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Comparative Study of Quality Deterioration and Microbiological Safety of Oven-Dried and Smoked Products from African Catfish (*Clarias Gariepinus*) At Various Storage Condition

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ABSTRACT: *This study aimed to investigate the effects of oven-drying and smoked-drying on nutritional qualities, quality deterioration and microbiological safety of African catfish (Clarias gariepinus) at various storage condition (1st, 14th , 28th and 42nd Day). Fresh fish samples were obtained from Klassik Integrated Aquafarm, Ado Ekiti, Nigeria. Fish specimens were divided into two equal parts. One part was dried with smoking kiln and the second part with drum kiln. Proximate parameters (protein, lipid and carbohydrate, ash, fibre), quality deterioration and spoilage parameters (TBAR, TVB-N, PV and TMAN) and microbiological parameters (total viable and mould counts) were determined for the oven-dried and smoked products stored at different storage condition using standard methods. According to the proximate assessment of the oven-dried products under 42 days storage conditions, the moisture content ranged between 4.34 and 13.02%, crude protein ranged between 60.24 and 72.84%, fibre ranged between 0.16 2.08%, fat 14.62 and 16.82%, ash 5.44 and 9.04%. TVB-N value ranged between 8.67 and 14.06mgN/100g,PV 1.08 and 6.14 meq, TBAR 0.98 and 2.04 mgMA/kg and TMA-N 2.22 and 3.96 mgN/100g. TVC ranged between 1.34 and 1.52x10^3 cfu/g and yeast and mould count 1.16 and 3.88x10^{2}cfu/g. Considering all the parameters, it can be concluded that the oven-dried products maintained its excellent nutrients quality under 42 days storage condition while there were significant reduction in nutrients quality, quality deterioration and spoilage, high microbial loads were evidence at 28 days storage condition in smoked products.*

KEYWORDS: quality deterioration, microbiological safety, oven-dried and smoked products, African catfish (clarias gariepinus), storage condition

INTRODUCTION

The term fish is defined as all fresh or salt water finfish, mollusc, shelf fish, crustaceans and other forms of aquatic animal life. The fish trade has grown significantly over the last decade due to improvement of technology, transportation, communication and sustained demand. Fish can be classified into 3 categories of marine, fresh water and aquaculture (Eyo, 2014). Fish is considered an excellent food of high-quality protein that can replace both red and white meat especially with the fast-growing aquaculture industry in recent years (Kari et al., 2020). It contains both important micro- (minerals and vitamins) and macro- (protein, fat) nutrients. Furthermore, fish contains a high level of polyunsaturated fats (PUFA) which helps in lowering cardiovascular diseases in humans (Mishra, 2020).

There is a global increase in the consumption of fish and fish products as it constitutes more than 60% of the total protein intake in adults especially in the rural areas where they are widely accepted and form a much-cherished delicacy that cuts across economic, age, religious, and educational barriers (Otolowo and Olapade, 2018 and Oluwatoyin *et al.*, 2010))A problem that has been identified in the storage of smoked fish in Nigeria is that of rapid deterioration as a result of high ambient temperatures, poor postharvest handling, lack of processing, and storage facilities, thereby creating the gap between the demand and supply of fish resulting in shortage of fish and posing great challenge to food security of the increasing population of the entire nation (Adeyeye *et al*., 2017 and Ayeloja *et al*., 2015).

Moreover, smoking increases the protein content and reduces moisture content, it also resulted in value-added products by improving the sensory acceptability of fish (Akinwumi, 2014). Many processors prefer the use of smoking as an easy and simple method for fish preservation to elongate its shelf life and allows selling it at a higher price (Magawata and Musa, 2015). However, fish is considered a highly perishable food that undergoes many deteriorative changes including propagation of bacterial flora as well as lipid oxidation, enzymatic and chemical changes which led to rapid spoilage (Khoshmanesh, 2006). Different preservation techniques e.g., cold storage, salting, drying, fermentation, and smoking are commonly used in fish preservation technology (Alcicek and Atar, 2010). For centuries, smoking is considered the chief method of fish preservation and is still used worldwide in many countries (Bilgin *et al.*, 2008). During smoking, several compounds e.g., phenols and formaldehyde result from the partial burning of specific types of wood. The smoke products impart a harmful effect on both spoilage and food poisoning bacteria and retard the oxidative enzymes which collectively preserve the fish quality and extend its shelf life (Pagu *et al.*, 2013). The combination of taste, cultural relevance, nutritional benefits, and versatility in cooking, economic importance and affordability make the fish a popular demand food item in the country. That's why African catfish (*Clarias gariepinus*) have been selected for the present research work with the aim to increase its production and find potentiality of oven-dried and smoked fish products to serve as one of the well acceptable quality fishery products with high nutrient quality, low deteriorating and

spoilage quality, longer shelf-life and low microbiological infestation under 42 days storage condition.

