



## **Myco-deterioration of Smoke-Dried African Catfish (*Clarias gariepinus*) Stored at Ambient Temperature**

**Moses A. Abiala<sup>1,2\*</sup>, Abiola M. Okusanya<sup>1</sup>, Afolake A. Olanbiwoninu<sup>1</sup>,  
Opeyemi A. Abiala<sup>3</sup> and Francis H. Ibadin<sup>2</sup>**

<sup>1</sup>Department of Biological Sciences, Ajayi Crowther University, Oyo, Nigeria.

<sup>2</sup>Department of Biological Sciences, Mountain Top University, Nigeria.

<sup>3</sup>Department of Animal Science, University of Ibadan, Nigeria.

### **Authors' contributions**

This work was carried out in collaboration among all authors. Authors MAA, AMO, OAA and AAO designed the experiment. Authors MAA, AMO and OAA performed the experiment. Author MAA analysed the data. Authors MAA, AMO, AAO and FHI interpreted the data. All the authors wrote, carefully edited and approved the manuscript.

### **Article Information**

DOI: 10.9734/MRJI/2020/v30i1130282

Editor(s):

(1) Dr. Ana Cláudia Coelho, University of Trás-os-Montes and Alto Douro, Portugal.

Reviewers:

(1) Majid M. Taher, Basrah University, Iraq.

(2) Akeem Oladipupo Sotolu, Nasarawa State University, Nigeria.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/65050>

**Original Research Article**

**Received 27 October 2020**  
**Accepted 29 December 2020**  
**Published 31 December 2020**

### **ABSTRACT**

The current study was carried out on moulds associated with sequential deterioration of smoke-dried *Clarias gariepinus* stored at ambient temperature. Samples of smoke-dried catfish were obtained from street shops, commercial vendors and as well as from neighbouring rural markets where large percentage of population used to buy for consumption. Mould infestation, nutritional composition, pH and moisture content were determined in parallel at week 0, 3 and 6. Results of the study pointed that mould load increased with storage period and ranged from  $2.00 \times 10^2$  to  $11.31 \times 10^2$  cfu/g. The associated moulds were identified as *Aspergillus flavus*, *A. versicolor*, *A. niger*, *A. fumigatus*, *Fusarium solani*, *Penicillium* species and *Mucor* species. As the storage duration advances at the ambient temperature, the associated moulds maintained sequential succession in the smoke-dried catfish. Specifically, *A. flavus* and *A. versicolor* succeeded *A. niger* and *A. fumigatus* till week 3, and *A. flavus* activated the succession till week 6. Unfortunately, apart from *Penicillium commune* that joined the activities of *P. crysogenum* at week 6, other moulds were not

\*Corresponding author: E-mail: mos4me@gmail.com, maabiala@mtu.edu.ng;

succeeded. The crude fat, fibre, protein and ash content decreased while the moisture content of the smoke-dried catfish gradually increased. Slightly acidic to neutral pH was maintained throughout the period of storage. Our study therefore revealed that sequential myco-deterioration of smoke-dried catfish is possible when stored for long period at ambient temperature.

**Keywords:** Catfish; myco-deterioration; mould; nutritious food; smoke-dried.

## 1. INTRODUCTION

Globally, fish is an important protein source for human dietary protein [1-2]. In Africa, consumption of fish is now in high demand as representative of animal dietary protein [3-6]. In addition to proteins, fish use to supply a good balance of vitamins and minerals. Hence, its role in nutrition cannot be over-emphasized [7]. In spite of the nutritional importance of fish, it is highly perishable especially in the hot climatic regions where average temperature is warm enough to enhance proliferation of mycodeteriogens. For example, available records show that about 40% of the total fish catch in Nigeria are lost annually due to inadequate or poor preservation, processing and handling methods [8]. Also, the rate of fish spoilage depends on acidity level, fish species, weather, mode of storage and temperature during transportation [9].

Chemical breakdown of protein, fat and water contents also contribute to quick spoilage of fish. Therefore, to prevent the huge loss of fish during and after harvest, and during storage to consumption [10], smoking was employed in many regions of Africa as sustainable practice for preservation of fish prior to consumption. Smoking does not require sophisticated and technology based equipment or highly skilled workers [11]. Smoking contributes to fish preservation and improved shelf-life by drying to maintain nutritional quality and reduction of microbial contaminants [12-18]. Unfortunately, quality instability during storage presents a challenge for all fish types which include catfish. Generally, in Africa countries, smoke-dried catfish is usually hawked without taking cognizance of the microbial contamination from the environment. The smoke-dried *Clarias gariepinus* could be contaminated with microorganisms from the processing units and in storage at the market centres before reaching the consumers [19]. Thus, could act as bioindicators for deterioration [20] of nutritional contents in smoke-dried fish.

Among the microbial flora, the presence of fungi especially the mould play significant role as

baseline indicator to ensure the saving of smoke-dried catfish for consumption [21-23]. Moulds have the potentials to influence changes in sensory and nutritional characteristics of smoke-dried catfish [24-27]. During storage, mould contaminants used to compromise ambient temperature and appear invisible on smoke-dried catfish even after long duration of storage. Therefore, in comparison to other studies that have focused on mould infestation and nutritional deterioration of smoke-dried catfish in southwestern Nigeria [28], current study systematically investigates sequential colonization and mould succession on nutritional composition of smoke-dried catfish based on duration of storage.

