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MICROBIOLOGICAL QUALITY ASSESSMENT OF DRIED YAM CHIPS *(Dioscorea rotundata)* DURING STORAGE

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ABSTRACT

Microbiological and physico-chemical analyses of dried yam chips (gbodo) retailed in four markets in Ilorin and its environs alongside a laboratory – prepared control were carried out over a six month period. Microbiological assay consisted of total viable and coliform counts as well as microbial isolation. A total of 11 fungi and 5 bacteria were isolated from the different samples which included *Acremonium* sp., *Aspergillus fumigatus*., *A. niger, A. ochraceus, Fusarium solani, Mucor hiemalis, Mucor racemosus, Penicillum notatum, Rhizopus oryzae, Rhizopus stolonifer, Syncephalastrum racemosum* and *Bacillus cereus, Bacillus subtilis, Erwinia carotovora, Escherichia coli* and *Staphylococcus aureus* respectively. Total Viable Counts ranged from 3.0-120.0 cfu g^{-1} and coliform counts ranged from 0.00 - 18.80 cfu g^{-1} pre-storage to 0.10-219 cfu g^{-1} and 0.0-31.0 cfu g^{-1} post storage respectively. The physico-chemical parameters analysed were moisture content which ranged between 14.38-17.10% pre-storage to 13.43-24.96% post-storage; crude protein: 5.81-7.53% and 2.11-6.75%; crude fat: 0.35-0.71% and 0.07-0.61%; ash content: 3.30-5.18% and 1.17-4.77%; crude fibre: 0.77-1.45%; carbohydrate: 70.18-74.00% and 70.93-75.17% pre-storage and post-storage content respectively. Levels of Aflatoxin B_1 were also monitored throughout the storage period. Insect infestation of the samples occurred during the storage period. Four species were identified; these were *Tribolium casteneum, Dinoderus porcellus, Rhyzopertha dominica* and *Sitophilus zeamais.* The traditional practice of open air sun-drying of yam chips should be discouraged, rather oven drying is recommended to minmize microbial contamination. In addition, sorting to exclude extreneous material and minimize mouldiness and insect infestation is suggested.

Keywords: Dried yam chips, elubo, storage, gbodo

INTRODUCTION

White yam (*Dioscorea rotundata* Poir) is a staple food in West Africa and is a good source of carbohydrates and nutrient energy. West Africa is the most important yam-producing region in the world and Nigeria produces over 26.6 million metric tonnes of yam annually to account for over 75% of the world's production of the crop (**FAO, 2005**). Other main yam producers are Cote d'Ivoire (8.1%), Benin (4.3%) and Ghana (3.5%). About 20-25% of harvested yams in Nigeria and some parts of West Africa are converted into yam chips/ flour (**Onayemi and Idowu, 1988; Akissoe *et al.*, 2005; Ogunlade *et al.*, 2010**). Lack of adequate storage facilities leads to rapid physiological and microbiological deterioration of tuber leading to weight losses up to 60% in 9 months (**Mestres *et al.*, 2004a**). To prevent heavy losses fresh yam tubers are processed to dried yam chips. The tubers are peeled, sliced to a thickness of about 10mm or less depending on the dryness of the weather; the slices are then parboiled in water at about 63±3^{0}C and sun dried for 5-7 days (**Mestres *et al.*2004a; Jonathan *et al.*, 2011**). While dried yam chips are more storage stable than the yam tubers, a major problem faced by the storage of the dried yam chips is deterioration mainly due to fungal contamination which have food safety considerations if the moulds are toxigenic.

Among the 18 different types of aflatoxins which have been identified, Aflatoxin B_1 (AFB_1) exists predominantly in food products (**Jonathan *et al.*, 2011**). The occurrence of AFB_1 has been identified in some food items sold in African markets such as 'gari', cassava flour, dry yam chips, maize flour etc with concentrations sometimes above tolerance level (**Mestres *et al.*, 2004b; Okigbo and Nwakammah, 2005**).

The objective of our study was to investigate the nutrient, microbiological, Aflatoxin B_1 contents and insect infestations of dried yam chips purchased from four different markets in Ilorin Nigeria and monitor them for a six month storage period.

MATERIAL AND METHODS

Collection of samples and preparation for storage

Dried yam chip samples were obtained from 4 markets Ipata (IP), Ganmo (GM), Oja-tutun (OT) and Ago (AG) in Ilorin and its environs. A laboratory sample was prepared to serve as control (CTRL). Ten (10) kg of each of the yam chip samples were packed into clean, new, polypropylene bags separately and sealed. The samples were stored at room temperature 28±2^{0}C for six months. At the expiration of the 6 months storage, another dried yam chip sample was purchased from the market to serve as an additional control (PC).

