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Microbiological Quality of Packaged and Exposed Cassava, Yam and Plantain Flour Sold in Markets and Supermarkets in Port Harcourt Metropolis, Nigeria

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Abstract The presence of pathogens in edible flours generally considered as microbiologically safe is a threat to public health. In this study, microbial load of thirty (30) samples of exposed and packaged cassava, plantain and yam flour from open markets and supermarkets were determined. Similar flours were prepared in the laboratory as control. Morphological and molecular characterization methods were adopted in this study. On average, packaged flour samples had lower total fungal count (TFC) and total heterotrophic count (THC) than exposed flour samples. Maximum THC of the flour samples were slightly above 5 $\log_{10}$cfu/g except packaged yam flour (3.91 $\log_{10}$cfu/g). THC, TFC, *Bacillus* and *Staphylococcal* count of the control samples range between 4.64-4.72, 2.3-2.6, 2.3-2.8, 3.44-3.53 $\log_{10}$cfu/g, respectively. As for packaged yam, plantain and cassava flours, their TFC range between 3.45-3.55, 2.30-3.10 and 2.15-2.80 $\log_{10}$cfu/g, while THC was 3.70-3.91, 2.0-5.69, 5.48-5.54 $\log_{10}$cfu/g, respectively. Therefore, exposing cassava, plantain and yam flour in open markets should be discouraged and strict good manufacturing practices during flour processing are recommended in order to drastically reduce microbial load in edible flour.

Keywords: *packaged, exposed, flour, microbiological quality*

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1. Introduction

Flour is powdery and generally regarded as being microbiologically safe because of its low water activity [1,2]. Grains, roots, tubers and fruit cluster are usually processed into flour which is usually used to develop diverse food products [3]. During small and medium scale processing of yam, cassava and plantain into edible products such as yam, cassava and plantain flour, respectively, microbial contamination of the product could occur [4,5,6,7].

Contamination of food takes place along the food production chain i.e. from production to dining table. Microbiological quality is considered as the most important aspect of food safety [8]. Like any other food product, yam, plantain and cassava processed into flour is susceptible to microbial contamination during processing, packaging and retailing [5,9,10,11]. Consumption of microbially contaminated edible flour is considered a threat to public health [12].

In their separate studies, Gacheru *et al*. [5] and Ogundare-Akanmu *et al.* [13] assessed the level of microbial contamination of cassava and plantain flour sold in some markets in Nairobi Kenya and Port Harcourt Nigeria, respectively. Ogundare-Akanmu *et al.* [13] reported that insects did not infest plantain flour samples which were stored for four months but moulds were noticed on the samples within the last month of storage except the reference sample. Total viable count (TVC) of flours from 10 cassava varieties reported by Eleazu *et al.* [14] ranged between 2.0 x 10^3 - 4.5 x 10^5 cfu while that of fungal counts is 0.5-2.5 x 10^3 cfu. According to Gacheru *et al.* [5], *Escherichia coli* was present in only one cassava flour sample whereas *Staphylococcus aureus* was detected in 87 % of the flour samples. Microorganisms associated with plantain flour processed using plantain bought from the market were identified by Ajayi [15] to be *E. coli*, *Klebsiella* spp., *Bacillus cereus*, *B. globisporus*, *B. circulans* and *Enterococcus* spp. Percentage frequency of occurrence of bacterial isolates from cassava flour represented as *Enterobacter* sp. (6.3 %), *Klebsiella* sp. (72.9 %), *Acinetobacter* sp. (12.5 %) *Campylobacter* sp. (2.1 %) and *Bacillus subtilis* (6.25 %) was reported by Aruwa and Ogundare [16] while *Pencillium crustosum* (66.7 %), *P. chrysogenum* (11.1 %) and *Aspergillus niger* (22.2 %) were fungal isolates. They also reported that in plantain flour it was *Klebsiella* sp. (94.5 %) and *Campylobacter* sp. (5.1 %) for bacterial isolates; *Rhizopus oryzae* (38.5 %) and *Aspergillus niger*

(61.5 %) as fungal isolates. Lawal *et al*. [17] reported that TVC and fungal counts in yam flour stored for three months inside Hessian and polyethene bags increased during the period of storage. Although fungal count was higher than bacterial count in the yam flour packaged inside polyethene and Hessian bags, microbial load of the product was within acceptable limits.