## 2. MATERIALS AND METHODS

### 2.1 Sample Collection, Preparation, Isolation and Identification of Moulds

Fifteen samples of smoke-dried catfish were obtained from local markets (Ajegunle, Akesan and Awe) in Oyo town, Nigeria. Five samples were obtained from each market to form a composite per experimental sample and transported to the laboratory in sterile polythene bags. The samples were randomly mixed together, replicated to make three sample preparations and stored at ambient temperature for a period of six weeks. Isolation of moulds from the smoke dried catfish samples was carried out at week 0 (immediately after purchase), week 3 and week 6. Portions of the tissues were aseptically cut from all the regions of the fish body and ground. Briefly, 1 g of the ground sample was weighed and macerated in 9 ml of sterile distilled water. From this, subsequent serial dilution was made and an aliquot was inoculated into already set plates of potato dextrose agar (PDA). The plates were allowed to solidify and were incubated at  $28 \pm 1^\circ\text{C}$  for 5-7 days and observed daily for growth [29]. The mean number of all mould colonies appearing was taken into consideration. This was used to estimate the number of mould colony forming units per gram of fish sample. The colony forming unit per gram (cfu/g) was

calculated using the formula: Total viable counts per gram = average number of colonies counted per dilution factor. All observed colonies with distinct morphologies were subculture on PDA, incubated at  $28 \pm 2^\circ\text{C}$  for 3 to 5 days and observed daily for growth. The identification of each isolated fungus was based on observable characters on the culture plates and under the microscope. The notable features used for identification were colony diameter, the obverse and reverse view of the mycelium, pigment production and texture. Microscopic identification was also aided by the use of a photomicrograph which focused on the presence or absence of phialides, vesicle structure, presence of metulae, chlamydospores, microconidia and macroconidia (for *Fusarium*) and structure of the conidia using the illustration manual for identification of *Aspergilli*, *Fusaria*, and *Penicilli* [30] and Introduction to Industrial Mycology [31].

## 2.2 Determination of pH

Five grams of fish samples were macerated in 95 millilitre of distilled water in triplicates and stirred thoroughly to make a fish slurry. The average pH of the triplicates was taken as the pH value. The pH readings were taken using digital pH meter (at  $31^\circ\text{C}$ ) equipped with a glass electrode, pH-25 pH metre, serial number 601308129087 [32].

## 2.3 Moisture Content

Moisture content was carried out following the protocol described by AOAC [32]. Oven temperature at  $105^\circ\text{C}$  was used for 24 hours. The weight of the dry sample and the dish was recorded and percentage moisture content and dry matter was calculated as: Percentage (%) moisture content =  $(W_1 - W_2) / 5 \times 100$ , Where  $W_1$  = Weight of sample + dish before drying,  $W_2$  = Weight of sample + dish after drying, 5 = Weight of sample.

## 2.4 Proximate Analyses

The proximate analysis of the samples which included crude fat, crude fibre, ash content and crude protein were periodically carried out at week 0, 3 and 6 during storage in-line with the methods described by AOAC [32]. Apart from the fact that, the experiment was carried out under close observation for six weeks of storage at room temperature, other protocols were maintained before contact with the smoke-dried catfish to avoid contamination. Five grams of fish samples in triplicates were equally maintained for

each proximate analysis. For crude fat, the extracted fat was calculated using the formula:  $(W_1 - W_2) / 5 \times 100$ , Where:  $W_A$  = Weight of the flask with the fat,  $W_B$  = Weight of dry extraction flask and petroleum ether, 5 = Weight of sample, while that of crude fibre was calculated as Weight of crude fibre = Residue - Ash dried residue. % crude fibre = Weight of crude fibre / Weight of sample  $\times 100$ . AOAC [32] was also used for ash content. The percentage ash content was calculated as % Ash content = Weight of ash - Weight of sample / Weight of sample  $\times 100$ . The protein content is an integral part of nutritional composition of smoke-dried catfish. In this study, the protein content in the smoke-dried catfish was determined using nitrogen concentration based on Micro-Kjeldal method [33].

## 2.5 Statistical Analysis

Data collected on physico-chemical and nutritional composition analyses of smoke-dried catfish were subjected to proper statistical analysis of variance using Student-Newman-Keuls Test [34]. Also, frequency of occurrence of each mould was determined.

## 3. RESULTS

### 3.1 Moulds Associated with Smoke-Dried Catfish

At week 0, the mean mould count in the PDA plates was  $2.00 \times 10^2$  cfu/g, this increased to  $4.78 \times 10^2$  cfu/g at week 3 and  $11.31 \times 10^2$  cfu/g at week 6 (Fig. 1). Based on identification, a total number of 18 mould were isolated from the smoke-dried catfish during storage. *Aspergillus flavus* dominated, followed by *A. niger* and *Penicillium chrysogenum* while the least moulds were *A. fumigatus*, *P. commune*, *Fusarium solani* and *Mucor* species (Table 1). With respect to occurrence, *A. flavus* isolated at week 0, 3 and 6 had the highest occurrence (27.8%), followed by *A. niger* (16.7%) and *Mucor* species (16.7%) at week 0 and 3 (Table 1). At week 3 and 6, *A. versicolor* (11.1%) and *P. chrysogenum* (11.1%) were similar in their occurrence (Fig. 1 and Table 1). During storage, *A. flavus*, *A. niger* and *A. versicolor* dominated at week 0. At week 3, *A. niger* gradually reduced while *A. versicolor* succeeded disappearance of *A. fumigatus*. At week 6, only *A. flavus* and *A. versicolor* maintain succession of other *Aspergillus* species. *P. commune* was not succeeded but joined the activities of *P. chrysogenum* in smoke-dried

catfish. *Mucor* species was evidence at week 0 and 3, *F. solani* at week 0 but their presence was no longer evidence at week 6.