Physicochemical Analysis

The yam chip samples were subjected to physicochemical analysis at two week intervals until the end of the storage period. Representative samples were thereafter taken fortnightly from the stored samples an analyzed. Moisture, ash, crude protein, crude fibre, fat and Aflatoxin B_1 were determined using the methods of **AOAC (2005)**, while the carbohydrate was calculated by difference **(AOAC, 2005)**.

Microbiological Analysis

Microbial isolation was carried out using the method of **Fawole and Oso (2004)** and **Bell *et al.* (2005)**. One gram of each sample was ground in a porcelain mortar and pestle, this was then suspended in sterile distilled water and streaked on to the surface of sterile Nutrient agar (NA) and Potato Dextrose agar (PDA) for bacteria and fungi respectively. Total viable and coliform counts were carried out using serial dilutions of the ground samples the pour plate technique.

Post-storage Analysis

After the 6-month storage period, a positive control sample (PC) was purchased and analyzed along with other stored samples and the results were compared using the paired sampled T-test.

RESULTS AND DISCUSSION

The proximate composition of the dried yam chip samples before storage showed the moisture contents of samples ranged from 14.38-17.10%, the control sample had the least moisture while the AG sample had the highest moisture content. Protein and carbohydrate contents also ranged between 7.53% (IP sample) – 5.81% (AG sample) and 70.18% (IP sample) - 74.0% (control sample) respectively (Table 1). Results of this proximate composition confirm the food value of dried yam chips and generally conform to food values reported by earlier workers **(Akingbade *et al.*, 1995; Jimoh and Olatidoye, 2009; Jonathan *et al.*, 2011**). However **Jonathan *et al.* (2011)** reported the absence of crude fat in his samples. The Aflatoxin B_1 content of all the samples is also recorded as less than 2ppb which is within the Nigerian Industrial Standards and CODEX standards respectively (**NIS, 2004**). The pre-storage samples did not show any visible signs of insect infestation. The microbiological assay of the samples revealed the presence of 17 microbial types consisting of 11 fungi and 5 bacteria (Table 2b, Fig. 1, Fig. 2). The predominance of moulds is attributed to the low moisture content of the samples. The isolated fungi were Acremonium sp., *Aspergillus fumigatus, A. niger, A. ochraceus, Fusarium solani, Mucor hiemalis, Mucor racemosus, Penicillum notatum, Rhizopus oryzae, Rhizopus stolonifer* and *Syncephalastrum racemosum.* The source of these organisms can be traced to contamination during processing which included direct exposure to the atmosphere during sundrying, handling and direct contact with other agricultural products in the market during retailing. Microorganisms such as *Mucor racemosus, P. varioti, P. notatum, Fusarium* sp., *R. stolonifer* as well as a wide variety of *Aspergillus* spp. including *A, flavus, A. fumigatus, A. niger, A. japonium, A. parasiticus, A. ochraceus, A. tamari* and *A. terreus* have been isolated from dried yam chips (**Ekundayo, 1986; Aboaba and Amisike, 1991; Bankole and Adebanjo, 2003; Bankole and Mabekoje, 2004; Babajide *et al.* 2006; Djeri *et al.* 2010**). *Bacillus cereus* and *B. subtilis* which are mesophilic spore formers, *S. aureus* and *E. carotovora* were also isolated from the samples. The presence of these organisms can be attributed to contamination by air and soil microorganisms during processing. The presence of *E.coli* is thought to be due to unhygienic practices during processing or the use of poor quality water for processing. **Djeri *et al.* (2010)** reported the presence of *Bacillus* spp., coliforms and moulds in dried yam chip samples in Togo. **Bankole and Adebanjo, (2003); Bankole and Mabekoje, (2004)** and **Babajide *et al.* (2006)** also reported coliforms in yam chips.