Regular monitoring of microbial quality of edible flours available in the markets for public consumption is important because of health risk posed by these products. Therefore, this study is aimed at evaluating microbiological quality of packaged and exposed yam, cassava and plantain flour sold in some markets and supermarkets in Port Harcourt, Rivers state Nigeria methods.

2. Materials and Methods

Fifteen samples of 1 Kg packaged yam, cassava and plantain flour which comprise five samples each were purchased from three popular supermarkets coded ED, SL and SR in Port Harcourt metropolis. Similarly, one kilogram (1 Kg) of fifteen samples of exposed yam, cassava and plantain flour which comprise five samples each were purchased from market sellers doing business in three popular open markets in Port Harcourt metropolis coded RO, MT and OM using a sterile plastic container. All the samples were transported to Food and Industrial Microbiology Laboratory, University of Port Harcourt for analysis. Using the methods described by Onyenwoke and Simonyan [18], Omohimi *et al*. [4] and Ajayi [15] with slight modification, 1 Kg each of cassava, yam and plantain flour, respectively was separately prepared in the laboratory under hygienic condition which is the control samples.

2.1. Microbiological Analysis

The method described by Odu *et al*. [19], Eman and Sarifar [20] were employed in this study. In addition, APHA [21] method was used to detect *Salmonella* sp. in the flour samples.

2.2. Morphological Study of Isolates

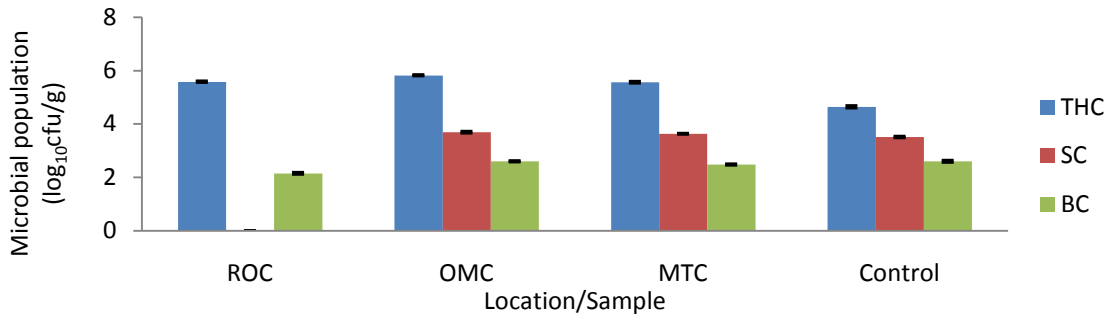
The bacterial isolates were identified using methods described by Cheesbrough [22]. Similarly, fungal isolates were identified using the method described by Frazier and WestHoff [23]. Macroscopic and Microscopic Atlas were also used as a reference.

2.3. Statistical Analysis

Average of duplicate results of microbial counts of each sample evaluated for each group of microorganisms was determined. Values obtained were analyzed using One-way ANOVA by comparing the mean and standard error. A probability value at p = .05 was considered as being statistically different.