### 3.2 Moisture Content, pH and Nutritional Composition of Smoke Dried Catfish

A significant level of moisture content was observed across the duration of storage from week 0 to week 3 and then to week 6 (Fig. 2). Specifically, the moisture content at week 6 was higher (11.17%), followed by week 3 (9.38%) while that of week 0 was the least (8.79%). The

smoke-dried catfish maintained acidic to neutral pH during storage (Fig. 3). The highest (1.09%) crude fibre content was observed at week 0. However, there was a reduction in this value at week 3 to 0.63% and week 6 to 0.01% (Fig. 4). The crude fat content showed that its highest value (36.44%) was at week 0, reduced to 24.24% at week 3 and 18.48% at week 6 (Fig. 5). The crude protein significantly ( $P \leq 0.05$ ) reduced from week 0 to week 3 and then to week 6. The ash content value was highest (15.32%) at week 0, reduced to 11.59% at week 3 and 7.39% at week 6 (Fig. 7).

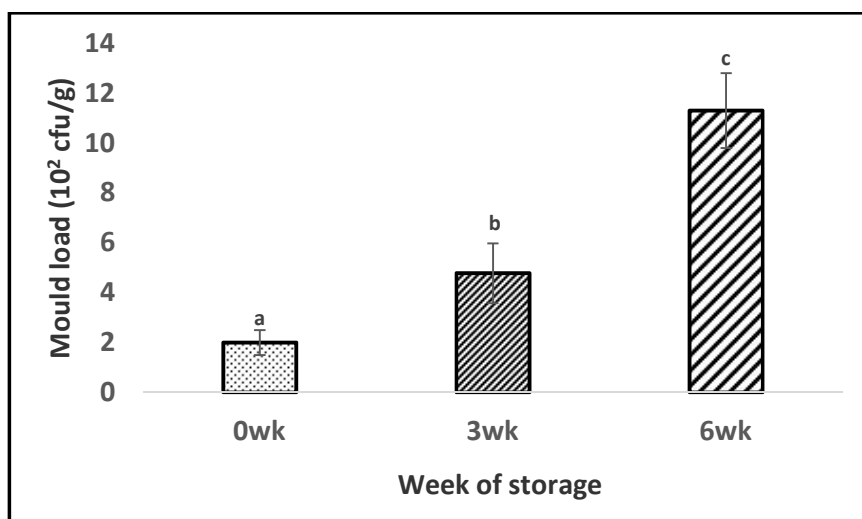


Fig. 1. Mould load of the smoke-dried catfish in storage at ambient temperature for six weeks

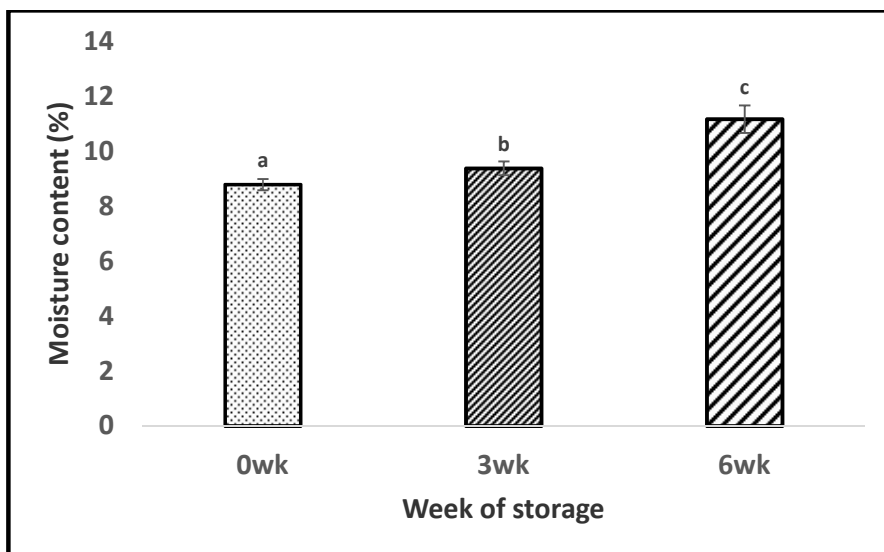


Fig. 2. Moisture content (%) of the smoke-dried catfish in storage at ambient temperature for six weeks

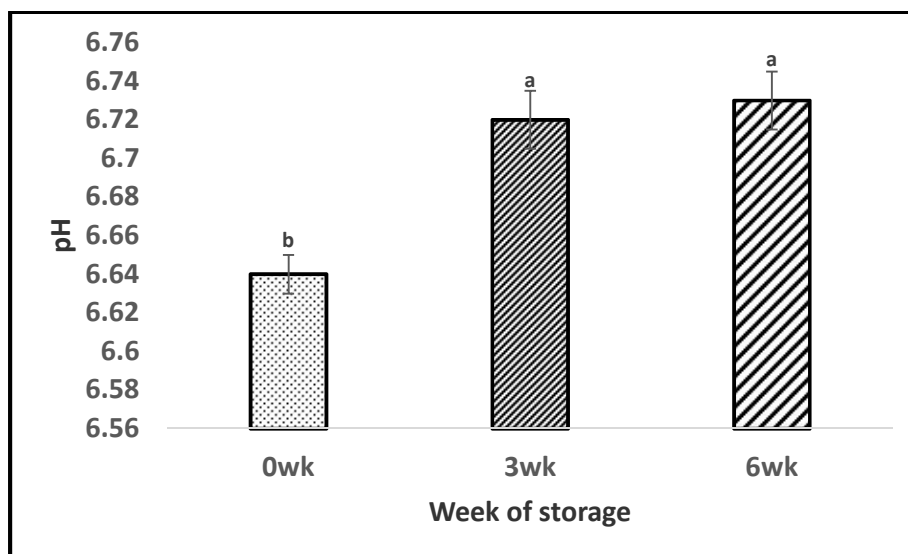


Fig. 3. pH of the smoke-dried catfish in storage at ambient temperature for six weeks