Moisture content of all the samples reduced significantly up to the 6th week of storage. CTRL (14.37 to 12.98%), IP (16.04 to 13.65%), GM (15.88 to 13.50%), OT (14.40 to 13.02%), and AG (17.01 to 15.06%) and later increased gradually over the weeks (Table 3). **Akaninwor and Sodje (2005**) reported that moisture content of dried yam chips increased generally over the period of storage. This initial reduction in moisture content may be attributed to dry climatic conditions over the first few weeks of storage which was harmattan/dry season (late November to January with low relative humidity) which caused the samples to lose moisture rather than increase in moisture content. This initial reduction in moisture may be the cause of the initial increase in content of other nutrients (Tables 4-8) before they started to reduce gradually over the remainder of the storage period. Protein, carbohydrate, fat and total ash content of the samples reduced gradually but significantly in all samples over the storage period (Tables 4,5,6,7 &8). The reduction in these constituents is not unexpected due to both physiological deterioration and also microbial utilization.Root and tuber crops may record fresh weight losses up to 60% by 9 months after stotage (**Mozie, 1988**) and up to 60 – 70% loss of consumable dry matter after 10 months of storage (**Girardin *et al., 1998***) However, the reduction was more pronounced in samples AG and OT. This was probably because these two samples (AG and OT) had the highest moisture contents, which in turn supported the high microbial growths (Table 2a, 3, 10). Moisture contents above 15% are reported to be above safe levels and are known to encourage the growth of moulds (**Agboola, 1982; Odeyemi and Daramola, 2000; Kuku *et al.*, 1980**). Samples AG and OT were the only two samples that showed visible signs of insect infestation (Table 11). Sample AG was infested with insects by the 6th week, while sample OT was infested by the 14th week. The insects found in these samples were *Tribolium casteneum, Dinoderus porcellus, Rhyzopertha dominica* and *Sitophilus zeamais.* These insects together with the moulds and bacteria metabolized the nutrients in the stored samples for their growth (Tables 4-8). The high moisture content of samples AG and OT occasioned by insect infestation is in line with **Danjuma (2004)** who reported that after infestation of dried yam chips by *Prostephanus truncatus* and *Araecerus fasciculatus*, the moisture content increased significantly. After insect infestation, the samples changed from light brown to dark brown and the chips became brittle and crumbled when subjected to slight pressure by the 20th week of storage. This also correlates with the report of **Adebiyi (2008)** that deterioration of stored products can bring about changes in colour, texture and taste and that stored products lose their natural luster and become rather dull in appearance due to the activities of the agents of deterioration.

Analysis of the samples for the presence of Aflatoxin B_1 showed <2ppb for all the samples over the storage period. The relatively low levels of AFB_1 may be due to the low occurrence of *Aspergillus* spp. in the samples. In addition, most of the period of this study fell within the dry season when the relative humidity was as low. Yam chips produced in the rainy season have poor hygienic quality. The chips are usually not well dried as the drying period is often interrupted by rain (**Djeri *et al.*, 2010**). The production of AFB_1 is usually occasioned by high moisture contents and relative humidity (**Shephard, 2005**). When the proximate composition of the post storage control (PC) sample was compared with that of the other samples after storage (Table 9), using the paired sample t-test, it was found that there was no significant difference. This shows that processing is the vital period during which contaminants penetrate the yam chips and these multiply during drying and storage.

Table 1 Pre-storage proximate composition and aflatoxin content of yam chip samples

Samples	Moisture Content (%)	Protein Content (%)	Crude Fat Content (%)	Total Ash content (%)	Crude Fibre Content (%)	Carbohydrate Content (%)	Aflatoxin B_1 (ppb)
CTRL	14.38 ± 0.06^{a}	6.20 ± 0.03^{c}	0.37 ± 0.01^{a}	3.65 ± 0.01^{b}	1.45 ± 0.01^{e}	74.00 ± 0.11^{d}	<2
IP	16.04 ± 0.74^{ab}	7.53 ± 0.04^{e}	0.71 ± 0.01^{c}	4.33 ± 0.04^{c}	1.27 ± 0.02^{d}	70.18 ± 0.08^{a}	<2
GM	15.88 ± 0.17^{ab}	5.93 ± 0.01^{b}	0.55 ± 0.01^{b}	4.24 ± 0.05^{c}	0.77 ± 0.01^{a}	72.85 ± 0.33^{c}	<2
OT	14.40 ± 1.44^{a}	6.60 ± 0.03^{d}	0.52 ± 0.01^{b}	5.18 ± 0.04^{d}	1.04 ± 0.01^{c}	72.25 ± 0.07^{b}	<2
AG	17.10 ± 0.74^{b}	5.81 ± 0.01^{a}	0.35 ± 0.07^{a}	3.30 ± 0.14^{a}	0.82 ± 0.02^{b}	72.55 ± 0.07^{bc}	<2

Results are presented as content mean $\pm$ standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun matket, AG- Ago market

Table 2a Microbial count of yam chip samples before storage

Sample	Total Colony Count (TCC) 10^4 cfu/g	Total Coliform Count 10^4 cfu/g
CTRL	3.0	0.0
IP	3.2	1.90
GM	91.0	1.83
OT	7.0	0.0
AG	120.0	18.8

Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun matket, AG- Ago market

Table 2b Occurrence of isolated microorganisms in dried yam chip samples

Microorganism	Source of Isolate Pre-storage	Source of Isolate Post-storage
Aspergillus fumigatus	CTRL	CTRL, IP, GM, OT, AG, PC
Aspergillus niger	AG,	AG, OT, GM
Mucor racemosus	CTRL, OT,	OT, AG, PC
Rhizopus stolonifer	IP,	CTRL, IP
Syncephalastrum racemosum	GM,	GM, OT, AG
Acremonium sp.	OT,	OT
Rhizopus oryzae	AG,	CTRL, IP, GM, OT, AG, PC
Mucor hiemalis		CTRL, IP, GM, OT, AG
Aspergillus ochraceus		IP, GM, OT, AG
Fusarium solani		IP, OT, AG
Penicillium notatum		OT
Bacillus cereus	IP, GM, OT,	IP, GM, OT
Bacillus subtilis	CTRL, IP, AG,	CTRL, IP, GM, OT, AG, PC
Erwinia carotovora	OT, AG,	OT, AG
Escherichia coli	AG,	AG,PC
Staphylococcus aureus		OT, AG, PC

Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market, PC- Post storage sample

Table 3 Moisture content of yam chip samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES (Moisture %) CTRL	IP	GM	OT	AG
2	14.22 ± 0.03^{d}	14.82 ± 0.59^{b}	14.62 ± 0.74^{c}	14.35 ± 0.01^{bcd}	16.11 ± 0.01^{b}
4	12.94 ± 0.20^{a}	13.66 ± 0.27^{a}	13.43 ± 0.04^{a}	14.31 ± 0.04^{bcd}	15.10 ± 0.01^{a}
6	12.98 ± 0.08^{a}	13.65 ± 0.14^{a}	13.50 ± 0.04^{a}	13.02 ± 0.03^{a}	15.56 ± 0.60^{ab}
8	13.23 ± 0.12^{bc}	13.63 ± 0.16^{a}	13.64 ± 0.06^{ab}	13.69 ± 0.04^{ab}	15.93 ± 0.20^{b}
10	13.33 ± 0.10^{bc}	13.72 ± 0.17^{a}	13.77 ± 0.17^{ab}	13.88 ± 0.11^{abc}	15.99 ± 0.27^{b}
12	13.21 ± 0.03^{b}	13.87 ± 0.01^{a}	13.83 ± 0.06^{ab}	14.74 ± 0.01^{cd}	15.07 ± 0.02^{a}
14	13.23 ± 0.14^{bc}	13.89 ± 0.01^{a}	13.90 ± 0.00^{ab}	14.87 ± 0.03^{d}	15.96 ± 0.05^{b}
16	13.32 ± 0.02^{bc}	13.91 ± 0.01^{a}	13.92 ± 0.01^{ab}	15.03 ± 0.10^{de}	16.10 ± 0.15^{b}
18	13.33 ± 0.00^{bc}	13.95 ± 0.02^{a}	13.93 ± 0.03^{ab}	15.11 ± 0.01^{de}	16.22 ± 0.04^{b}
20	13.35 ± 0.01^{bc}	13.97 ± 0.01^{a}	13.96 ± 0.01^{ab}	15.84 ± 0.10^{ef}	18.67 ± 0.58^{d}
22	13.41 ± 0.01^{bc}	14.05 ± 0.03^{a}	14.05 ± 0.09^{b}	16.21 ± 0.13^{f}	20.12 ± 0.50^{e}
24	13.43 ± 0.03^{c}	14.10 ± 0.00^{a}	14.08 ± 0.13^{b}	18.80 ± 0.04^{g}	24.96 ± 0.07^{f}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 4 Protein content of yam chip samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES CTRL	IP	GM	OT	AG
2	6.13 ± 0.03^{c}	7.06 ± 0.03^{b}	5.93 ± 0.01^{b}	6.52 ± 0.01^{i}	5.30 ± 0.01^{j}
4	6.09 ± 0.01^{bc}	6.75 ± 0.01^{a}	6.01 ± 0.01^{c}	6.44 ± 0.01^{h}	4.93 ± 0.04^{i}
6	6.09 ± 0.03^{bc}	6.76 ± 0.01^{a}	6.22 ± 0.00^{d}	5.44 ± 0.01^{g}	4.80 ± 0.01^{h}
8	6.09 ± 0.00^{bc}	6.78 ± 0.01^{a}	6.39 ± 0.03^{e}	4.23 ± 0.03^{f}	5.92 ± 0.03^{i}
10	6.09 ± 0.01^{bc}	6.79 ± 0.01^{a}	6.39 ± 0.06^{e}	4.15 ± 0.01^{e}	4.62 ± 0.01^{g}
12	6.09 ± 0.00^{bc}	6.80 ± 0.00^{a}	6.39 ± 0.01^{e}	4.05 ± 0.01^{d}	4.59 ± 0.03^{g}
14	6.09 ± 0.03^{bc}	6.80 ± 0.01^{a}	6.39 ± 0.01^{e}	4.00 ± 0.00^{c}	4.45 ± 0.01^{f}
16	6.07 ± 0.01^{b}	6.77 ± 0.03^{a}	6.37 ± 0.06^{e}	3.97 ± 0.01^{c}	4.39 ± 0.01^{e}
18	6.07 ± 0.00^{b}	6.75 ± 0.03^{a}	6.34 ± 0.01^{e}	3.97 ± 0.03^{c}	4.33 ± 0.01^{d}
20	6.02 ± 0.03^{a}	6.77 ± 0.04^{a}	6.01 ± 0.03^{c}	3.90 ± 0.01^{b}	4.12 ± 0.00^{c}
22	6.02 ± 0.03^{a}	6.77 ± 0.01^{a}	5.99 ± 0.01^{bc}	3.87 ± 0.01^{b}	3.60 ± 0.04^{b}
24	6.00 ± 0.01^{a}	6.75 ± 0.03^{a}	5.42 ± 0.03^{a}	3.66 ± 0.01^{a}	2.11 ± 0.01^{a}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 5 Crude fat content of yam chip samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES (Fat %) CTRL	IP	GM	OT	AG
