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Microbial contamination, proximate and cyanide content of fresh cassava and dried chips

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ABSTRACT: The study investigates the levels of microbial contamination in both dried cassava chips and fresh cassava chips, shedding light on the microbiological safety and nutritional aspects of these widely consumed food items. Microbial analysis and Physicochemical parameters were done using the standard method. The research revealed diverse microbial populations in the samples, with total heterotrophic bacteria counts ranging from $3.6x10^5$ cfu/g to $1.36x10^6$ cfu/g in dried cassava chips, and $3.5x10^5$ cfu/g to $1.5x10^6$ cfu/g in fresh cassava chip, coliform counts varied from $3.9x10^4$ cfu/g to $8.4x10^4$ cfu/g in dried cassava chip and $2.7x10^4$ cfu/g to $5.4x10^6$ cfu/g in wet cassava chip. Staphylococcus counts in dried cassava chips ranged from $2.5x10^3$ cfu/g to $8.2x10^3$ cfu/g, with no counts recorded in specific samples, while fresh cassava chips exhibited counts from $2.6x10^3$ cfu/g to $6.8x10^3$ cfu/g. Fungal counts varied widely, with dried cassava chips ranging from $8.0x10^2$ cfu/g to $4.2x10^3$ cfu/g and fresh cassava chips from $1.1x10^3$ cfu/g to $2.9x10^3$ cfu/g. Varying occurrences of bacteria and fungi between wet and dry cassava. Notably, *Staphylococcus spp*. exhibited a frequency of 33.8%, *Bacillus* spp. 23.5%, *Escherichia coli* 7.4%, *Micrococcus* spp. 4.4%, *Proteus* spp. 11.8 %, *Pseudomonas* spp. 11.8%, *Lactobacillus* 1.5%, and *Klebsiella* spp. 5.9%. The most frequent fungal species included *Candida spp*. (3.9%), *Aspergillus niger* (11.5%), *Mucor* (21.2%), *Fusarium* (13.5%), *Aspergillus flavus* (3.9%), *Penicillium* (3.9%), *Rhizopus spp*. (7.7%), *Saccharomyces spp*. (5.8%), Yeast (17.3%), pink yeast (3.9%), *Aspergillus fumigatus* (3.9%), and *Trichoderma spp*. (3.9%). Proximate content, revealing protein content of 1.03% and 1.25%, carbohydrate content of 91.5% and 87.35%, ash content of 0.349% and 0.88%, lipid content of 0.82% and 0.97%, moisture content of 6.24% and 9.55% for dried and fresh cassava chip, respectively. The cyanide content was higher in the fresh cassava chip compared to the dried cassava chip. This comprehensive assessment provides valuable insights into the microbial landscape and nutritional composition of cassava products, laying the groundwork for informed quality control and safety measures in their production and consumption.

Keywords: Abacha, cassava products, microbial contamination.

INTRODUCTION

Cassava root, scientifically identified as *Manihot esculenta,* holds a significant place in the diet of numerous Nigerian communities. Freshly sliced cassava root denotes the unprocessed roots of the cassava plant, a dicotyledonous species belonging to the Euphorbiaceae family. Cultivated widely across tropical regions in Asia, South America, and Africa, cassava serves as a vital economic crop, providing essential calories for millions of people. Its resilience in adverse conditions and high yield potential have made it a favoured choice among farmers. In Nigeria specifically, cassava stands as a primary staple food, contributing approximately 70% of the daily caloric intake for 50 million Nigerians. Nigeria ranks as the largest global producer of cassava, with an annual yield exceeding 34 metric tons.

The cultivation process of cassava involves planting stem cuttings in well-prepared soil and ensuring regular care and maintenance until the roots reach harvest readiness, typically occurring 8 to 24 months post-planting.

Harvesting mature roots involves uprooting the entire plant or cutting off the roots close to the ground. Freshly sliced cassava roots find versatile use as ingredients in various Nigerian dishes, prepared through boiling, frying, or stewing. Rich in carbohydrates, they serve as a substantial energy source for many Nigerians.

Additionally, dried cassava root, known as *Abacha*, plays a prominent role in Nigerian cuisine, particularly in dishes like "African Salad" or "Abacha". This versatile crop can be processed into several consumable products, including *gari*, cassava flour, and *abacha*. *Abacha*, available in dry or wet forms, is obtained by shredding or slicing boiled cassava tubers, followed by soaking, washing, and drying as needed. Often consumed as a snack or main meal in the Eastern States of Nigeria. *Abacha* offers a nutritious blend of carbohydrates, vitamins, minerals, and dietary fibre from the cassava root and other ingredients. It remains a beloved and satisfying dish among many Nigerians, forming an integral part of their traditional diet. Cassava plays a crucial role in enhancing food security, generating income, and creating employment opportunities in rural sub-Saharan Africa, as highlighted by Githunguri *et al.* (2007) and Kiura *et al.* (2005). However, the quality of cassava roots may deteriorate due to microbial activity and adverse biochemical changes during harvesting, often stemming from physiological reactions and microorganisms entering through bruises and cuts. Traditional methods of processing cassava chips and flour frequently lack proper hygiene, with sun-drying occurring in unsanitary environments such as rocks, roads, rooftops, baskets, or bare ground, as noted by FAO (2005) and FAO/WHO (1991).