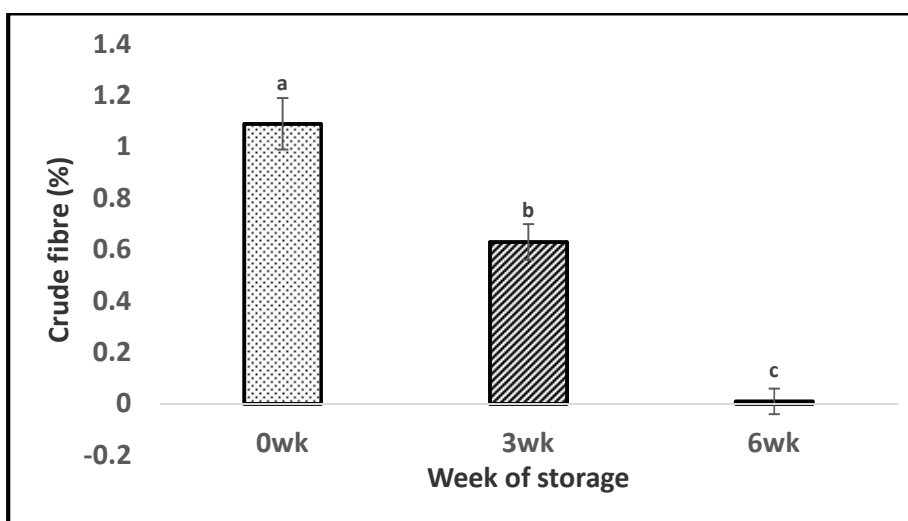


Fig. 4. Crude fibre of the smoke-dried catfish in storage at ambient temperature for six weeks

Table 1. Frequency of occurrence of isolated moulds and percentage of occurrence

Week 0	Week of occurrence		Frequency of isolation (Total)	Occurrence (%)
	Week 3	Week 6		
<i>A. flavus</i> (1)	<i>A. flavus</i> (2)	<i>A. flavus</i> (2)	5	27.8
<i>A. niger</i> (2)	<i>A. niger</i> (1)	-	3	16.7
<i>A. fumigatus</i> (1)	-	-	1	5.6
-	<i>A. versicolor</i> (1)	<i>A. versicolor</i> (1)	2	11.1
-	-	<i>P. commune</i> (1)	1	5.6
-	<i>P. chrysogenum</i> (1)	<i>P. chrysogenum</i> (2)	3	16.7
<i>Mucor</i> species (1)	<i>Mucor</i> species (1)	-	2	11.1
<i>Fusarium</i> species (1)	-	-	1	5.6
Total			18	100

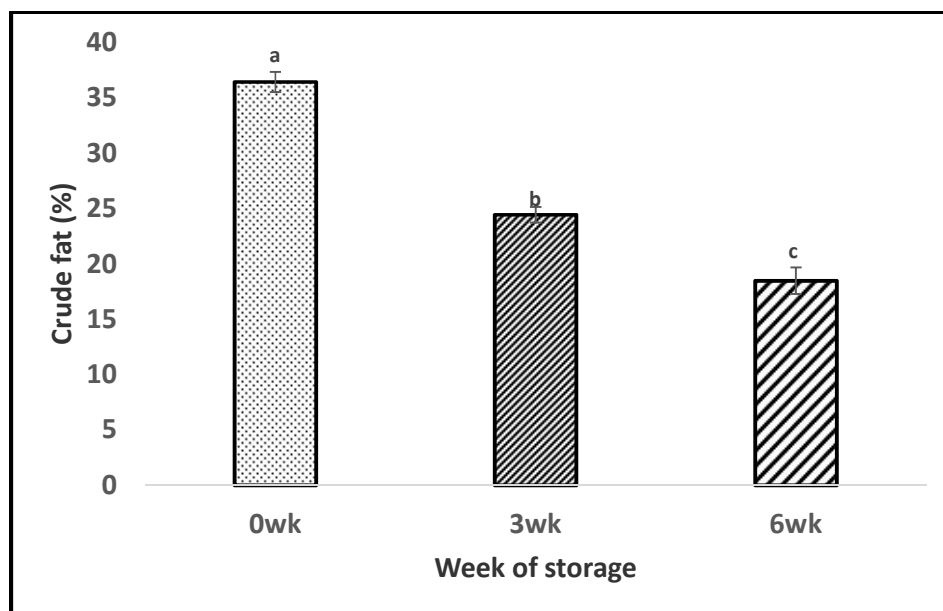


Fig. 5. Crude fat of the smoke-dried catfish in storage at ambient temperature for six weeks