MATERIALS AND METHODS

Collection of samples

For the experiment, African catfish (*Clarias gariepinus*) were procured from from Klassik Integrated Aquafarm, Ado Ekiti, Ekiti State and conveyed with the use of covered plastic container to the research farm of Fisheries Technology Department, the Federal Polytechnic Ado Ekiti. A total of one hundred and five (105) pieces of fish with an average weight of 450 ± 40 g were used for the experiment, fifty (50) fish were loaded in each kiln i.e smoking and drum kiln.

Drying procedures

The fish were dried using smoking kiln (oven-drying) and drum kiln (smoked drying) in the Department of Fisheries Technology, the Federal Polytechnic Ado Ekiti. Prior to drying both kiln were cleaned thoroughly and their racks oiled properly to avoid samples getting stuck on them during drying. The fish samples were killed immediately after capture, carefully degutted and washed with clean water to remove blood and slime according to the standard method described by Ogbonnaya and Ibrahim (2009). The samples were divided into two equal parts. Fifty (50) fresh fish were loaded in smoking kiln while the second part (50) was arranged on mesh of drum kiln. The fish smoking kiln was operated by first loading charcoal into the heat chamber, preheating for some minutes, and then loading the fish onto the trays in its central chamber. The kiln was closed for some time to allow the smoking to take place. The smoking time, temperature and ambient conditions were monitored during the smoking operations. The smoking was terminated when the fish were properly dried (Olayemi *et al.*, 2011). The products were allowed to cool for 15-20 minutes at room temperature (30-35°C) after smoking. The smoked products from each kiln were packed separately. The product was kept at room temperature 30-35ºC under 42 days storage conditions for shelf-life purposes.

Storage was carried out for 42 days, while samples were taken on fourteenth (14^{th}) days for analyses. Each sample was divided into three for replicates.

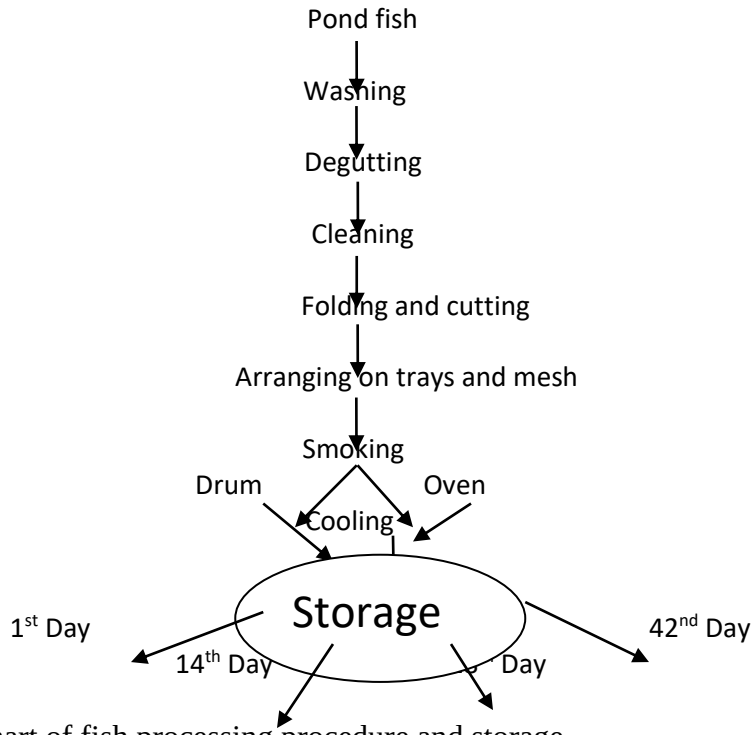

Fig. 1: Flow chart of fish processing procedure and storage

PROXIMATE COMPOSITION

Smoked fish samples stored at room temperatures were collected at day one (1) and at every 14-days interval to 42 days for proximate composition. Proximate chemical composition analysis which includes determination of moisture content, crude protein, crude fat, fibre and total ash of the smoked fish was performed according to A.O.A.C official methods (AOAC. 2015).