2	0.42 ± 0.03^{b}	0.70 ± 0.04^{d}	0.56 ± 0.01^{cd}	0.50 ± 0.00^{fg}	0.33 ± 0.03^{gh}
4	0.58 ± 0.04^{c}	0.60 ± 0.00^{c}	0.59 ± 0.01^{d}	0.50 ± 0.03^{fg}	0.30 ± 0.01^{fgh}
6	0.60 ± 0.04^{cd}	0.53 ± 0.03^{ab}	0.56 ± 0.01^{cd}	0.45 ± 0.07^{ef}	0.27 ± 0.00^{efg}
8	0.67 ± 0.00^{e}	0.58 ± 0.03^{bc}	0.50 ± 0.00^{b}	0.39 ± 0.01^{de}	0.23 ± 0.04^{def}
10	0.65 ± 0.01^{de}	0.58 ± 0.03^{bc}	0.50 ± 0.01^{b}	0.38 ± 0.01^{cd}	0.20 ± 0.03^{cde}
12	0.64 ± 0.01^{de}	0.60 ± 0.00^{c}	0.50 ± 0.00^{b}	0.35 ± 0.03^{bcd}	0.19 ± 0.03^{cd}
14	0.64 ± 0.01^{de}	0.60 ± 0.00^{c}	0.50 ± 0.01^{b}	0.33 ± 0.03^{abcd}	0.17 ± 0.03^{bcd}
16	0.64 ± 0.00^{de}	0.60 ± 0.01^{c}	0.50 ± 0.00^{b}	0.32 ± 0.02^{abc}	0.17 ± 0.04^{bcd}
18	0.62 ± 0.01^{cde}	0.59 ± 0.01^{c}	0.48 ± 0.03^{b}	0.31 ± 0.03^{ab}	0.15 ± 0.00^{bc}
20	0.61 ± 0.01^{cd}	0.57 ± 0.03^{abc}	0.48 ± 0.01^{b}	0.31 ± 0.03^{ab}	0.13 ± 0.03^{abc}
22	0.60 ± 0.00^{cd}	0.57 ± 0.03^{abc}	0.48 ± 0.03^{b}	0.30 ± 0.00^{ab}	0.11 ± 0.00^{ab}
24	0.61 ± 0.01^{cd}	0.52 ± 0.01^{a}	0.44 ± 0.03^{a}	0.28 ± 0.03^{a}	0.07 ± 0.01^{a}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 6 Total ash content of samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES (ASH %)				
	CTRL	IP	GM	OT	AG
2	3.92 ± 0.00^{d}	4.55 ± 0.03^{f}	4.68 ± 0.45^{i}	5.19 ± 0.04^{i}	3.77 ± 0.08^{e}
4	4.03 ± 0.04^{f}	4.83 ± 0.01^{j}	5.05 ± 0.01^{k}	3.81 ± 0.12^{a}	3.97 ± 0.01^{f}
6	4.03 ± 0.04^{f}	4.80 ± 0.04^{i}	5.00 ± 0.06^{j}	4.50 ± 0.11^{b}	4.01 ± 0.23^{h}
8	4.05 ± 0.01^{g}	4.62 ± 0.01^{h}	4.57 ± 0.09^{f}	4.93 ± 0.02^{d}	4.08 ± 0.07^{i}
10	4.05 ± 0.01^{g}	4.61 ± 0.03^{g}	4.58 ± 0.03^{g}	4.97 ± 0.01^{e}	4.30 ± 0.05^{l}
12	4.06 ± 0.04^{h}	4.61 ± 0.04^{g}	4.59 ± 0.05^{h}	5.02 ± 0.04^{g}	4.23 ± 0.06^{k}
14	4.06 ± 0.04^{h}	4.61 ± 0.04^{g}	4.59 ± 0.01^{h}	5.02 ± 0.02^{g}	4.21 ± 0.17^{j}
16	4.02 ± 0.06^{e}	4.61 ± 0.04^{g}	4.52 ± 0.01^{e}	5.00 ± 0.01^{f}	4.21 ± 0.17^{j}
18	4.02 ± 0.06^{e}	4.53 ± 0.06^{e}	4.51 ± 0.00^{d}	5.00 ± 0.01^{f}	3.99 ± 0.01^{g}
20	3.78 ± 0.07^{c}	4.44 ± 0.01^{d}	4.32 ± 0.01^{c}	5.00 ± 0.01^{f}	2.79 ± 0.00^{c}
22	3.60 ± 0.04^{a}	4.30 ± 0.00^{b}	4.19 ± 0.03^{a}	5.00 ± 0.01^{f}	2.31 ± 0.10^{b}
24	3.60 ± 0.01^{a}	4.29 ± 0.02^{a}	4.19 ± 0.03^{a}	4.77 ± 0.07^{c}	1.17 ± 0.01^{a}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 7 Crude fibre content of samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES				
	CTRL	IP	GM	OT	AG
2	1.44 ± 0.00^{a}	1.30 ± 0.04^{c}	0.75 ± 0.01^{c}	1.10 ± 0.04^{c}	0.88 ± 0.02^{d}
4	1.45 ± 0.01^{b}	1.59 ± 0.06^{g}	0.75 ± 0.01^{b}	1.13 ± 0.01^{e}	0.95 ± 0.03^{f}
6	1.44 ± 0.00^{a}	1.59 ± 0.00^{g}	0.95 ± 0.02^{g}	1.23 ± 0.02^{h}	0.93 ± 0.03^{e}
8	1.45 ± 0.01^{b}	1.59 ± 0.00^{g}	0.95 ± 0.02^{g}	1.23 ± 0.02^{h}	0.75 ± 0.00^{b}
10	1.45 ± 0.01^{b}	1.58 ± 0.04^{f}	0.94 ± 0.01^{f}	1.23 ± 0.02^{h}	0.75 ± 0.00^{b}
12	1.45 ± 0.01^{b}	1.58 ± 0.04^{f}	0.93 ± 0.01^{e}	1.23 ± 0.02^{h}	0.75 ± 0.00^{b}
14	1.45 ± 0.01^{b}	1.51 ± 0.01^{e}	0.81 ± 0.04^{d}	1.21 ± 0.03^{f}	0.71 ± 0.01^{a}
16	1.45 ± 0.01^{b}	1.32 ± 0.04^{d}	0.76 ± 0.01^{c}	1.11 ± 0.03^{d}	0.71 ± 0.01^{a}
18	1.44 ± 0.00^{a}	1.25 ± 0.06^{b}	0.70 ± 0.00^{a}	1.03 ± 0.02^{b}	0.71 ± 0.01^{a}
20	1.45 ± 0.01^{b}	1.25 ± 0.06^{b}	0.70 ± 0.00^{a}	1.03 ± 0.02^{b}	0.71 ± 0.001^{a}
22	1.45 ± 0.01^{b}	1.20 ± 0.07^{a}	0.70 ± 0.00^{a}	0.99 ± 0.06^{a}	0.71 ± 0.01^{a}
24	1.45 ± 0.01^{b}	1.20 ± 0.04^{a}	0.70 ± 0.00^{a}	0.99 ± 0.06^{a}	0.71 ± 0.01^{a}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 8 Carbohydrate content of samples over storage period