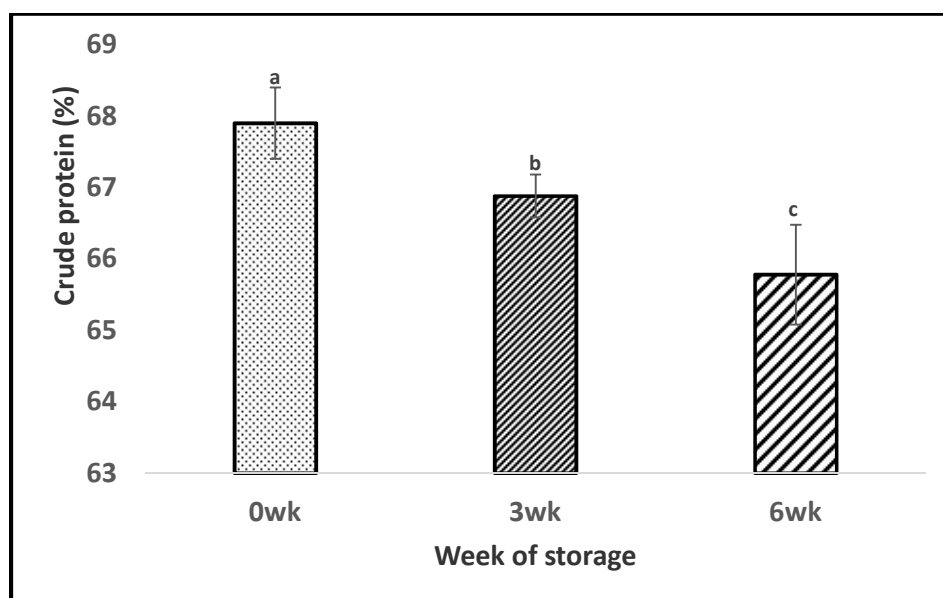
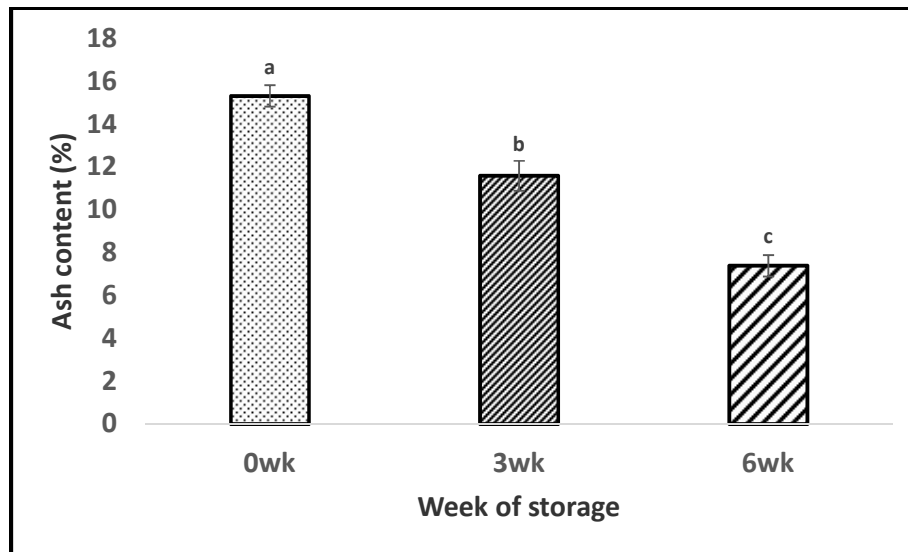


Fig. 6. Crude protein of the smoke-dried catfish in storage at ambient temperature for six weeks

#### 4. DISCUSSION

In many African countries, storage of smoke-dried catfish are always compromised by ambient temperature which directly and indirectly encourage the growth of moulds. In the present study, high level of mould load was observed especially at week 6. Although, the mould load

falls within the acceptable limit ( $5 \times 10^5$  cfu/g) for quality fish product [35,36] from microbiological point of view. However, the presence of these moulds at week 3 and 6 were considered relevant in the study to ascertain safety of smoke-dried catfish for consumption in Nigeria. Parts of the study revealed sequential mould load based on duration of storage [18].



**Fig. 7.** Ash content of the smoke-dried catfish in storage at ambient temperature for six weeks

The isolated moulds are of significant to public health. *Aspergillus* species, *Penicillium* species and *Fusarium* species dominated [18]. In southwestern Nigeria, Fafioye et al. [37] reported similar occurrence of *Aspergillus* species, *Fusarium* species and *Mucor* species in smoke-dried catfish. *Aspergillus* species and *Penicillium* species were the most dominant genera [38,39]. Mould occurrences in smoke-dried catfish have been catalogued for *Aspergillus*, *Rhizopus*, *Penicillium* and *Fusarium* not only in Nigeria but also in Indonesia [40], Sri Lanka [39] and China [41]. On a more specific note, *A. flavus*, was the most prevalent in smoke-dried catfish [18,37,41]. The duration of storage has significant implications on the occurrence of *Aspergillus* species. It was observed that *A. flavus*, *A. niger* and *A. versicolor* occurred [42] in clean and odour free smoke-dried catfish at week 3. Thus, the presence of *A. flavus* and *A. versicolor* at week 3 posed significant threat to public health due to their mycotoxigenic potentials. Notably, *A. flavus* was adequately present from week 0 to week 6 [18]. The presence of this mould could be attributed to handling processes during smoking and cross contamination during storage or sales in commercial market. The occurrence of *Penicillium* species, *Mucor* species and *Fusarium* species could not be underestimated [18,37,41] on safety of smoke-dried fish for consumption in Nigeria.

*A. flavus*, *A. niger* and *A. fumigatus* successfully colonized smoke-dried catfish and maintained succession for *A. versicolor* till week 3. It was

observed that, *A. flavus* activated the succession till week 6 [18]. Similar trend of succession was observed between *Penicillium chrysogenum* at week 3 and *Penicillium commune* at week 6. This suggests that as the storage duration advances, the mould associated with smoke-dried catfish at ambient temperature have the potentials to maintain sequential succession [18]. Also, the metabolites involved could be an advantage for succession among moulds. In addition, Odu et al. [43] stated that warm humidity and environmental temperatures can facilitate growth and succession of moulds in smoke-dried catfish during storage. The occurrence of these moulds suggests that the heat supplied during smoke-drying might not be adequate to kill the mould contaminants, and this may negatively enhance other unfavourable factors that can lead to mycodeterioration of smoke-dried catfish.

