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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 work aimed to evaluate the effects of oven-dried and smoked-dried on nutrient qualities, quality deterioration and microbiological safety of African catfish (*Clarias gariepinus*) at various storage condition (1st, 14th, 28th and 42nd Day). Live fish samples were obtained from Klassik Integrated Aquafarm, Ado Ekiti, Nigeria. Two equal portions were separated from the fish specimens. A smoking kiln was used to dry one portion, while a drum kiln was used to dry the other. 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/100 g, PV 1.08 and 6.14 meq, TBAR 0.98 and 2.04 mgMA/kg and TMA-N 2.22 and 3.96 mgN/100 g. 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, African catfish, *Clarias gariepinus*

Introduction

Fish include all mollusks, shellfish, crustaceans, freshwater and saltwater finfish and other aquatic animals. The previous ten years have seen a substantial increase in the fish trade because to advancements in communication, transportation, and technology as well as persistent demand. Fish are divided into three groups: marine, freshwater, and aquaculture (Eyo, 2014) [28].

Fish is regarded as a great source of high-quality protein that can substitute both red and white meat, particularly in light of the rapidly expanding aquaculture industry in recent years (Kari *et al*., 2020) [29]. It is rich in macronutrients like protein and fat as well as micronutrients like vitamins and minerals. Additionally, fish has a high concentration of polyunsaturated fats (PUFA), which may help prevent cardiovascular diseases in humans (Mishra, 2020) [30].

The consumption of fish and fish products has increased globally because they account for over 60% of adults' protein intake, particularly in rural areas where they are widely consumed and considered a delicacy that transcends social, economic, age, and educational boundaries (Otolowo and Olapade, 2018 and Oluwatoyin *et al*., 2010) [24, 23].

Rapid deterioration due to high ambient temperatures, inadequate postharvest handling, inadequate processing, and a lack of storage facilities has been identified as a problem with smoked fish storage in Nigeria. This has created a gap between the supply and demand for fish, which has led to a shortage and posed a serious threat to the food security of the countries expanding population (Adeyeye *et al*., 2017 and Ayeloja *et al*., 2015) [2, 7].

Contrarily, fish is thought to be a very perishable food that spoils quickly as a result of a number of deteriorative processes, including lipid oxidation, enzymatic changes, chemical changes, and the development of bacterial flora (Khoshmanesh, 2006) [16].
Additionally, smoking lowers the moisture level and raises the protein content. It also improves the fish's sensory acceptability, which leads to value-added products (Akinwumi, 2014) [6]. Many fish processors favor smoking fish since it's a quick and straightforward way to extend its shelf life and increase its price (Magawata and Musa, 2015) [17]. Fish preservation technology frequently uses a variety of preservation methods, such as cold storage, salting, drying, fermenting, and smoking (Alcicek and Atar, 2010) [31]. Smoking has been the primary technique for preserving fish for millennia and is still practiced in many nations today (Bilgin *et al*., 2008) [8].
Several substances, such as formaldehyde and phenols, are produced during smoking when some types of wood are partially burned. According to Pagu *et al*. (2013) [25], smoke products have a detrimental effect on bacteria that cause food poisoning and spoiling. They also slow down the oxidative enzymes that help to maintain the quality of fish and increase its shelf life.
Fish is a highly sought-after food item in the nation due to its taste, cultural significance, nutritional value, adaptability in cooking, economic significance, and affordability. With the intention of increasing its production and determining the potential for oven-dried and smoked fish products to serve as one of the well-acceptable quality fishery products with high nutrient quality, low deteriorating and spoiling quality, longer shelf-life, and low microbiological infestation under 42-day storage conditions, African catfish (*Clarias gariepinus*) have been chosen for the current research project.

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.

Fish processing

Locally fabricated smoking kiln and perforated drum kiln was used for oven dried and smoked sample respectively in the processing laboratory of the Fisheries Technology Department, the Federal Polytechnic Ado Ekiti. Prior to drying both kilns and their racks were thoroughly cleaned to prevent contamination of sample with residues and undesirable substances. The fish samples were promptly killed, meticulously degutted, and thoroughly cleaned using clean water to remove any remaining blood or slime, following the standard procedure outlined by Ogbonnaya and Ibrahim (2009) [21]. The experimental fish were divided into two equal portions. One portion of the fish (50) were loaded in fabricated smoking kiln while the other portion (50) was arranged on perforated drum kiln mesh. Fish was loaded onto trays in the central chamber of the fabricated smoking kiln after the charcoal had been loaded into the heat chamber and heated for a few minutes. For a while, the kiln was closed so that smoking could occur. Throughout the smoking operations, the temperature, smoking time, and surrounding circumstances were recorded. When the fish had sufficiently dried, the smoking process was stopped (Olayemi *et al*., 2011) [22].
After smoking, the items were left to cool for fifteen to twenty-five minutes at room temperature (30 to 35 °C). The smoked products from the two kilns were packaged differently. For 42 days, the product was stored at room temperature (30–35 °C) for shelf life purposes. Samples were taken on the first (1st) day and every fourteenth (14th) days for analyses.