EVALUATION OF PHYSICO-CHEMICAL CHANGES IN DRIED PRODUCTS

The oven-dried and smoked samples were grounded separately into powder with a Kenwood blender. The samples were determined for thiobarbituric acid reactive substances (TBARS), peroxide value (PV), trimethylamine nitrogen (TMA-N) and total volatile basic nitrogen (TVB) by the method outlined by (Hamdy *et al.,* 2021).

MICROBIOLOGICAL ANALYSIS

Total viable count (TVC), yeast and mould count (YMC) were determined by the standard method described by Khanipour and Mirzakhani, (2013).

Data Statistical Analysis

Data that resulted from the experiments were subjected to a one-way analysis of variance (ANOVA) using SPSS (Statistical Package for Social Science 23.0). Duncan's multiple range tests were used to compare the differences among individual means at P= 0.05.

RESULTS

The obtained results of proximate chemical composition for the wet weight and dried African catfish, *Clarias gariepinus* under storage condition are shown in Table (1). Data illustrated that the moisture, crude protein, fibre, fat and ash content of wet weight sample were 78.36±0.02%, 17.26±0.04%, 0.88±0.02%, 1.26±0.03% and 1.84±0.02% respectively. Table 1 shows significant increase in protein, fat and ash content while there was decrease in the value of moisture content after smoking with smoking kiln and drum kiln as compared to fresh sample. Highest protein content 72.84±0.02% was recorded in oven-dried sample at first day (1st) storage condition. Highest moisture content, fibre, fat and ash was also recorded in sample smoked with drum kiln at the first day storage with 9.49±0.02%, 21.38±0.02% and 12.32±0.03%. At fourteenth (14th) day storage condition, the oven-dried sample recorded increase in protein and fibre content 67.94±0.04% and 0.54±0.04% respectively and decrease in moisture, fat and ash content with 7.67±0.03%, 16.82±0.04% and 6.68±0.03% respectively. At twenty-eight (28th) and forty-two (42) days storage condition, highest value of protein was recorded in oven-dried product with 62.64±0.04% and 60.24±0.62% respectively.

Table 1: Proximate composition of fresh and smoked catfish (Clarias gariepinus) during storage at room temperature (26oC-31oC)

STORAGE TIME	SAMPLE	MOISTURE (%)	CRUDE PROTEIN (%)	FIBRE (%)	FAT (%)	ASH (%)
1st Day	Fresh (Control)	78.36±0.02	17.26±0.04	0.88±0.02	1.26±0.03	1.84±0.02
	Oven	4.34±0.02^{a}	72.84±0.02^{b}	0.16±0.06^{b}	16.82±0.01^{a}	5.44±0.02^{a}
	Drum	9.48±0.02^{b}	56.42±0.06^{a}	0.08±0.02^{b}	21.38±0.02^{b}	12.32±0.03^{b}
14th Days	Oven	7.67±0.03^{a}	67.94±0.04^{b}	0.54±0.02^{a}	16.82±0.04^{a}	6.68±0.03^{a}
	Drum	15.32±0.02^{b}	52.33±0.01^{a}	0.44±0.01^{a}	23.42±0.08^{b}	10.82±0.06^{b}
28th Days	Oven	12.87±0.02^{a}	62.64±0.04^{b}	1.82±0.01^{a}	14.82±0.02^{a}	7.42±0.02^{a}
	Drum	34.68±2.48^{b}	49.82±0.05^{a}	1.84±0.02^{a}	22.82±0.06^{b}	9.88±0.04^{b}
42nd Days	Oven	13.02±0.24^{b}	60.24±0.62^{b}	2.08±0.22^{a}	14.62±0.22^{a}	9.04±0.36^{a}
	Dum	24.62±0.36^{a}	20.32±0.42^{a}	3.24±0.23^{b}	32.38±0.46^{b}	18.98±0.64^{b}

Mean value with different superscript in the same column for each parameter are significantly ($P<0.05$) different

Changes in Quality Indices for oven –dried and smoked products

The obtained results of quality deterioration parameters of wet weight and smoked –dried catfish under storage condition at room temperature were presented in table 2. Data illustrated that the TVB-N (Total volatile base nitrogen), PV (Peroxide value), TBAR (Thiobabituric acid) and TMAN (Trimethylamine nitrogen) of wet weight were 6.02±0.22mgN/100g, 0.98±0.02meq/kg, 0.52±0.02mgMA/kg and 0.52±0.02mgN/100mg respectively. In general there was an increment in the values across all the parameters after smoking with increase in duration of storage. As the fish stay longer in storage condition, the values of the parameters increases. And significant differences ($p<0.05$) were observed in all the parameters between oven-dried and smoked products. Highest value was observed in sample smoked with drum kiln.