Storage Period (Weeks)	YAM CHIP SAMPLES (Carbohydrate content%)				
	CTRL	IP	GM	OT	AG
2	73.87 ± 0.28^{a}	71.57 ± 0.78^{b}	73.46 ± 0.45^{b}	72.34 ± 0.00^{c}	73.61 ± 0.05^{f}
4	74.91 ± 0.17^{j}	72.57 ± 0.08^{d}	74.17 ± 0.07^{c}	73.81 ± 0.03^{e}	74.75 ± 0.01^{l}
6	74.86 ± 0.29^{i}	72.67 ± 0.23^{f}	73.77 ± 0.07^{d}	75.60 ± 0.71^{m}	73.79 ± 0.06^{g}
8	74.51 ± 0.11^{e}	72.81 ± 0.08^{i}	73.95 ± 0.20^{g}	75.53 ± 0.70^{c}	73.09 ± 0.02^{c}
10	74.43 ± 0.09^{c}	72.72 ± 0.00^{g}	73.81 ± 0.11^{e}	75.38 ± 0.01^{k}	74.14 ± 0.00^{h}
12	74.55 ± 0.40^{g}	72.54 ± 0.01^{c}	73.76 ± 0.00^{c}	74.61 ± 0.04^{j}	75.17 ± 0.01^{m}
14	74.53 ± 0.00^{f}	72.57 ± 0.01^{e}	73.81 ± 0.65^{e}	74.57 ± 0.00^{h}	74.50 ± 0.02^{j}
16	74.50 ± 0.07^{d}	72.79 ± 0.17^{h}	73.95 ± 0.01^{f}	74.56 ± 0.00^{g}	74.42 ± 0.02^{i}
18	74.51 ± 0.37^{e}	72.93 ± 0.67^{j}	74.04 ± 0.02^{h}	74.58 ± 0.00^{i}	74.60 ± 0.01^{k}
20	74.79 ± 0.57^{h}	73.00 ± 0.71^{k}	74.53 ± 0.06^{j}	73.92 ± 0.02^{f}	73.58 ± 0.01^{e}
22	74.92 ± 0.01^{k}	73.11 ± 0.04^{l}	74.59 ± 0.31^{k}	73.63 ± 0.28^{d}	73.19 ± 0.01^{d}
24	74.91 ± 0.01^{l}	73.14 ± 0.01^{m}	75.17 ± 0.04^{l}	71.50 ± 0.05^{a}	70.93 ± 0.04^{a}

