 ± 2.50 | 90.24 ± 0.11 |
|         | Fufu        | 70.81 ± 0.57     | 0.53 ± 0.12 | 1.25 ± 0.05 | 21.04 ± 0.41 | 29.53 ± 0.01 |
|         | Tapiaoca    | 7.79 ± 0.35      | 0.32 ± 0.01 | nd             | 80.85 ± 0.56 | 92.21 ± 0.35 |
| C       | Yellow garri | 9.37 ± 0.55      | 0.30 ± 0.02 | 1.64 ± 0.05 | 68.75 ± 0.54 | 90.63 ± 0.55 |
|         | White garri | 11.40 ± 0.10     | 0.24 ± 0.05 | 3.94 ± 0.02 | 72.66 ± 0.59 | 88.60 ± 0.10 |
|         | Igbodo      | 8.35 ± 0.14      | 1.60 ± 0.01 | 2.63 ± 0.03 | 80.68 ± 0.57 | 91.65 ± 0.14 |
|         | Lafun       | 9.13 ± 0.36      | 1.22 ± 0.04 | 2.43 ± 0.08 | 75.03 ± 1.14 | 90.87 ± 0.36 |
|         | Fufu        | 72.25 ± 0.40     | 0.49 ± 0.09 | 1.13 ± 0.02 | 18.61 ± 0.02 | 27.56 ± 0.40 |
|         | Lebu        | 6.21 ± 0.17      | 1.59 ± 0.14 | 1.83 ± 0.01 | 78.07 ± 0.62 | 93.79 ± 0.17 |
| D       | Yellow garri | 8.28 ± 0.18      | 1.65 ± 0.21 | 1.89 ± 0.01 | 74.77 ± 0.63 | 91.72 ± 0.18 |
|         | White garri | 8.21 ± 0.15      | 1.54 ± 0.06 | 3.65 ± 0.01 | 80.37 ± 0.85 | 91.79 ± 0.15 |
|         | Igbodo      | 7.27 ± 0.06      | 1.75 ± 0.07 | 2.55 ± 0.05 | 80.74 ± 0.32 | 92.73 ± 0.06 |
|         | Lafun       | 7.94 ± 0.14      | 1.03 ± 0.06 | 2.89 ± 0.02 | 74.46 ± 0.57 | 92.06 ± 0.14 |
|         | Abacha      | 9.00 ± 0.10      | 0.32 ± 0.07 | 5.28 ± 0.03 | 78.59 ± 0.33 | 91.00 ± 0.10 |
|         | Fufu        | 67.72 ± 0.29     | 0.28 ± 0.02 | 1.86 ± 0.02 | 28.18 ± 2.16 | 32.28 ± 0.29 |
| E       | White garri | 7.72 ± 0.07      | 1.48 ± 0.09 | 1.66 ± 0.02 | 78.45 ± 0.32 | 92.28 ± 0.07 |
|         | Igbodo      | 9.15 ± 0.08      | 1.60 ± 0.01 | 1.61 ± 0.03 | 79.14 ± 0.31 | 90.85 ± 0.08 |
|         | Lafun       | 8.22 ± 0.55      | 1.32 ± 0.27 | 1.43 ± 0.02 | 74.05 ± 0.87 | 91.78 ± 0.55 |

*Means within the same column with unshared superscript letters are significantly different (P<0.05), nd= not detected.
The carbohydrate content obtained from white *gari* from market D had the highest value of 80.37 % among all the *gari* samples tested during this study. However, a higher carbohydrate content of 85.8 % was reported by Okolie *et al.* (2012), from *gari* 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 *gari* samples might also be due to the fact that the isolated microorganisms have the tendency to utilize the *gari* 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* (Ikujeniola 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 *gari* 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 *gari* products were within the stipulated limit and they are; *lebu* (market A and C) and *gari 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.
The bacterial load of fermented food samples ranged from 0.1–10.9×10⁴ CFU/g, while the fungi and yeast ranged 1.1–8.2×10⁵ CFU/g. The highest bacterial load was observed from market D from *Lafun* with microbial loads of 5.4± 0.1×10⁴ CFU/g, while the lowest was observed from market C from *Lebu garri* with bacterial counts of 0.1±0.0×10⁴ 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 8.1×10⁶ 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 3.5×10⁶ CFU/g observed by Oyeyiola *et al.* (2014), from fermented cassava food products sold in Oyo town, Oyo State, Nigeria.