Subsequent storage conditions, particularly in high humidity, contribute to increased microbial growth. Unsanitary practices throughout production, storage, and slow sun-drying, particularly during rainy seasons, resulting in bacterial and mold contamination, including the production of aflatoxins by *Aspergillus species*, posing health risks to both humans and livestock, as highlighted by Chiona *et al*. (2014) and Manjula *et al.* (2009). The presence of *Staphylococcus aureus* and *Escherichia coli* underscores issues with hygiene standards, excessive handling, and the use of low-quality water during processing, post-processing, and marketing, as reported by Obadina *et al.* (2008). Analysis reveals that dried cassava typically contains 10-12% water, 60-72% starch, and 0.01-0.02% glycoside (Kareem, 2022). Detoxification processes occur during various processing steps, such as fermentation, peeling, grating, boiling, and sun-drying (Kuliahsari *et al.,* 2021). While microorganisms, including some pathogenic strains, naturally occur, the root of the problem lies in unhygienic practices by sellers before and during sales to consumers. The study aimed to investigate the extent of microbial contamination, proximate composition, and cyanide content in both fresh and dried cassava chips.

MATERIALS AND METHODS

Sample collection

30 samples of fresh and dried cassava chips were randomly procured locally using a simple random sampling technique from vendors at Choba Market in Port Harcourt, Rivers State.

Method of processing

Cassava roots were obtained from the farm, peeled and washed then cut into chunks, boiled thereafter sliced and soaked for 16 hours then washed to get the fresh cassava chips. To obtain the dried cassava chips, samples were dried at 65°C for 6 hours.

Microbial analysis

Samples preparation

25 g of samples were put into 225 ml of diluent/peptone water and then homogenized in a stomacher to get the stock solution. Tenfold serial dilution was done from 10^1 to 10^4 then 0.1ml was inoculated into the Petri dishes containing the different media and spread, this follows incubation.

Preparation of samples

25 g of each fresh and dried cassava chip sample was weighed into a stomacher bag containing 225 ml of sterile diluent (peptone water) and homogenized in a stomacher for 2 minutes to obtain the stock solution. Ten-fold serial dilution was performed on the samples. 1 ml of the aliquot was pipetted into a test tube containing 9 ml sterile peptone water to make a tenfold serial dilution of up to 10^{-7}. Using a sterile 1 ml pipette (syringe), 0.1 ml of each of the dilutions were inoculated on the different agar plates (Potato dextrose agar (PDA), McConkey agar, Mannitol salt agar, Plate count agar (PCA), Mannitol salt agar (MSA)) for enumeration and culture.

Enumeration of microbial count/purification of isolates

The microbial count for each sample was obtained on different agars including Plate Count Agar, Potatoes dextrose agar, MacConkey agar and Mannitol Salt agar. Pure culture was then obtained from the previously incubated Petri dishes and counts obtained from the various selective media were expressed as a colony forming unit (cfu/g). Colonies were subcultured on nutrient agar by streak plate method to obtain pure distinct colonies.

Determination of colony forming unit per meter cube (CFU/g)

The cfu/g was determined using:

Cfu/ml = Number of colonies x dilution factor / Volume of culture plate.

Identification of isolates

Morphological identification of bacteria

Bacterial isolates were characterized and identified using cultural, morphological and microscopic examinations. The macroscopic examination of the colonies was differentiated based on size, colour, pigmentation, elevation surface texture and margin.

Biochemical identifications of bacteria

Different biochemical tests such as Gram staining, Catalase, Coagulase, Methyl-red, Oxidase, Voges-Proskauer and sugar fermentation tests were employed to differentiate the bacterial isolates according to the standard microbiological methods as described by Cheesbrough (2006).

Fungal Identification

Identification of all fungal isolates was also carried out using standard methods based on macroscopic and microscopic features as described by Lacto-phenol (Cotton blue test). On a clean slide, a drop of methanol was placed and a portion of fungi growth was cut with the aid of a surgical blade and tested in the methanol. A drop of lacto-phenol cotton blue was added. A cover slip was placed on it gently and observed under the microscope with x40 objectives.

Chemical analysis

Cyanide content in fresh and dried cassava chips

Crude protein, fat, fibre, ash and carbohydrate contents were determined using the method of AOAC (2000) while cyanide (HCN) was determined by the method of Bradbury *et al*. (1999) and Iliya and Madumelu (2019).

Statistical analyses

The means of the samples were compared using analysis of variance (ANOVA) and the level of significant difference was determined at $p < 0.05$. This analysis was carried out with an SPSS program.

RESULTS

Total heterotrophic bacteria count obtained from dried and fresh cassava chips

The total heterotrophic bacteria count of all the dried cassava samples studied ranged from 3.6×10^5 CFU/g to 1.36×10^6 CFU/g. The fresh cassava sample likewise had a total heterotrophic bacteria count ranging from 3.5×10^5 CFU/g to 1.5×10^6 CFU/g (Figure 1).