3. Results

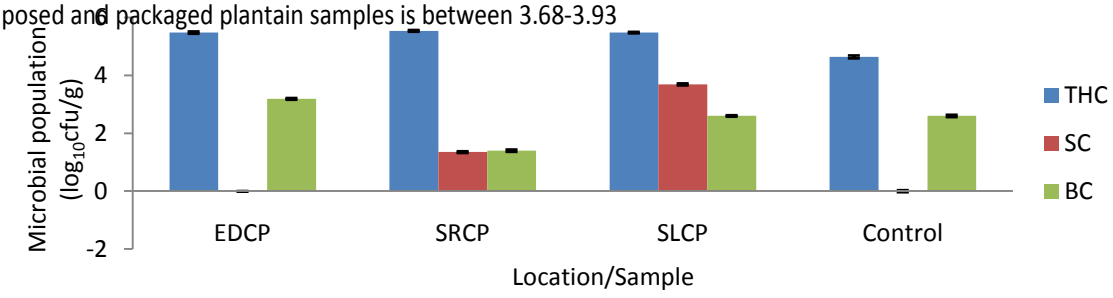
The result presented in Figure 1 and Figure 2 shows that total heterotrophic count in exposed and packaged cassava flour obtained from three markets and supermarkets, respectively in Port Harcourt metropolis was quite high. In exposed and packaged cassava flour, it ranges between 5.56-5.82 and 5.48-5.54 $\log_{10}$cfu/g, respectively. *Bacillus* sp. and *Staphylococcus* sp were detected in the cassava flour samples.



Key: RO, OM and MT are open markets; C- Exposed cassava flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count

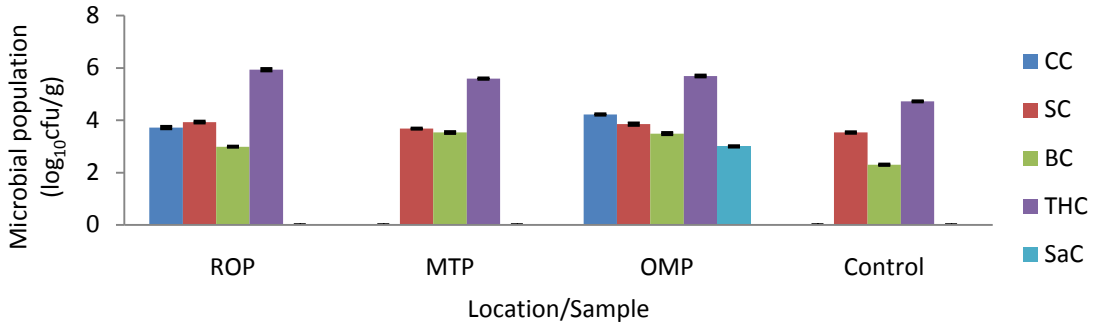
Figure 1. Microbial load of exposed cassava flour obtained from three open markets

posed and packaged plantain samples is between 3.68-3.93



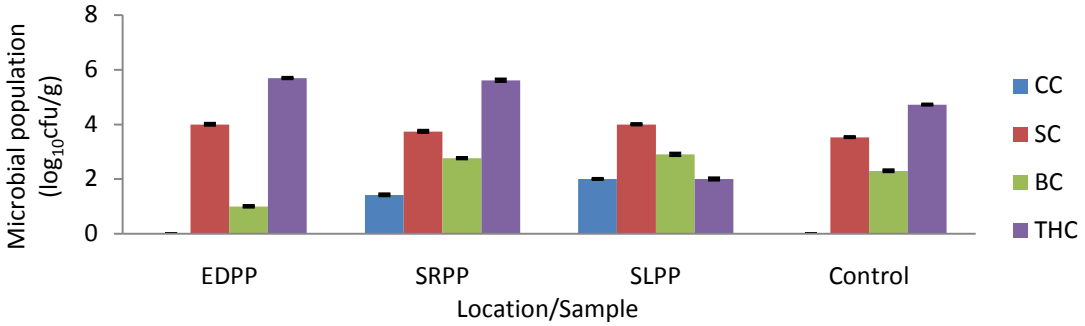
Key: ED, SR and SL are supermarkets; CP - Packaged cassava flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count