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### 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 (×10⁴ cfu/g) | PDA (×10⁵ 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  f    |
|        | Igbodo        | 0.5 ± 0.0 hi   | 3.0 ± 0.1 e     |
|        | Lafun         | 0.3 ± 0.0 ijkf | 5.0 ±0.0 c      |
|        | Lebu          | 0.9 ± 0.1 f    | 3.0 ± 0.0 e     |
|        | Fufu          | 5.5 ± 0.1 b    | 1.0 ± 0.1 gh    |
|        | Gari ijebo    | 0.3 ± 0.0 ijkf | 0.1 ± 0.0 m     |
|        | Tapioca       | 0.4 ± 0.1 hjk  | 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 c     |
|        | Igbodo        | 0.2 ± 0.0 lm   | 2.0 ± 0.1 f     |
|        | Lafun         | 0.3 ± 0.0 ijkf | 2.1 ± 0.1 f     |
|        | Fufu          | 0.8 ± 0.1 ef   | 4.1 ± 0.2 d     |
|        | Tapioca       | 2.9 ± 0.1 c    | 5.2 ± 0.3 c     |
| C      | Yellow gari   | 0.9 ± 0.1 ef   | 2.0 ± 0.0 f     |
|        | White gari    | 0.6 ± 0.1 h    | 1.1 ± 0.1 gh    |
|        | Igbodo        | 0.3 ± 0.1 ijkf | 2.9 ± 0.1 c     |
|        | Lafun         | 0.2 ± 0.1 klm  | 8.2 ±0.3 a      |
|        | Fufu          | 0.3 ± 0.1 jkln | 0.9 ± 0.1 h     |
|        | Lebu gari     | 0.1± 0.0 jklm  | 2.0 ± 0.1 f     |
| D      | Yellow gari   | 0.3 ± 0.1 jkln | 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 c    | 6.1 ± 0.1 b     |
|        | Igbodo        | 0.5 ± 0.1 hjk  | 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)
Table 3:

| Market Samples | Cellular shape (R: Rod, C: Cocci) | Colonial elevation (R: Raised, F: Flat) | Colonial opacity (T: Translucent, O: Opaque) | Colonial arrangement (C: Chain, CL: Clusters, S: Single) | 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 |
|----------------|----------------------------------|----------------------------------------|---------------------------------------------|------------------------------------------------|------------------------------------------------|----------------|---------------|----------------|----------------|--------------|----------------|----------------------|---------------------|----------------|---------------------------------|--------------------------|
| A Yellow garri | R                                | R                                      | T                                          | S                                           | YC C                                         | + + - - - + - - + - AE | A A A AG       | Pseudomonas aeruginosa | Staphylococcus aureus |
| White garri    | C                                | R                                      | E                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A -      | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Lactobacillus sp | Bacillus cereus |
| Igbodo         | C                                | R                                      | E                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A -      | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Acinetobacter sp | Bacillus cereus |
| Lofun          | C                                | R                                      | E                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A -      | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Lactobacillus sp | Bacillus cereus |
| Lebu           | C                                | R                                      | E                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A -      | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Lactobacillus sp | Bacillus cereus |
| Fufu           | C                                | R                                      | E                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A -      | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Lactobacillus sp | Bacillus cereus |
| Garri ijebu    | R                                | R                                      | L                                          | O S                                        | CW CL                                       | + - - - + + + + FAN  | AG A A A AG     | S. aureus       | S. aureus       | S. aureus     | S. epidermis | Streptococcus faecalis | Lactobacillus sp | Bacillus cereus |
| Tapioca        | R                                | R                                      | L                                          | T R                                        | C S                                         | + - - - + + + + + AN | A A - - - | Lactobacillus sp | Acinetobacter sp |

Continued..
Table 3 Continued.