Staphylococcus count obtained from dried and fresh cassava chips

The staphylococcus counts of all the dried cassava samples studied ranged from 2.5×10^3 CFU/g to 8.2×10^3 CFU/g. No *Staphylococcus* counts were recorded for dried cassava samples. The fresh cassava sample likewise had *Staphylococcus* counts ranging from 2.6×10^3 CFU/g to 6.8×10^3 CFU/g (Figure 2).

Total coliform count obtained from dried and fresh cassava chips

The total coliform counts of all the dried cassava samples studied ranged from 3.9×10^4 CFU/g to 8.4×10^4 CFU/g. The fresh cassava sample likewise had coliform counts ranging from 2.7×10^4 CFU/g to 5.4×10^6 CFU/g (Figure 3).

Total fungi count obtained from dried and fresh cassava chips

The total fungi count of all the dried cassava samples studied ranged from 8.0×10^2 CFU/g to 4.2×10^3 CFU/g. The fresh cassava sample likewise had fungi counts ranging from 1.1×10^3 CFU/g to 2.9×10^3 CFU/g (Figure 4).

Frequency of occurrence of bacteria isolated from fresh and dried cassava chips studied

The frequency of occurrence of the bacteria isolates was different among fresh and dried cassava chips studied. The overall frequency obtained was: *Staphylococcus* spp. 33.8%; *Bacillus* spp. 23.5%; *Escherichia coli* 7.4%; *Micrococcus* spp. 4.4%; *Proteus* spp. 11.8%; *Pseudomonas* spp. 11.8% *Lactobacillus* 1.5 % and 5.9%; *Klebsiella* spp (Table 1).

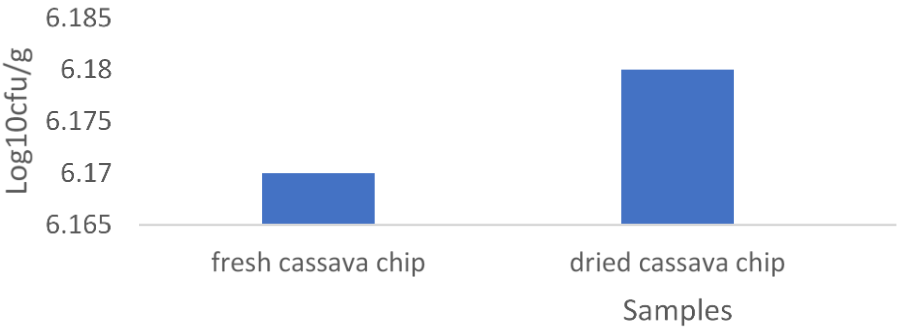

Figure 1. Mean Total heterotrophic bacteria count of Dried and Fresh cassava chips.

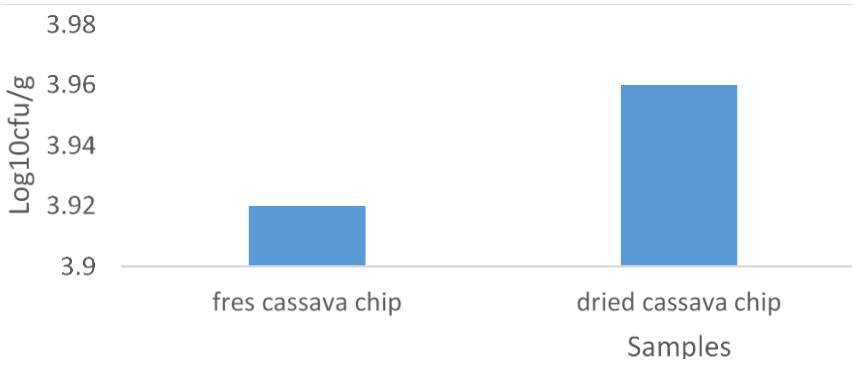

Figure 2. Mean Total Staphylococcus count of dried and fresh cassava chips.

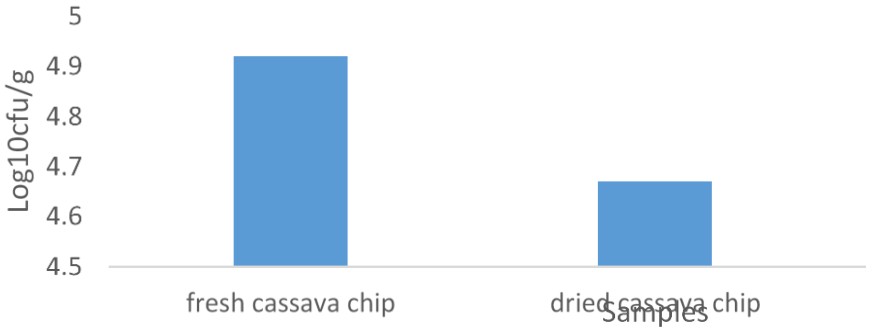

Figure 3. Mean total coliform count of dried and fresh cassava chips.

Frequency of occurrence of fungi isolated from fresh and dried cassava chips studied

The frequency of occurrence showed that the most frequent fungal species across samples studied were: *Candida* spp. 3.9%; *Aspergillus niger* 11.5%; *Mucor* 21.2%; *Fusarium* 13.5%, *Aspergillus flavus* 3.9 %; *Penicillium* 3.9%, Rhizopus spp. 7.7%, *Saccharomyces* spp. 5.8%, Yeast 17.3%, pink yeast 3.9%; *Aspergillus fumigatus* 3.9% and *Trichoderma* spp. 3.9% (Table 2).