Figure 2. Microbial load of packaged cassava flour obtained from three supermarkets



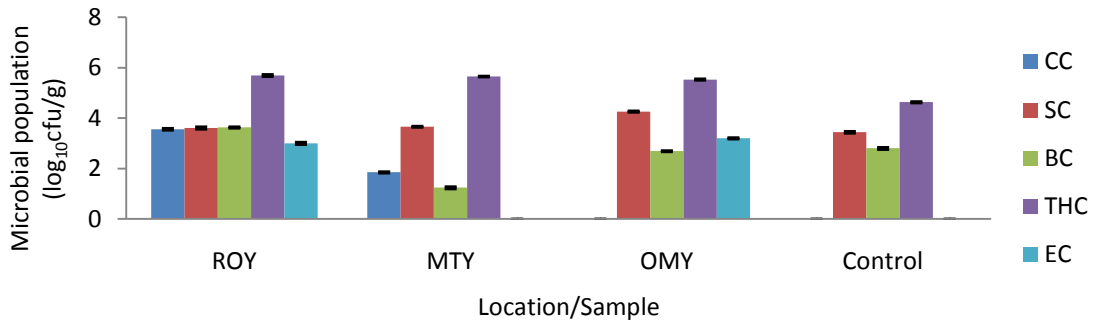
Key: RO, OM and MT are open markets; P- Exposed plantain flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count; CC – Coliform count; SaC-*Salmonella* count.

Figure 3. Microbial load of exposed plantain flour samples from three open markets



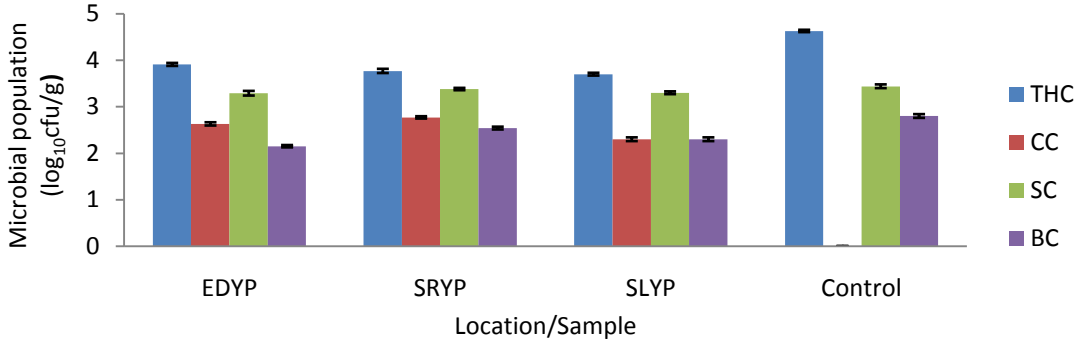
Key: ED, SR and SL are supermarkets; CP -packaged plantain flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count; CC – Coliform count

Figure 4. The microbial load of packaged plantain flours from three supermarkets



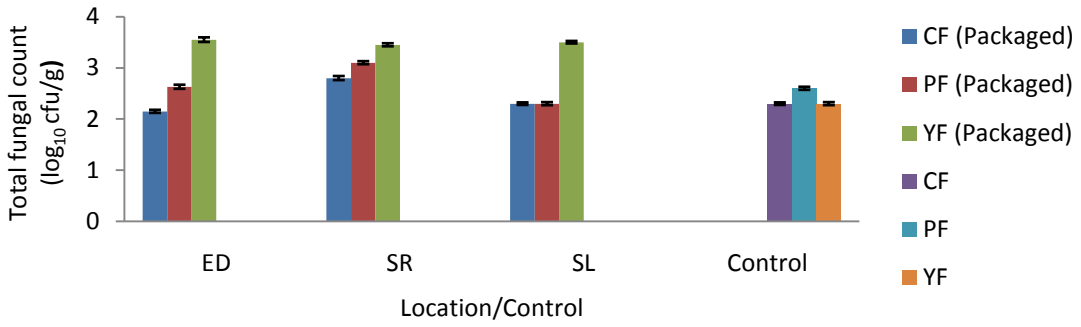
Key: RO, OM and MT are open markets; Y - Exposed yam flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count; EC-*Escherichia coli* count; CC – Coliform count