| Market Samples | Cellularity shape (R: Rod, C: Cocci) | Colonial elevation (R: Raised, F: Flat) | Colonial opacity (E: Entire, O: Opague) | 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 | Sugar hydrolysis | Citrate utilization | Oxygen reaction | Action on simple carbohydrates | probable microorganism |
|----------------|-------------------------------------|----------------------------------------|----------------------------------------|---------------------------------------------|---------------------------------------------|------------------------------------------------|----------------|---------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------------|-------------------|
| 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 A A A -                          | 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 R E T S C C                        | - - + - + + +                       | FAN AG A A A -                          | Bacillus subtilis                           |
| Igbodo         | R R E O S CW CL                      | + - - - + + +                       | FAN AG A A A -                          | Streptococcus faecalis                      |
| Lafun          | R R E T S C C                        | - - + - + + +                       | FAN AG A A A -                          | E.coli                                      |
| Fufu           | R R E O S CW CL                      | + - - - + + +                       | FAN AG A A A -                          | Lactobacillus sp                            |
| Abacha         | R R E O S Y S                        | + - - - + + +                       | FAN AG 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                                   |

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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, Shamsudddeen 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*, *Penicillium* 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 (Ikujienlola 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., Penicillium spp., Aspergillus spp. |
|        | Igboho       | Aspergillus niger, *A. fumigatus*, Fusarium spp., Mucor spp. |
|        | Lafun        | Aspergillus niger, *A. flavus*, Rhizopus spp., Penicillium spp., Mucor spp. |
|        | Lebu         | Fusarium spp., Rhizopus spp., Penicillium spp., Aspergillus spp. |
|        | Fuji         | Saccharomyces spp., Candida spp. |
|        | Garri ijebu  | *A. niger*, Saccharomyces spp., *A. fumigatus*, Mucor spp. |
|        | Tapioca      | Rhizopus spp., Penicillium spp., Aspergillus spp., Fusarium spp. |
| B      | Yellow garri | Aspergillus niger, *A. fumigatus*, Penicillium spp., Fusarium spp. |
|        | White garri  | Penicillium spp., Aspergillus spp., Mucor spp. |
|        | Igboho       | Aspergillus niger, *A. flavus*, Rhizopus spp., Penicillium spp. |
|        | Lafun        | Penicillium spp., Aspergillus spp., Fusarium spp. |
|        | Fuji         | Saccharomyces spp., Candida spp., Aspergillus niger |
|        | Tapioca      | Penicillium spp., Aspergillus spp., Fusarium spp., Saccharomyces spp. |
| C      | Yellow garri | Mucor spp., Saccharomyces spp., Aspergillus *fumigatus* |
|        | White garri  | Rhizopus spp., Penicillium spp., Aspergillus spp. |
|        | Igboho       | Mucor spp., Aspergillus niger, *A. fumigatus*, Fusarium spp., |
|        | Lafun        | Aspergillus flavus, Rhizopus spp., Penicillium spp., Mucor spp. |
|        | Fuji         | Saccharomyces spp., Candida spp. |
|        | Lebu garri   | Rhizopus spp., Penicillium spp., Aspergillus spp. |
| D      | Yellow garri | Aspergillus *fumigatus*, Mucor spp., *A. niger* |
|        | White garri  | Fusarium spp., Penicillium spp., Aspergillus spp., Mucor spp. |
|        | Igboho       | Aspergillus niger, *A. fumigatus*, Fusarium spp., Mucor spp. |
|        | Lafun        | Rhizopus spp., Penicillium spp. |
|        | Fuji         | Saccharomyces spp., Candida spp. |
|        | Abacha       | Aspergillus *fumigatus*, *A. niger*, Saccharomyces spp., Mucor spp. |
| E      | White garri  | Rhizopus spp., Penicillium spp., Aspergillus spp. |
|        | Igboho       | Aspergillus flavus, Rhizopus spp., Penicillium spp. |
|        | Lafun        | Aspergillus flavus, Rhizopus spp., Penicillium 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 cerevisiae* |
| 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. | *Penicillium 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 stolonifer* |
| The colony was white and woolly. The hypha were thick and non-septate, columnella were round. The sporangiopores 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.

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