Mean proximate composition and cyanide content of fresh and dried cassava chips studied

The proximate and cyanide content showed that the fresh and dried cassava chips had protein content of 1.03 and 1.25%, carbohydrate content of 91.5 and 87.35%, ash content of 0.349 and 0.88%, lipid content of 0.82 and 0.97%, moisture content of 6.24 and 9.55% as well as cyanide content of 0.0025 (0.025 mg/kg) and 0.0055% (0.055 mg/kg), respectively (Table 3).

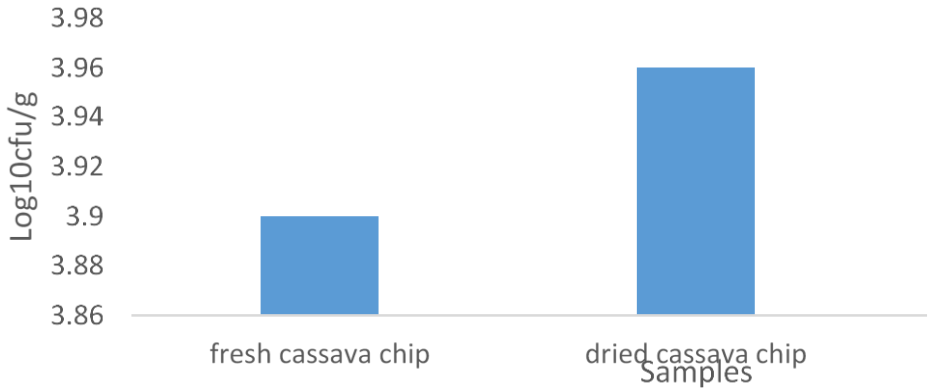

Figure 4. Mean total fungal count of dried and fresh cassava chips.

Table 1. Frequency of occurrence of bacteria isolated from fresh and dried cassava chips studied.

Bacterial Isolates	Fresh cassava chip (%)	Dried cassava chip (%)	Total N (%)
Staphylococcus spp.	11 (33.3)	12 (34.3)	23 (33.8)
Bacillus spp.	8 (24.1)	8 (22.9)	16 (23.5)
Lactobacillus spp.	1 (3.0)	0	1 (1.5)
Escherichia coli	2 (6.0)	3 (8.6)	5 (7.4)
Micrococcus spp.	2 (6.0)	1 (2.9)	3 (4.4)
Pseudomonas spp.	3 (9.1)	5 (14.3)	8 (11.8)
Klebsiella spp.	3 (9.1)	1 (2.9)	4 (5.9)
Proteus spp.	3 (9.1)	5 (14.3)	8 (11.8)
Total	33 (100)	35(100)	68 (100)

Table 2. Frequency of occurrence of fungi isolated from fresh and dried cassava chips studied.

Fungi Identity	Fresh cassava chip (%)	Dried cassava chip (%)	Total N (%)
Aspergillus niger	2 (9.5)	4 (12.9)	6 (11.5)
Aspergillus fumigatus	1 (4.8)	1 (3.2)	2 (3.9)
Aspergillus flavus	1 (4.8)	1 (3.2)	2 (3.9)
Mucor spp.	5 (23.8)	6 (19.4)	11 (21.2)
Fusarium spp.	2 (9.5)	5 (16.1)	7 (13.5)
Penicillium spp	1 (4.8)	1 (3.2)	2 (3.9)
Rhizopus spp	2 (9.5)	2 (6.5)	4 (7.7)
Saccharomyces spp	1 (4.8)	2 (6.5)	3 (5.8)
Candida spp.	1 (4.8)	1 (3.2)	2 (3.9)
Yeast	3 (14.3)	6 (19.4)	9 (17.3)
Pink yeast	1 (4.8)	1 (3.2)	2 (3.9)
Trichoderma sp.	1 (4.8)	1 (3.2)	2 (3.9)
Total	21 (100)	31 (100)	52 (100)

DISCUSSIONS

Microbial quality of fresh and dried cassava chips

This study evaluates and compares microbial contamination levels in fresh and dried cassava chips. The study's findings indicated significant differences in microbial counts between the two forms of cassava chips, potentially highlighting variations in their susceptibility to microbial contamination. The total heterotrophic bacteria count in dried cassava chip samples ranged from 3.6 x 10^5 cfu/g to 1.36 x 10^6 cfu/g, while fresh cassava chip samples

Table 3. Mean proximate and cyanide content of from fresh and dried cassava chips studied.