There was sharp increase in moisture content from week 0 to week 3 and then from week 3 to 6. Edema and Agbon [44] also observed in their study that moisture content increases within the range of 14.42 to 26.7% which is totally unacceptable for smoke-dried catfish [45]. A standard moisture content of 12% was reported by [45] as the level beyond which fish products begin to grow moulds after few days. In the present study, the moisture contents were within the acceptable limit but sample collections at week 0, 3 and 6 justify the presence of moulds and this could be attributed to slight increase in moisture content which is enough to enhance growth of moulds in tissues of smoke-dried

catfish. In agreement with the present study, Daramola et al. [18] also reported gradual increase in moisture content of smoke-dried catfish stored for 6 weeks at ambient temperature. They attributed the increase to the absorption of moisture from the surroundings since there was no re-drying during storage. This implied that the moulds contamination were as a result of high level of increase in moisture content. Thus, it could be deduced that the smoke-dried catfish is not at safe level for consumption at week 3 and 6 due to the fact that the moisture content was 9.38% and 11.17% at week 3 and 6 respectively in comparison to moisture content that was recommended safe (6-8%) for dried fish by Foline et al. [46]. In addition, Kaneko [47] have reported that a lot of proteolytic, lipolytic deterioration and microbial proliferation are encouraged at moisture levels higher than recommended standard. The increase in moisture content directly influence the pH. It was observed that the pH increases as the storage duration increases. Daramola et al. [18] stated that the pH of smoke-dried catfish may slightly change though within the acceptable limit. As the storage duration increases, the pH of our smoke-dried catfish slightly changes [48]. Shenderyuk and Bykowski [49] reported that the increase in pH could be as a result of composition of nitrogenous compounds due to increase moisture content that may have resulted to decomposition of protein content in smoke-dried catfish with passing time [50].

The nutritional contents of stored smoke-dried catfish may affect wholeness, safety and shelf-life of the products [51]. The crude protein slightly decreased between week 0 and 3, and between week 3 and 6. The crude protein may have degraded to more volatile products such as total volatile bases, hydrogen sulphide and ammonia [3]. In addition, as the storage duration increases, water soluble protein may have diffused out to the surrounding for exosmosis [52]. In the study conducted by Agbolagba and Osifo [53], the crude protein content of *Heterobranchus longifilis* significantly reduced during storage. In-line with our study, the reduction in crude protein of smoke-dried catfish is not new as similar observation has been documented by Daramola et al. [18]. The study carried out by Hassan et al. [52] revealed that ash content changes with duration of storage due to absorbance of moisture and loss of protein, thus, could be as a result of why there was reduction in ash content in both week 3 and 6. Similarly, the crude fat and fibre contents

reduced drastically in the smoke-dried catfish [18,54]. The low fat level could be probably due to rancidity problems during storage [54] while that of low crude fibre could be attributed to energy content in smoke-dried catfish since crude fibre is considered as indigestible [55].

Generally, following 6 weeks storage of smoke-dried catfish, the mould may have invisibly colonized and proliferated the smoke-dried catfish due to alteration of pH in favour of moisture content, thus, significantly reduced the nutritional contents. This implies that, the moulds deteriorated the smoke-dried catfish throughout the storage period as they cannot be seen with the naked eyes except with the aid of microscope. Therefore, it could be deduced that, under ambient temperature condition, smoke-dried catfish may look physically fit for consumption but nutritionally low and as well posed public health threat due to the presence of toxigenic moulds. Daramola et al. [18] established similar fact that smoke-dried catfish could not keep up well till the 6<sup>th</sup> week under ambient temperature. Directly or indirectly, this suggests that the shelf-life of smoke-dried catfish is contingent to the state of dryness [56].

## 5. CONCLUSION

During storage of smoke-dried catfish, ambient temperature deceptively encouraged growth and proliferation of moulds. Apart from the fact that the smoke-dried catfish still maintained good appearance till 3<sup>rd</sup> and 6<sup>th</sup> week, the nutritional composition have reduced due to high moisture content and pH. That is, the longer the smoke-dried catfish stays in storage at ambient temperature, the higher the mould load and consequently, the rate of deterioration. Hence, smoke-dried catfish is not fit for consumption most especially at week 3 and 6 after purchase. Strategic methods should be employed in the preservation of smoke-dried catfish for optimum shelf stability and retention of its nutritional quality.

## ACKNOWLEDGEMENT

The authors are thankful to Mr. Okunlola for his technical assistant

## COMPETING INTERESTS

Authors have declared that no competing interests exist.