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 9 Post – storage Proximate composition of Dried Yam Chip Samples Stored Over a Six-month Storage Period

Sample	Moisture Content %	Protein Content %	Crude Fat Content %	Total Ash content %	Crude Fibre Content %	NFE content %	Aflatoxin B_1 (ppb)
PC	17.02 ± 0.05^{d}	5.82 ± 0.00^{d}	0.19 ± 0.02^{b}	4.05 ± 0.03^{c}	0.74 ± 0.01^{c}	72.18 ± 0.02^{c}	6.0
CTRL	13.43 ± 0.03^{a}	6.00 ± 0.01^{e}	0.61 ± 0.01^{f}	3.60 ± 0.01^{b}	1.45 ± 0.01^{f}	74.91 ± 0.01^{e}	<2
IP	14.10 ± 0.00^{c}	6.75 ± 0.03^{f}	0.52 ± 0.01^{e}	4.29 ± 0.02^{e}	1.20 ± 0.04^{e}	73.14 ± 0.01^{d}	<2
GM	14.08 ± 0.13^{b}	5.42 ± 0.03^{c}	0.44 ± 0.03^{d}	4.19 ± 0.03^{d}	0.70 ± 0.00^{a}	75.17 ± 0.04^{f}	<2
OT	18.80 ± 0.04^{e}	3.66 ± 0.01^{b}	0.28 ± 0.03^{c}	4.77 ± 0.07^{f}	0.99 ± 0.06^{d}	71.50 ± 0.05^{b}	<2
AG	24.96 ± 0.07^{f}	2.11 ± 0.01^{a}	0.07 ± 0.01^{a}	1.17 ± 0.01^{a}	0.71 ± 0.01^{b}	70.93 ± 0.04^{a}	<2

Results are presented as content mean ± standard deviation (n=3)
Means along the same column with different superscript are significantly different at (P<0.05)
Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market, AG- Ago market

Table 10 Post-storage microbial count of yam chip samples

Sample	Total Colony Count (TCC) $x10^4$ cfu/g	Total Coliform Count $x10^4$ cfu/g
PC	102.0	33.0
CTRL	-	-
IP	-	-
GM	83.0	-
OT	36.0	-
AG	219.0	31.0

Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market; AG- Ago market

Table 11 Occurrence of Insects in Dried Yam Chips during storage period

Samples	Storage Period (Weeks)											
	2	4	6	8	10	12	14	16	18	20	22	24
CTRL	-	-	-	-	-	-	-	-	-	-	-	-
IP	-	-	-	-	-	-	-	-	-	-	-	-
GM	-	-	-	-	-	-	-	-	-	-	-	-
OT	-	-	-	-	-	-	TC	TC	TC	TC,DP	TC,DP	TC,DP
AG	-	-	TC,DP	TC,DP	TC,DP	TC,DP, RD	TC,DP, RD, SZ	TC,DP, RD, SZ	TC,DP, RD, SZ	RD,SZ	RD,SZ	RD,SZ

Legend: CTRL- Control, IP- Ipata market, GM- Ganmo market, OT- Oja-tuntun market AG- Ago market, TS: *Tribolium casteneum*, DP: *Dinoderus porcellus*, RD: *Rhyzopertha dominica*, SZ: *Sitophilus zeamais*