Sample code	Protein (%)	Carbohydrates (%)	Ash (%)	Lipid (%)	Moisture (%)	Cyanide (%)
Dried cassava chip	1.03	91.56	0.349	0.82	6.24	0.0025%
Fresh cassava chip	1.25	87.35	0.88	0.97	9.55	0.0055%.

exhibited counts between 3.5 x 10^5 cfu/g and 1.5 x 10^6 cfu/g. The mean log_{10}cfu/g of the fresh and dried cassava chip is 6.17 and 6.18, respectively as shown in Figure 1. These findings align with the research conducted by Adebayo-Oyetoro *et al.* (2013) who reported a total heterotrophic bacteria count of 8.1 x 10^6 cfu/g for cassava products. Similarly, the results are consistent with the findings of Gacheru *et al*. (2013) and the study of Johnson *et al.* (2016) who had a mean total bacterial count from cassava products of 4.24 X10^4 cfu/g which is slightly lower than this study. The high bacterial load in both fresh and dried cassava chip samples may be attributed to several factors, including injury to the roots during harvesting, which provides a pathway for bacterial invasion. Additionally, post-harvest handling, particularly during processing by various handlers and drying, where cassava comes into direct contact with insects, dirt, and animals, increases the likelihood of contamination and subsequently higher microbial loads.

The total coliform counts in both fresh and dried cassava chip samples showed a significant range. In the dried cassava chip, the counts ranged from 3.9 x 10^4 cfu/g to 8.4 x 10^4 cfu/g, while in the fresh cassava chip, the range was broader, spanning from 2.7 x 10^4 cfu/g to a significantly high count of 5.4 x 10^6 cfu/g in a fresh cassava sample ($p < 0.05$). The mean total coliform count of fresh and dried cassava chips is Log $_{10}$ 4.67 and 4.92 cfu/g as shown in Figure 3. These findings align with the research conducted by Gacheru *et al*. (2016).

Olopade *et al.* (2014) reported no growth to 6.0 x 10^3 cfu/g for coliform count in cassava products which is slightly lower than the present study. The detection of coliforms in cassava products suggests inadequate hygiene standards and the possibility of faecal contamination during processing and retailing, including packing and display. The presence of coliforms in food indicates that they might have been subjected to conditions conducive to the entry and proliferation of harmful microorganisms. These findings align with previous research conducted by Odetunde *et al.* (2014) in Nigeria. High coliform counts in cassava chips may be attributed to post-process contamination via food handlers and the environment. The *Staphylococcus* counts in dried cassava chip samples ranged from 2.5 x 10^3 cfu/g to 8.2 x 10^3 cfu/g, with some dried cassava chip samples showing no detectable count. This variability in contamination levels among different dried cassava samples is noteworthy. In fresh cassava samples, *Staphylococcus* counts ranged from 2.6 x 10^3 cfu/g to 6.8 x 10^3cfu/g, which is similar to the findings reported by Gacheru *et al*. (2016) at 3.1 x 10^3cfu/g for cassava products. The mean *Staphylococcus* count of fresh and dried cassava chips is 3.92 and 3.96, respectively as shown in Figure 4.

However, these counts exceed the acceptable limit set by the Codex Alimentarius Commission (CAC) at 2.00 CFU/g. The staphylococcal species found in cassava products were higher than the acceptable limits established by EAS 739:2010 at 2.00 log cfu/g. The presence of this organism in cassava products is attributed to post-processing handling and exposure at both processing sites and markets, as drying is often conducted in open-air environments where animals are raised (Obadina *et al.,* 2008). The narrower range in *Staphylococcus* counts in fresh cassava chips compared to dried cassava suggests that the higher moisture content in wet cassava may provide a more favourable environment for the survival of *Staphylococcus* bacteria. Research by Liston and Matches (1976) and Guthrie (1983) confirmed that the primary sources of this organism in foods and beverages are nasal canals and infected hands, posing health hazards. Staphylococcal spores possess the ability to withstand high temperatures and produce enterotoxins that are resistant to destruction and may cause food poisoning.

The total fungi count in both fresh and dried cassava chip samples exhibited a range of values. For dried cassava chips, counts ranged from 8.0 x 10^2 cfu/g to 4.2 x 10^3 cfu/g. In fresh cassava chips, fungi count ranged from 1.1 x 10^3 cfu/g to 2.9 x 10^3 cfu/g. The mean fungi count of both fresh and dried cassava chips is 3.9 and 3.96, respectively as shown in Figure 5. The total fungi count was lower compared to the findings of Adetunji *et al*. (2017) and Adebayo-Oyetoro *et al*. (2013) ranged 1.1 x 10^4 to 8.2 x 10^5 cfu/g and 3.5 x 10^6 cfu/g, respectively. Also, the fungi count in 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. The dried samples are significantly higher than the fresh samples ($p < 0.05$).

This aligns with the conclusions drawn by Akinsanya *et al.* (2013), who emphasized that the sale, distribution, and marketing of cassava products like boiled cassava, *abacha* (dried cassava), *garri*, and *akpu* in local markets are linked to unsanitary practices. These practices, such as handling with unwashed hands and utensils, and exposure to animals and contaminants, can contribute to