## REFERENCES

1. Ekpenyong E, Ibok CO. Effect of smoking, salting and frozen-storage on the nutrient composition of the African catfish (*Clarias gariepinus*). Journal of Food, Agriculture and Environment. 2012;10:64-66.
2. Eyo AA. Fish processing technology in the tropics. National Institute for Freshwater Fisheries Research. University of Ilorin Press. 2001;10-70.
3. Abolagba OJ, Melle OO. Chemical composition and keeping qualities of a scaly fish tilapia, *Oreochromis niloticus* smoked with two energy sources. African Journal of General Agriculture. 2008; 4(2):113-117.
4. Kumolu-Johnson CA, Ndimele PE. The anti-oxidative and anti-fungal effects of fresh garlic (*Allium sativum*) on the shelf-life of hot smoked Catfish (*Clarias gariepinus*, Burchell, 1822). World Applied Sciences Journal. 2011;13(7):1628-1634.
5. Awe S, Adejo SO. Microorganisms associated with selected fresh fishes from river niger, lokoja and their antibiotic susceptibility. International Journal of Agriculture Innovations and Research. 2008;6(4):136-141.
6. Ojutiku RO, Kolo RJ, Mhammed ML. Comparative study of sun drying and solar tent drying of *Hyperopisus bebe occidentalis*. Pakistan Journal of Nutrition. 2009;8(7):955-957.
7. Oladosun OH, Akande GR, Tobor JG. Technology needs assessment in the conceptualisation and design of magbon-aladefish smoke-drying equipment in Niomr. FAO Expert Consultation of Fish Technology in Africa; Kisumu, Kenya; 1996.
8. Ghaly AE, Dave D, Budge S, Brooks MS. Fish spoilage mechanisms and preservation technology: Review. American Journal of Applied Sciences. 2010;7:859-877.
9. Oluborode GB, Omorinkoba WS, Bwala RL. Development and construction of an electric furnace and control system for fish drying. African Journal of Engineering, Research and Development. (Devon Science Publication). 2010;3(2):123-128.
10. Olayemi FF, Raji AO, Oyelese OA, Oyewole SN, Omodara MA. Effective fish smoking kiln for developing country. International Journal of Scientific and Engineering Research. 2013;4(1):2229 – 5518.
11. Gilbert J, Knowles ME. The chemistry of smoked foods: A review. Journal of Food Technology. 1995;10:245–261.
12. Doe PE. Fish drying and smoking, production and quality. Technomic Publishing Co. Inc., Lancaster, PA. 1998;89-115.
13. Rorvik LM. *Listeria monocytogenes* in the smokes salmon industry. International Journal of Food Microbiology. 2000;62:183 – 190.
14. Garrow JS, James WPT. Human nutrition and dietetics. London: Churchill Living Stone. 2000;84.
15. Daramola JA, Fasakin EA, Adeparusi EO. 2007. Changes in physicochemical and sensory characteristics of smoke-dried fish species stored at ambient temperature. African Journal Food Agriculture, Nutrients and Development. 2007;7(6):1684-5358.
16. Ahmed EO, Ali ME, Kalid RA, Taha HM, Mahammed AA. Investigating the quality changes of raw and hot smoked *Oreochromis niloticus* and *Clarias lazera*. Pakistan Journal of Nutrition. 2010;9(5):481-484.
17. Daramola JA, Kester CT, Allo OO. Biochemical changes of hot smoked African catfish (*Clarias gariepinus*) Samples from Sango and Ota Markets in Ogun State. The Pacific Journal of Science and Technology. 2013;14(1):380-386.
18. Akinwumi FO, Adegbehingbe KT. Microbiological analysis of three smoked fish obtained from Ondo State, Nigeria. Food and Public Health. 2015;5(4):122-126.
19. Gram L, Oundo JO, Bon J. Shelf life of fish depends on storage temperature and initial bacteria load. Tropical Science. 2000;25:28–30.
20. Olawale AK, Oluduro AO, Famurewa O. Evaluation of microbiological and sanitary Standards of canteens and eateries in Osun State Polytechnic, Iree. In: The book of abstract of the 29th Annual conference and general meeting of the Nigerian Society for Microbiology Abeokuta, 6 -10th November. 2005;19.
21. Adesokan IA, Ogunbanwo ST, Odetoyinbo BB. Microbiological quality of selected brands of beer in Nigeria. In: the Book of abstracts of the 29th annual conference and general meeting (Abeokuta 2005) of Nigerian society for microbiology (NSM), University of Agriculture, Abeokuta, 6- 10th November. 2005;21.