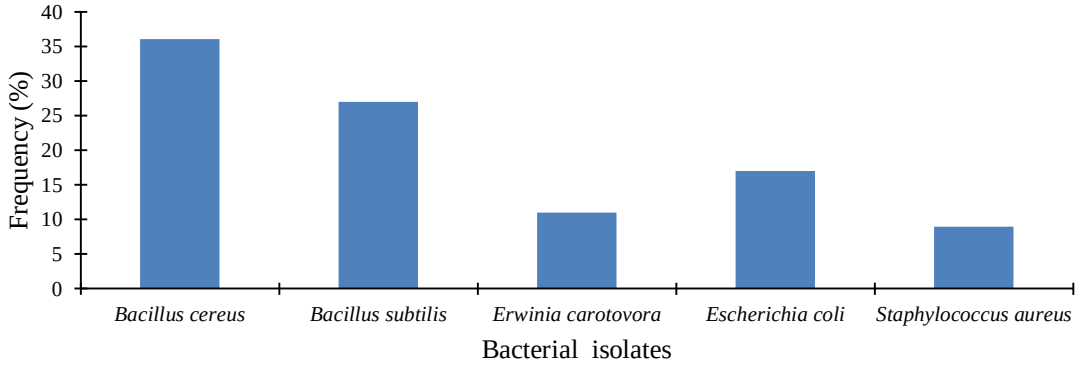

Figure 1 Frequency of occurence of bacterial isolates in yam chip samples over storage period

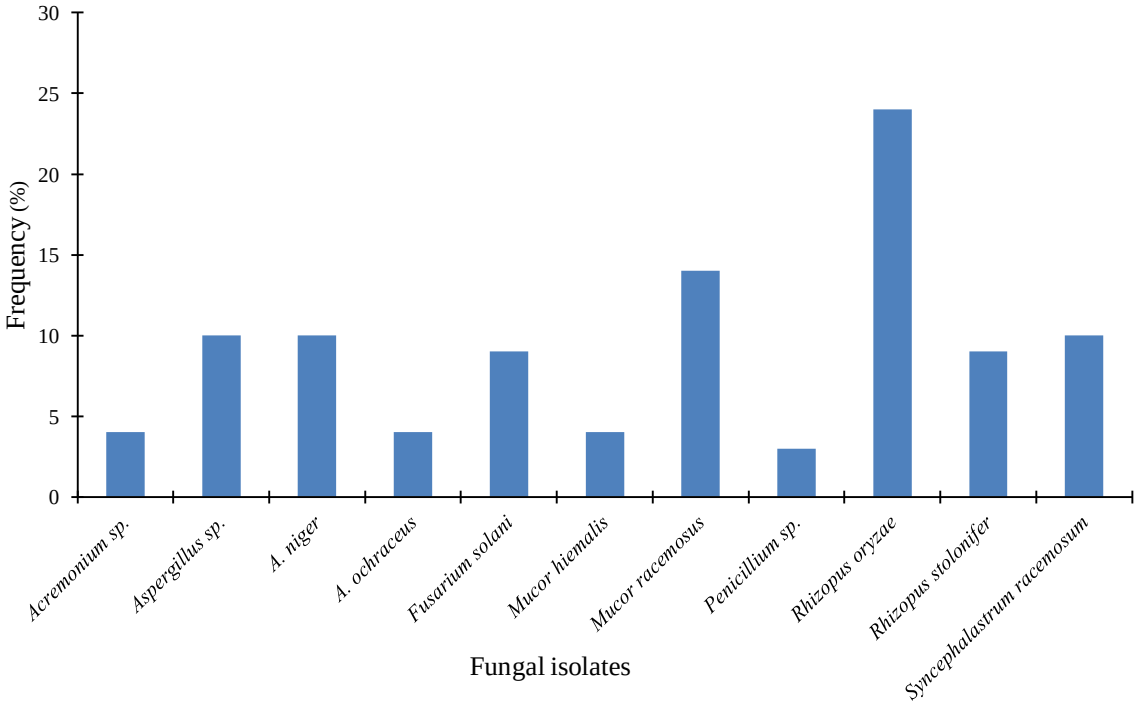

Figure 2 Frequency of occurence of fungal isolates in yam chip samples over storage period

CONCLUSION

In conclusion, clean, potable water should be employed for processing of yam chips. Traditional sun drying where the yam chips are left in the open for many days should be discouraged to curtail microbial contamination. Instead oven drying should be used which will also ensure that the yam chips are properly dried. Sorting of the drying chips should be practiced to minimize interference by extraneous materials, moulds and insects. Finally, mouldiness should be used as one of the standards for the acceptability of yam chips for marketing to reduce the risk of aflatoxin ingestion by the consumers.

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