Figure 5. Microbial load of exposed yam flours from three open markets



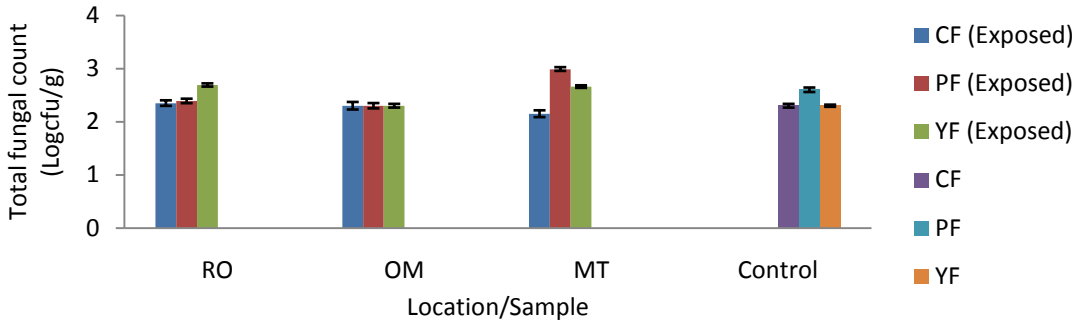
Key: ED, SR and SL are supermarkets; YP - Packaged yam flour; SC –*Staphylococcal* count; BC- *Bacillus* count; THC- Total heterotrophic count; CC – Coliform count.

Figure 6. Microbial load of packaged yam flour from three supermarkets



Key: ED, SR and SL are supermarkets; CF-Cassava flour; PF-Plantain flour; YF-Yam flour

Figure 7. Total fungal count of packaged flours from three supermarkets



Key: RO, OM and MT are open markets; CF-Cassava flour; PF-Plantain flour; YF-Yam flour;

Figure 8. Total fungal count of exposed flours from three open markets

Table 1. Average microbial population in cassava flour compared with control sample

Cassava flour	THC	TFC	*Staphylococcal* sp.	*Bacillus* count
CF (exposed)	5.65 ± 0.25^{c}	2.27±0.03^{a}	3.66±0.035^{b}	2.41±0.05^{a}
CF (Packaged)	5.50± 0.02^{b}	2.42±0.04^{b}	3.23±0.04^{a}	2.52±0.015^{a}
Control	4.64±0.20^{a}	2.30±0.02^{a}	3.51±0.05^{b}	2.60±0.04^{a}

Values are duplicates of samples. Mean scores with same superscripts down the column are not significant at p=0.05, while others with different superscripts are significant. Where: THC=Total heterotrophic count; TFC=Total fungal count; CF= Cassava flour; Control = cassava flour prepared in the laboratory.

Table 2. Average microbial population in plantain flour compared with control sample

Plantain flour	THC	TFC	*Staphylococcal* count	*Bacillus* count
PF (exposed)	5.74 ± 0.25^{b}	2.56±0.05^{a}	3.00±0.03^{a}	3.34±0.02^{b}
PF (Packaged)	4.43± 0.18^{a}	2.68±0.03^{a}	3.91±0.01^{b}	2.22±0.04^{a}
Control	4.72±0.02^{a}	2.60±0.03^{a}	3.53±0.08^{a}	2.30±0.02^{a}

Values are duplicates of samples. Mean scores with same superscripts down the column are not significant at p=0.05, while others with different superscripts are significant. Where: THC=Total heterotrophic count; TFC=Total fungal count; PF= Plantain flour; Control = Plantain flour prepared in the laboratory.