22. Abolagba OJ, Igbinevbo EE. Microbial load of smoked fish (*Clarias* sp) marketed in Benin Metropolis, Nigeria. *Research Journal of Fisheries and Hydrobiology*. 2010;5(2):99-104.
23. Rubbi SF, Muzibar M, Khan AR, Jahan SS, Majeda B. Proximate composition and quality of some commercial species of fresh water fishes. *Bangladesh Journal of Science Research*. 1987;5(1):1-20.
24. Mollah AH, Rahman MS, Alam MT. Study of proximate chemical analysis of Bangladeshi freshwater fish Rita rita (Ham.) and seasonal variation of lipid, protein and related substances. *University Journal of Zoology*. Rajshahi University. 1998;17:1- 6.
25. Mollah AH, Hasan F, Azad TMA, Salam SMA, Alarn, MT. Biochemical and nutritional status of *Eutropichtys vacha* (Ham-Buchanan). *Journal of Biological Sciences*. 2000; 8:23-26.
26. Doyle EM. Microbial food spoilage- losses and control strategies. *Food Research Institute, University of Wisconsin – Madison, WI 53706*; 2007.
27. Osibona A, Ogunyebi OO, Samuel TO. Storage fungi and mycotoxins associated with stored smoked Catfish (*Clarias gariepinus*). *Journal of Applied Sciences and Environmental Management*. 2018;22: 643.
28. Adesemoye AO, Adedire CO. Use of cereals as basal medium for the formulation of alternative culture media for fungi. *World Journal of Microbiology and Biotechnology*. 2005;21:329–336.
29. Kulwant SJC. An illustrated manual on identification of some Seed borne Aspergilli, Fusaria, Penicillia and their Mycotoxins. Hellerup, Denmark. Danish Government Institute of Seed Pathology for Developing Countries and Department of Biotechnology, The technical university of Denmark; 1991.
30. Smith G. Smith's introduction to industrial mycology, 7th edition, A.H.S. Onions, D. Allsopp, H.O.W. Eggins. Edward Arnold (Publishers) Ltd. London, UK; 1981.
31. AOAC. Official methods of analysis of AOAC international (16th Edn). *Methods* 993.17, 968.22., Washington (D.C); 1995.
32. AOAC. Official methods of analysis. Association of official analytical chemists (15th Edn). Virginia. 1200; 1990.
33. SAS (Statistical Analysis System). SAS/STAT guide for personal computers version 9.2 (TSIMO) Edition. Cary, NC, USA, SAS Institute Inc. 2009;1028.
34. ICMSF. Sampling for microbiological analysis: Principles and specific applications, 2nd Edition. Oxford: Blackwell Science. 1986;398.
35. Cheesbrough M. *District Laboratory Practical in Tropical Countries*. Part 2. Cambridge University Press, Cambridge, UK. 2000;63–70.
36. Fafioye OO, Fagbohun TR, and Olubanjo OO. Fungal infestation and nutrient quality of traditionally smoked dried fresh water fish. *Turkish Journal of Fisheries and Aquatic Sciences*. 2008; 8:7-13.
37. Adebayo-Tayo BC, Onilude AA, Patrick UG. Mycofloral of smoke-dried fishes sold in Uyo, Eastern Nigeria. *World Journal of Agricultural Science*. 2008;4(3):346-350.
38. Atapattu R, Samarajeeva U. Fungi associated with dried fish in Sri Lanka. *Mycopathologia*. 1990;111:55-59.
39. Wheeler KA, Hocking AD, Pitt JI, Anggawati AM. Fungi associated with Indonesian dried fish. *Food Microbiology*. 1986;3:351-357.
40. Deng Y, Wang Y, Deng Q, Sun L, Wang R, Ye L, et al. Fungal diversity and mycotoxin contamination in dried fish products in Zhanjiang market, China. *Food Control*. 2021;121.
41. Martins AM. *Fisheries processing: Biochemical applications*. Published by Chapman and Hall, London. 1994;1-88.
42. Odu NN, Njoku HO, Mepba HD. Microbiological quality of smoke-dried mangrove oysters (*Crassostrea gasar*) sold in Port Harcourt, Nigeria. *Agriculture and Biology Journal of North America*; 2012.
43. Edema MO and Agbon AO. Significance of fungi associated with smoke-cured *Ethmalosa fimbrata* and *Clarius gariepinus*. *Journal of Food Processing and Preservation*. 2010;34:355-363.
44. FAO/APHCA. "The Use of Palm-Kernel Cake as Animal Feed". FAO/ APHCA Publication No. 8; 1989.
45. Foline OF, Rachael AM, Iyabo BE, Fidelis AE. Proximate composition of catfish (*Clarias gariepinus*) smoked in Nigerian stored products research institute (NSPRI): Developed Kiln. *International Journal of Fisheries and Aquaculture*. 2011;3:96-98.

46. Kaneko S. Smoked meat and microorganisms. *New Food Ind.* 18, 17-23. In *A review of Japanese studies. Fish smoking and drying. The effect of smoking and drying on the nutritional properties of fish* (ed. T. Moto - 1988). Elsevier Applied Science (ed. J. R. Burt). 1976;91-120.
47. Osibona AO, Bakare BN, Oluwakemi SB, Izuka IN, Kuton MP. *Journal of Science Research and Development.* 2010;12:10–21.
48. Shenderyuk VI, Bykowski PJ. Salting and Marinating of Fish. In: Z.E. Sikorski (ed.). *Seafood: Resources, nutritional composition and preservation.* CRC Press: Boca Raton, Florida; 1989.
49. Ghezala S. New packaging technology for seafood preservation shelf life extension and pathogen control. In: *Fisheries Processing Biotechnological Applications.* A.M. Martin (ed.). Chapman Hall: London, UK. 1994;83-110.
50. Adegunwa MO, Adebowale AA, Olisa ZG, Bakare HA. Chemical and microbiological qualities of smoked herring (*sardinella eba*, valenciennes 1847) in Odeda, Ogun state, Nigeria. *International Journal of microbiology research and reviews.* 2013;1(5):085-087.
51. Hassan MN, Rahman M, Hossain MM, Nowsad AAKM, Hossain MB. Post harvest loss and shelf life of traditionally smoked shrimp products produced in Bangladesh. *World Journal of Fish and Marine Science.* 2013;5(1):14-19.
52. Abolagba OJ, Osifo SJ. The effect of smoking on the chemical composition and keeping qualities of Catfish *Heterobranchus bidorsalis* using two energy sources. *Journal of Agriculture, Forestry and Fisheries.* 2008;5(1): 27-30.
53. Nahid M, Latifa G, Farid F, Begum M. Proximate composition of salted smoke-dried and salt-garlic treated smoke-dried chapila (*Gudusia chapra*; Hamilton-Buchanan, 1822) fish stored at room temperature. *Bangladesh Journal of Zoology.* 2015;42:205.
54. Plahar WA, Pace RD, Lu JY. Effects of storage methods on the quality of smoked-dry herring (*Sardinella eba*). *Journal of Science Food and Agriculture.* 1991;57:597-610.
55. Olagbemide PT. Nutritional values of smoked *Clarias gariepinus* from major markets in southwest, nigeria, *Global Journal of Science Frontier Research: D Agriculture and Veterinary.* 2015;15(6):32-43.
56. Bernaseek GM. Planning for the future of the fisheries post-harvest sector in Africa. *Proceedings of the FAO Expert Consultation on fish Technology in Africa.* FAO Fisheries Report. No. 1991;467:187–193.

© 2020 Abiala et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*  
<http://www.sdiarticle4.com/review-history/65050>