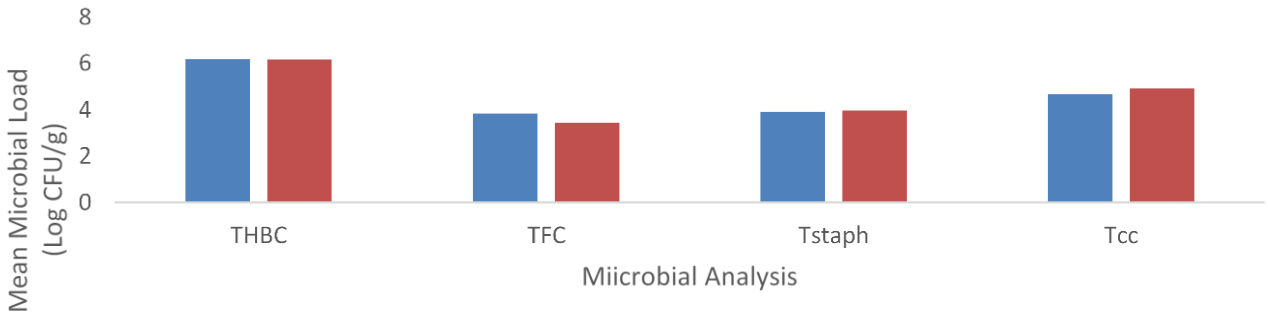

Figure 5. Mean microbial counts of fresh and dried cassava chips (**Keys:** THBC; Total heterotrophic bacteria count, TFC; Total fungi count, TSC; Total staphylococcus count, TCC; Total coliform count).

microbial contamination, thereby elevating the microbial load of these products. The differences in microbial counts observed between dried and fresh cassava samples raise important considerations. One possible explanation for these variances is the moisture content inherent in the cassava products. Dried cassava typically possesses lower moisture levels due to the dehydration process, potentially hindering bacterial growth and resulting in reduced microbial counts compared to wet cassava. However, contrary to expectations, this study found slightly higher microbial counts in the dried samples than in the fresh cassava chips.

Several factors may contribute to the high microbial count observed in dried cassava chips. Firstly, the drying process itself can expose the product to a greater risk of microbial contamination. Conditions such as temperature and humidity during drying can create favourable environments for microbial growth if proper hygiene practices are not maintained. Secondly, the lower moisture content in dried cassava chips, while initially inhibiting microbial growth, may lead to a temporary reduction that can be reversed when stored inadequately or for prolonged periods. Microorganisms typically require moisture for proliferation, and in the case of dried cassava chips, this reduced moisture content may not fully prevent microbial multiplication over time. To mitigate microbial contamination and ensure food safety, it is crucial to adhere to strict hygiene and sanitation protocols throughout the processing, storage, and handling of both fresh and dried cassava chips. The origin and handling procedures of cassava throughout its processing stages could also contribute to the observed differences. Contamination risks may arise at various points, starting from cultivation and harvesting, extending to processing and packaging (Udoro *et al*., 2021). Factors such as hygiene practices, utensil cleanliness, and storage conditions may all impact the microbial presence in both fresh and dried cassava chips.

The study revealed the presence of eight bacterial genera in both dried and fresh cassava including *Staphylococcus, Bacillus, Lactobacillus, Klebsiella, Micrococcus, Pseudomonas, Escherichia coli,* and *Proteus*. This is consistent with the findings of Nwokorie (2021), who identified *Staphylococcus spp., Bacillus spp*., and *Proteus spp*. in their assessments of the microbial quality of sliced cassava chips sold by vendors in Umuahia. Similarly, the microorganisms found in fermented cassava food products, as observed by Ogiehor and Ikenebomeh (2005), might be attributed to processing and poor handling practices during the sale of these products. This can further increase microbial hazards from cassava-based food products. The presence of these microorganisms is often associated with the individual hygiene of people handling them in marketplaces, as reported by Aboloma (2008), Oyeyi and Lum-nwi (2008), Shamsuddeen and Ameh (2008), and Wada-kura *et al*. (2009).

The research conducted by Kim *et al*. (2009) identified *Pseudomonas aeruginosa*, a pathogen with opportunistic tendencies, which can lead to bacteremia and gastrointestinal infections in affected individuals. Similarly, *Escherichia coli*, as reported by Nweze (2010), has been linked to diarrhoea in humans. Comprehending the microbial makeup in dried and fresh cassava chips is essential for devising suitable handling and processing methods to mitigate potential health risks stemming from these microorganisms. By doing so, the safety and quality of cassava-based food products can be ensured.

The frequency of occurrence of bacterial isolates varied between both fresh and dried cassava chips. *Staphylococcus* spp. exhibited the highest frequency at 33.8%, followed by *Bacillus* spp. at 23.5%, indicating their prevalence in both fresh and dried cassava chips. *Escherichia coli, Micrococcus* spp., *Proteus* spp., and *Pseudomonas* spp. also demonstrated notable frequencies of 7.4%, 4.4%, 11.8 % and 11.8%, respectively. The differences in bacterial occurrence may be attributed to variations in processing conditions, storage, and hygiene practices associated with both fresh and dried cassava chips.