Table 3. Average microbial population in yam flour compared with control sample

Yam flour	THC	TFC	*Staphylococcal* count	*Bacillus* count
YF (exposed)	5.62 ± 0.25^{c}	2.55±0.02^{b}	3.84±0.03^{a}	2.52±0.02^{a}
YF (Packaged)	3.79± 0.03^{a}	3.49±0.01^{c}	3.32±0.07^{a}	2.33±0.04^{a}
Control	4.63±0.04^{b}	2.3±0.04^{a}	3.44±0.18^{a}	2.80±0.02^{a}

Values are duplicates of samples. Mean scores with same superscripts down the column are not significant at p=0.05, while others with different superscripts are significant. Where: THC=Total heterotrophic count; TFC=Total fungal count; YF= Yam flour; Control = Yam flour prepared in the laboratory.

Figure 3 and Figure 4 shows that total heterotrophic count in exposed and packaged plantain flour was quite high except packaged plantain flour obtained from the supermarket 'SL' which was 2 log_{10}cfu/g. *Staphylococcus* sp., Coliforms and *Bacillus* sp. were detected in the plantain flour (exposed and packaged) samples. The range of *Staphylococcal*

count in the exposed and packaged plantain samples is between 3.68-3.93 and 3.74 - 4.0 log_{10}cfu/g, respectively. However, 3 log_{10}cfu/g *Salmonella* sp. was detected only in exposed plantain flour in one of the markets.

The microbial load in exposed and packaged yam flour is presented in Figure 5 and Figure 6, respectively. The total heterotrophic count was quite high in the exposed edible flour samples which range between 5.53-5.69 log_{10}cfu/g but lower in packaged yam flour samples which was between 3.70-3.91 log_{10}cfu/g. *Staphylococcus* sp., coliforms and *Bacillus* sp. were present in exposed and packaged plantain flour samples. However, *Escherichia coli* were detected only in exposed plantain flour samples obtained from two out of the three markets surveyed.

Figure 7 shows the total fungal count (TFC) in packaged cassava, yam and plantain flour samples. The results show that TFC of packaged yam flour was higher than that of packaged cassava and plantain flour obtained from the three supermarkets. In Figure 8, the TFC of exposed cassava, yam and plantain flour samples as well as that of control samples are reported. In one of the markets 'OM', the TFC of the flour samples recorded same total fungal count 2.3log_{10}cfu/g. The TFC of exposed yam and plantain flour obtained from open markets 'RO' and 'MT', respectively was higher than that of other exposed flour samples from the two markets. Among the control samples, plantain flour recorded the highest fungal count of 2.6 log_{10}cfu/g.

The results presented in Table 1 - Table 3 compares average microbial load in exposed and packaged cassava, plantain and yam flour with that of control samples.

4. Discussion

This study revealed that population of different categories of microorganisms present in exposed cassava, plantain and yam flour samples were higher than that of similar packaged flour samples with few exceptions. On average, higher microbial load in exposed flour samples compared with similar packaged flour samples could be as a result of exposing cassava, plantain and yam flour to atmosphere filled with numerous and diverse microorganisms, indiscriminate touching of the products with bare hands during retailing and contact with other contaminating materials. High level of hygiene during processing of cassava, yam and plantain flour as control samples could be responsible for minimal variation of microbial population (total heterotrophic count, total fungal count, *Bacillus* and *Staphylococcal* count) among the flour samples represented in Table 1, Table 2 and Table 3.