Microbiological Evidence

The results obtained from this study revealed higher incidence of microorganisms on the wet weight and smoked sample compared to oven-dried sample throughout the storage period.
This result shows that total viable counts (TVC), yeast and mould counts (YMC) of the fish sample increase after smoking with increase in storage period. At first day storage period, the sample smoked with drum kiln recorded highest value of total viable counts, yeast and mould counts with $2.45\pm0.34x10^3$cfu/g and $2.64\pm0.04x10^2$cfu/g respectively compared to oven –dried sample 1.34 ± 0.22 $x10^3$cfu/g and 1.18 ± 0.06 $x10^2$cfu/g respectively.

DISCUSSION

The crude proteins are important for normal function, growth, and maintenance of body tissue and hence protein content is considered to be an essential tool for the evaluation of biochemical and physiological standards of a given organism (Belton *et al.*, 2014). The highest value of crude protein recorded in this study after smoking as compared to the value of other parameters is an indication that crude protein formed the largest quantity of the dry matter in all fish samples.

In support of present findings, John *et al.,* (2017) in catfish, (*Clarias gariepinus*) and Neeta *et al.,* (2020) in Mrigal (*Cirrhinus mrigala*) reported significant decrease in protein content during storage condition at room temperature. The increase in fat content after smoking and further decrease with increase in storage time in sample smoked with oven compared to sample smoked with drum which shows high fat content could be attributed to possible loss of fat due to the high temperature generated from oven as observed in the studies Ahmed *et al.*, (2011) and Omoruyi *et al.,* (2017). The rate of removal of moisture content of the sample smoked-dried with oven was higher within first day storage time as presented in table 1. However the sample smoked with drum kiln retained more moisture content as compared to oven-dried sample in this study. Moisture is one of the factors that increase muscle spoilage in fresh fish as reported by Idah *et al.,* (2013). This findings coincides with work of Oparaku and Mgbenka, (2012), stating that a

fish well dried with moisture reduced to 25% (wet basis) will not be affected by spoilage organisms like mould and that if further dried to moisture content of 15%, the growth of mould will cease and the shelf life will increase. The moisture content observed in this study after smoked dried of fresh fish with oven and drum was also observed in the work of Aiyeloja and Akinrotimi, 2021 on evaluation of smoking process on proximate composition of some marine fish species.

The total volatile basic nitrogen (TVB-N) presented in table 2 is one of the most widely used measurements of seafood quality. TVB-N value is an important parameter for determining the freshness of fish products. TVB-N value is affected by species, catching region and season, age and sex of fish (Gökoğlu *et al.,* 1998). The present study showed higher value for TVB-N value after smoking for the two methods adopted and over storage time and showed that the raw material samples used in this experiment were of good quality as the total volatile nitrogen bases (TVB-N) were below the recommended maximum levels of 35 mg N/100 g for smoke fish., (Commission Regulation (EC) No 1022/2008, 2008). At the beginning, the TVB-N values of fresh catfish was 6.02±0.22mgN/100g and after smoking, it increased for the two products while the values of the sample smoked with drum kiln were higher than samples in smoking kiln throughout storage conditions. The results of this study are like the findings of other researchers Ikutegbe, (2014) and John *et al.,* (2017) where smoking processes influenced the TVB-N level of sample products. It is a general term which includes the measurement of trimethylamine (produced by spoilage bacteria), dimethylamine (produced by autolytic enzymes during frozen storage), ammonia (produced by the deamination of amino-acids and nucleotide catabolites) and other volatile basic nitrogenous compounds associated with seafood spoilage.