The presence of pathogenic organisms in both fresh and

dried cassava chip products poses substantial public health concerns, as it highlights potential threats to food safety and the emergence of foodborne illnesses. Among the notable pathogens identified in tapioca, *Staphylococcus species* and *Escherichia coli* are of significant concern. *Staphylococcus aureus*, commonly found on human skin and in the environment, can produce heat-stable toxins, such as enterotoxins, which, if present in cassava chips, can lead to food poisoning. Symptoms of this infection include nausea, vomiting, abdominal cramps, and diarrhoea, often with a swift onset, typically within hours. To mitigate Staphylococcus-related risks, it is crucial to emphasize strict hygiene practices during tapioca harvesting, processing, and packaging. This includes regular handwashing, equipment sanitation, and maintaining proper temperature control during storage. *Escherichia coli*, another pathogen found in tapioca, can cause symptoms such as abdominal cramps, bloody diarrhoea, and, in severe cases, kidney failure. To address the public health implications associated with *Escherichia coli* contamination in cassava chips, it is essential to focus on improving agricultural practices, water quality control, and implementing proper processing techniques. Ensuring cassava chips are sourced from hygienic environments and implementing effective sanitation measures during processing are vital steps in significantly reducing the risk of *E. coli*-related foodborne illnesses.

The examination of fungal species in both fresh and dried cassava chips has revealed a diverse range of organisms, including *Penicillium spp., Fusarium spp., Aspergillus fumigatus, Candida spp., Mucor spp., Saccharomyces spp., Aspergillus niger, yeast, pink yeast, Rhizopus stolonifera, Trichoderma spp*., and others. These findings align with those of Jonathan *et al*. (2017) who also identified similar fungal species in cassava products. The variations in the frequency of occurrence of these fungal species across samples demonstrate the dynamic nature of fungal contamination in tapioca. *Mucor spp*. emerged as the most prevalent at 21.2%, followed by *Aspergillus niger* at 11.5%. Other common fungal species found were *Fusarium*, yeast, *Rhizopus spp*., and *Aspergillus flavus*. The presence of potentially pathogenic bacteria, such as *Escherichia coli* and *Staphylococcus spp*., along with mycotoxin-producing fungi like *Aspergillus*, raises concerns about the safety of cassava products.

The organisms isolated are indicative that they could cause danger to the health of the consumers as the majority of those microbial organisms are pathogenic. The result from this study also revealed that bacterial and fungal isolates identified are commonly present as contaminants generated from human skin, cooking utensils processing equipment, the environment and water (Omemu and Faniron, 2011). Odetunde *et al.* (2014) observed that pathogenic organisms in foods may indicate that such foods were exposed to conditions favourable for their introduction and growth.

Proximate and cyanide content from fresh and dried cassava chips

The proximate composition and cyanide content in both fresh and dried cassava chips in this study offer insights into their nutritional profile and potential safety considerations, given their widespread consumption. The observed differences in proximate composition and cyanide content point towards variations in processing methods, which could affect both the nutritional quality and safety of these cassava forms.

Analysis of the proximate composition highlights discrepancies in their nutritional content, particularly in protein levels. Dried cassava chip exhibits a slightly lower protein content of 1.03% compared to 1.25% in fresh cassava chips. This finding is consistent with previous studies conducted by Manano *et al*. (2017), Nyirendah *et al*. (2012), and others, which reported protein levels ranging from 0.3 to 10.06%. Environmental factors, such as soil fertility and the application of nitrogen-rich fertilizers, can impact protein content in various cassava varieties. Research by Burns *et al.* (2012) and Agiriga and Iwe (2016) suggests that fertilization can elevate protein content from 4.3 to 19.30% in unfertilized cassava varieties from 9.6 to 20.9% in fertilized varieties (Shittu *et al*., 2008). During the drying process, saccharides replace water molecules bound to proteins, potentially altering protein binding sites and affecting their functionalities. This could potentially result in a decrease in protein content. However, it is noteworthy that all samples in the current study exhibited protein contents above the recommended minimum values set by SON (0.5% for starch and 1.0% for other cassava products).

Dried cassava samples typically exhibit a higher carbohydrate content (91.5%) compared to fresh cassava chips (87.35%). However, these values fall below the ranges reported by Charle *et al*. (2005) and Pomeranz and Chung (1978). The carbohydrate content is influenced by the levels of proteins, lipids, and moisture present. A reduction in these components can contribute to an increase in total carbohydrates. Carbohydrates in cassava form bonds with proteins via hydrogen bonding, involving hydroxyl groups on saccharides and amine groups on proteins, as noted by Passos *et al*. (2013). This bonding can lead to the formation of highly carbonyl-substituted carbohydrates, which may potentially diminish protein activity and availability. Moreover, carbohydrates interact with lipids to produce glycolipids through glycosidic bonds, thereby reducing free lipids, as highlighted by Pomeranz and Chung (1978). Additionally, carbohydrates bind with water molecules through hydrogen bonding, restricting water mobility. This phenomenon elucidates the inverse correlation between moisture and carbohydrate content, as observed by Li *et al.* (2018).

The ash content, representing mineral content, was observed to be lower in dried cassava products (0.349%)

compared to fresh cassava products (0.88%). This finding is consistent with previous studies conducted by Nyirendah *et al*. (2012), Rojas *et al*. (2007), and Eleazu and Eleazu (2012), which reported ash contents ranging from 1.44 to 3.46%. The variation in ash content might stem from variances in dry matter content and the drying process, which could concentrate minerals in dried cassava. Typically, crude ash content indicates the presence of inorganic constituents such as potassium (K), zinc (Zn), and calcium (Ca) and usually falls within the range of 1 to 2% in cassava. The ash contents reported in previous studies (ranging from 1.90 to 2.84% and 1.44 to 2.35%) are higher than the results of the current study. Omowonuola *et al*. (2017) found a higher ash content (3.49%) in cassava flour samples, which could be attributed to differences in dry matter content, genotypic variations in raw cassava roots, and their proximate composition. It is worth noting that higher dry matter contents are associated with lower ash contents, as indicated by Omowonuola *et al*. (2017).