Results obtained from this study also revealed that four bacterial species were isolated from exposed and packaged cassava, plantain and yam flour samples which are *Bacillus* sp., *Escherichia coli*, *Staphylococcus* sp. and *Salmonella* sp. This result is in agreement with bacteria genera isolated from plantain flour retailed at Urban market in Ondo state, Nigeria [16]. In another related study, Gacheru *et al*. [5] reported that *Staphylococcus* sp. and *Esherichia coli* were present in cassava flour sold in Nairobi and coastal regions in Kenya. Omohimi *et al.* [4] in a related study reported that *Staphylococcus* sp. and *Escherichia coli* were present in yam flour. According to International Commission on Microbiological Specification for Food (ICMSF), total bacterial count in food should not exceed 1 x 10^6 cfu/g; *Staphylococcus aureus* should not exceed 1 x 10^5 cfu/g and total coliforms should not exceed 1 x 10^4 cfu/g [4]. Based on ICMSF specification, total heterotrophic count of exposed and packaged cassava, plantain and yam flour were very close to recommended safe limits. Considering *Staphylococcal* and total coliform count in cassava, plantain and yam flour samples, the values obtained were within the range recommended by ICMSF [24]. According to Standards Codex 176-1989, EAS 7740:2010, EAS 739:2010 acceptable microbiological limits for cassava flour based on total viable count, mould and *Staphylococcus aureus* is 5.00 log_{10} cfu/g, 3.00 log_{10} cfu/g and 2.00 log_{10}cfu/g, respectively. Based on the results from this study, both packaged and exposed cassava flour did not meet the standard for total viable count and *Staphylococcal* count. This result is in agreement with a similar study conducted by Gacheru *et al.* [5]. Therefore, processing of cassava flour should involve hygienic practices and the final product need to be packaged before retailing the product in order to drastically reduce microbial contamination.

Escherichia coli which range between 3.0-3.2 log_{10}CFU/g was detected only in exposed yam flour obtained from 2 out of 3 markets in Port Harcourt metropolis. This is an indication that health hazard could occur if the public consume these products directly without further treatment [25]. Frequency of occurrence of *Escherichia coli* in yam flour was 10 %. Unnecessary handling of yam flour with bare hands during retailing of the product could have resulted in contamination of yam flour with *Escherichia coli*. Somorin *et al*. [10] in a related study reported the presence of *Escherichia coli* in white yam flour.

The total heterotrophic count, total fungal count, *Bacillus* count and *Staphylococcal* count which ranges were between 4.63-4.72 log_{10}cfu/g, 2.3-2.6 log_{10}cfu/g, 2.3-2.8 log_{10}cfu/g and 3.44-3.51 log_{10}cfu/g, respectively were present in cassava, plantain and yam flour which were control samples. It is interesting to note that *Salmonella* sp., coliforms and *Escherichia coli* that were present in some samples of exposed and packaged cassava, plantain and yam flour were not detected in the control samples. This could be as a result of hygienic practices involved during processing of cassava, yam and plantain flour in the laboratory. Statistical analysis in Table 1 - Table 3 revealed that total heterotrophic count, total fungal count, *Staphylococcal* and *Bacillus* count of packaged cassava, plantain and yam flour is not significantly different from that of the control flour samples with few exceptions. Packaging of the flour samples could be responsible for reduction of microbial contamination of the products to a level comparable with that of control flour samples prepared under hygienic conditions in the laboratory. This study further revealed that the control samples had a relatively lower total viable count than similar flour samples obtained from three open markets and three supermarkets in Port Harcourt metropolis which were either exposed or packaged. Djeri *et al*. [26] reported similar findings from a related study. That notwithstanding, packaged and exposed cassava, plantain and yam flour as well as the control samples

recorded relatively high microbial count. This result is in agreement with the findings of Omohimi *et al.* [4] from a related study.

5. Conclusion

Packaged and exposed cassava, yam and plantain flour available in some markets and supermarkets is considered not to be microbiologically safe because of microbial load and population of some pathogenic microorganisms present in the products. Therefore, strict implementation of good manufacturing practices during cassava, plantain and yam flour processing and packaging of the edible flours displayed in the markets is recommended. This could go a long way in reducing public health risk posed by consuming microbial contaminated edible flours.

Competing Interests

Authors have declared that no competing interests exist.

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