The food safety agencies recommended the assessment of TBARS, PV, TVBN, and pH values as they threatening the quality, shelf life, and acceptability of smoked fish (El-Lahamy *et al*., 2019). It can be seen that the TBARS values were gradually and significantly ($P < 0.05$) increased during the storage days, the rate of increase of TBARS value in smoked sample was higher than the rate of increase in oven-dried samples. The result in this study is in agreement with the findings of Domínguez *et al.,* (2019) and Shaban *et al.,* (2021), the observed increases in values of TBARS with increase in storage was as a result of both autoxidation of fish lipid and the formation some of TBA-reaction substances throughout the storage period. The initial value of TBAR 0.52±0.02 mg MA/kg (fresh state), suggesting that limited lipid oxidation occur during post-mortem handling. From this result, TBAR slightly increased during smoking (Table 2) and also during subsequent storage periods in oven-dried and smoked sample. The highest increase was reported in smoked sample after 48 days storage condition. The increase in TBAR value during the smoking and storage may be attributed to the partial dehydration of fish and to the increased oxidation of unsaturated fatty acids as a result of smoking. This result was also in agreement with results reported by Mohamed and Atef (2012) who observed increase in TBA value of Grass Carp (*Ctenopharyngodon idella*) fillets after smoking. Peroxide value is a primary indicator of oxidation of fat (rancidity) (Adeyemi *et al.,* 2013). Results presented in table 2 indicate that preservation method increased peroxide values in both oven-dried and smoked products with increase in storage. The peroxide values correspond to incipient spoilage usually in the order of

20-40 meq O2/kg ml/kg. However, Neeta *et al.,* (2020) reported that when peroxide value is above 10-20 meq O_2/kg, fish develop rancid taste and smell. Thus, it can be concluded that the values from sample smoked-dried with smoking kiln are still within acceptable limit of spoilage, while sample smoked with drum kiln exceeded the limit as reported by Neeta *et al.,* (2020).

TMA is a reduction product of trimethylamine oxide (TMAO) during spoilage and ammonia is mainly formed as a product of protein breakdown. Trimethylamine (TMA) is one of the volatile amines plus ammonia which can be used as an index of spoilage (Da Silva, 2002). The values obtained in this study were within the range of 0.21-0.47 from day 0-day to 15 day. The values obtained in sample smoked-dried with oven were lower (range 2.22±0.36-3.96±0.22mgN/100g) when compared to the value 5.00 mgN/100 g for doubtful quality specified U.S.F.D.A (Da Silva, et al., 2008). Trimethylamine is associated with fatty substance and is responsible for the fishy smell of spoiled fish. The lower level of trimethylamine in the sample smoked with oven indicates that there was low rate of decomposition of fish protein and the fish samples are of good quality. It is evidence that the two smoking processes adopted in this study reduce the microbial load of fish (Table 3). The result also shows that increase in storage period of smoked sample leads to increase in microbial loads on fish. From table 3, sample smoked with drum kiln has short shelf life at 28 days storage condition. The findings from this study agree with work of Dutta *et al*. (2018) reported that almost all microbes are killed by hot smoking, except certain pathogenic bacteria, since the fish is cooked and dried at high temperatures. The reduction of microbial values of oven-dried products and gradual increase with increase in storage period reported from this study could be owed to several hurdle factors e.g., decrease in pH, reduced water activity, long exposure to high temperature, increase the salt content used, and the bactericidal and antioxidant effect of phenolic content which increases with the time of smoking (Odeyemi *et al.,* 2020). The rapid increase in TVC and YMC in smoked sample in this study could be as a result of smoking facility used, which is not capable of drying the fish to withstand the storage period subjected to, the findings coincided with Shaban *et al.,* (2021) reported hot smoked sagan fish possessed higher quality, safety and acceptance than the cold-smoked fish. The increase in moisture content of the sample smoked with drum could lead to the proliferation of microorganisms, thereby resulting in the rapid increase in the microbial loads during storage period. This was in agreement with Ekelemu *et al.* (2021) who reported that microbial loads increased with the duration of storage.

CONCLUSION

The result of this research, based on oven-dried and smoked *Clarias gariepinus* suggested that fish smoked-dried with oven are safe for human consumption and still maintain its protein content up till 42 days of storage condition at room temperature. Therefore, the present study demonstrates that smoking and drying treatments applied to fish samples play great roles in preserving and prolonging the shelf life of fish. It also aids in shelf life extension of the fish and also maintenance of its consumer appeal and acceptability. Total viable and mould are low and within acceptable range in oven-dried sample for 42 days storage condition. Therefore, the present study demonstrates that smoking and drying treatments applied to fish samples play great

roles in preserving and prolonging the shelf stability of fish. It also aids in shelf life extension of the fish and also maintenance of its consumer appeal and acceptability. Prolonged ambient storage period for drum kiln sample beyond 14 day will reduce general quality and acceptability of the product and should be discouraged.

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