The lipid content, though generally low, was found to be slightly higher in fresh cassava products (0.97%) compared to dried cassava products (0.82%). These differences in lipid content could be attributed to the processing methods employed, which may influence lipid retention and contribute to the observed variations. Previous studies by Somendrika *et al.* (2016) and Eleazu and Eleazu (2012) reported fat contents ranging from 0.1 to 0.3% and 0.74 to 1.49%, respectively, which are notably lower than the results of the current study.

Lipids serve as alternative energy sources and can influence the moisture and dry matter contents in cassava. Research indicates that lower fat contents are associated with increased dry matter contents and total carbohydrates. Furthermore, lipids, such as monoglycerides and phospholipids, can form liquid-crystalline phases with water through their hydrophilic (polar-heads) or hydrophobic (methyl) groups. The analysis of moisture content revealed that dried cassava chips exhibited significantly lower moisture levels (6.24%) compared to wet cassava products (9.55%). This finding is consistent with the results reported by Manano *et al*. (2017), who observed moisture contents ranging from 5.43 to 10.87%. The variations in moisture content may stem from differences in chemical constituents and processing methods (Chisenga *et al.*, 2019)

Moisture content plays a crucial role in food preservation as it influences chemical, physical, and microbiological changes during storage. High moisture levels exceeding 12% can promote microbial growth, while lower levels are beneficial for longer shelf life, as noted by Rojas *et al*. (2007). The disparity in moisture content is expected, given that the drying process aims to reduce moisture for enhanced shelf stability. Consequently, the lower moisture content in dried cassava contributes to its longer shelf life compared to the more perishable fresh cassava.

The cyanide content in both fresh and dried cassava chips can vary due to factors like cassava variety, soil conditions, and agricultural practices. Generally, cassava tends to have higher cyanide levels in its raw form, which decreases during processing. One notable finding is the difference in cyanide content between fresh and dried cassava chips. Dried cassava chips exhibited a lower cyanide content of 0.0025% compared to fresh cassava chips, which had 0.0055%. Ekwu *et al*. 2012) reported that processing into wet '*abacha'* slices reduced the HCN content from 7.80 to 10.41 mg/100g. '*Abacha'* made from fresh cassava roots ranged from 8.67 to 10.41 mg/100g while the samples from dry cassava chips ranged from 7.80 to 9.54 mg/100 g. Drying of the wet '*abacha'* slices further reduced the HCN content to 7.32 – 8.63 mg/100g, this is similar to this present study as there was a reduction in the cyanide content in the dried cassava chips. This confirms that HCN can be readily volatilized by heat and reduced during drying processes (Okaka *et al*., 2006). A similar observation was made for *gari* produced from fresh cassava and dried chips (Ekwu and Ehirim, 2008). The '*abacha'* produced from dry chips was slightly different from the '*abacha'* produced from fresh cassava in the HCN content as indicated in this study.

These values are lower compared to the findings of Ezeh *et al.* (2018), who reported a cyanide content of 0.11%, exceeding the recommended safe level of 10 ppm (0.0001%). Another study by Iliya and Madumelu (2019) found cyanide levels in air and oven-dried cassava ranging from 0.0248 to 0.0254%, and in wet cassava from 0.0135 to 0.0162%, which is higher than the present study. This difference may be attributed to the processing methods employed. Fresh cassava, not subjected to extended drying, retains higher levels of cyanogenic glucosides, while the drying process contributes to their breakdown and reduction. The higher cyanide content in fresh cassava raises safety concerns, as excessive cyanide intake can have adverse health effects. These findings underscore the importance of proper processing methods, such as thorough peeling, washing, and drying, to minimize cyanide levels in cassava products and ensure consumer safety (Charles *et al*., 2004).

The presence of cyanide in cassava chips poses significant public health concerns. Cyanide is a toxic compound that, when ingested in high amounts, can lead to serious health issues. Cassava contains cyanogenic glycosides, which can release cyanide during processing or consumption. Consuming cassava chips with elevated cyanide levels may result in acute cyanide poisoning, leading to symptoms such as nausea, vomiting, headache, and, in severe cases, respiratory failure or death. Chronic exposure to lower levels of cyanide over time may contribute to neurological and thyroid-related health problems (Ndubuisi and Chidiebere, 2018).

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

Conclusion

The organisms isolated are indicative that they could cause danger to the health of the consumers as the majority of those microbial organisms are pathogenic. The result from this study also revealed that bacterial and fungal isolates identified are commonly present as contaminants generated from human skin, cooking utensils processing equipment, the environment and water. The presence of cyanide in cassava chips poses significant public health concerns. Cyanide is a toxic compound that, when ingested in high amounts, can lead to serious health issues.

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