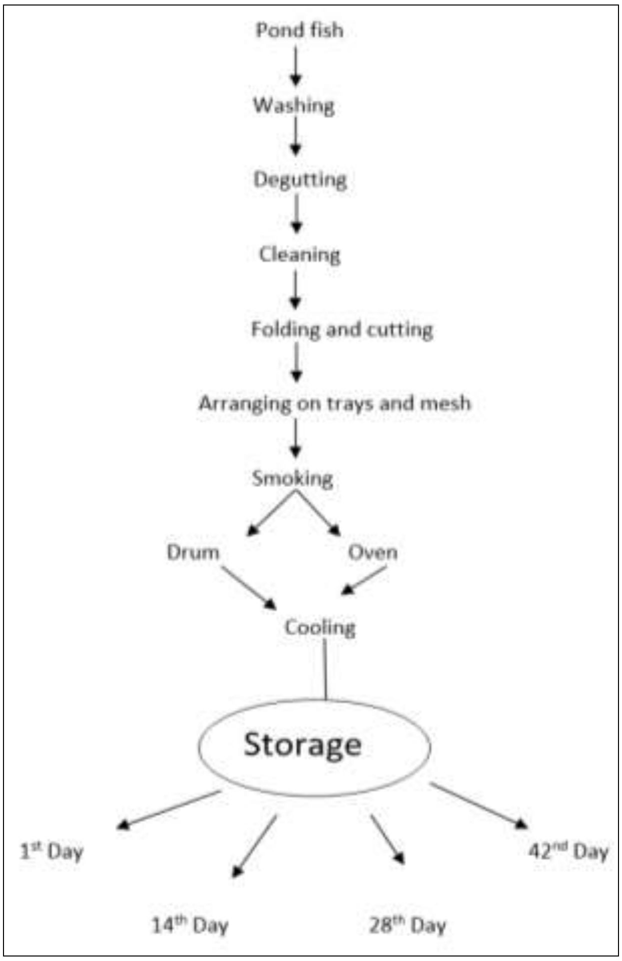

Fig 1: Flow chart of fish processing procedure and storage

Proximate Composition

For the purpose of proximate composition, smoked fish samples that had been kept at room temperature were taken on day one (1) and then every 14 days for a total of 42 days. The A.O.A.C. official procedures were followed for the approximate chemical composition analysis, which include determination of the smoked fish's moisture content, crude protein, crude fat, fiber, and total ash.

Evaluation of Physico-chemical changes in dried products

Using a Kenwood blender, the oven-dried and smoked samples were crushed into powder independently. Using the methodology described by (Hamdy *et al.*, 2021) [32], the samples' levels of trimethylamine nitrogen (TMA-N), total volatile basic nitrogen (TVB), peroxide value (PV), and thiobarbituric acid reactive substances (TBARS) were measured.

Microbiological Examination

The standard procedure outlined by Khanipour and

Mirzakhani (2013) [15] was used to obtain the total viable count (TVC) and the yeast and mold count (YMC).

Statistical Analysis of Data

Using SPSS (Statistical Package for Social Science 23.0), a one-way analysis of variance (ANOVA) was performed on the experiment data. At $P<0.05$, Duncan's multiple range tests were employed to compare the variations in individual averages.

Results

Table 1 displays the chemical composition values for the dried African catfish, *Clarias gariepinus*, under storage conditions, as well as the wet weight. The wet weight sample's moisture, crude protein, fiber, fat, and ash contents were 78.36±0.02%, 17.26±0.04%, 0.88±0.02%, 1.26±0.03%, and 1.84±0.02% respectively. When compared to fresh samples, Table 1 indicates a considerable rise in the content of protein, fat, and ash, but a decrease in the value of moisture content for fabricated smoking kiln and perforated drum kiln products. 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: Chemical composition of African catfish under storage condition (26ºC-31 ºC)

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±0.02a	72.84±0.02b	0.16±0.06b	16.82±0.01a	5.44±0.02a
	Drum	9.48±0.02b	56.42±0.06a	0.08±0.02b	21.38±0.02b	12.32±0.03b
14th Days	Oven	7.67±0.03a	67.94±0.04b	0.54±0.02a	16.82±0.04a	6.68±0.03a
	Drum	15.32±0.02b	52.33±0.01a	0.44±0.01a	23.42±0.08b	10.82±0.06b
28th Days	Oven	12.87±0.02a	62.64±0.04b	1.82±0.01a	14.82±0.02a	7.42±0.02a
	Drum	34.68±2.48b	49.82±0.05a	1.84±0.02a	22.82±0.06b	9.88±0.04b
42nd Days	Oven	13.02±0.24b	60.24±0.62b	2.08±0.22a	14.62±0.22a	9.04±0.36a
	Dum	24.62±0.36a	20.32±0.42a	3.24±0.23b	32.38±0.46b	18.98±0.64b

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

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±0.22 mg N / 100g, 0.98±0.02 meq / kg, 0.52±0.02 mg MA/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.

Table 2: Quality deterioration parameters of fresh and smoked-dried catfish during storage period

Storage Time	Sample	TVB-N(mg N/100g)	PV (meq /kg)	TBAR (mg malondialdehyde/kg)	TMA-N (mg N/100g)
1 Day	Fresh (Control)	6.02±0.22	0.98±0.02	0.52±0.02	0.52±0.02
	Oven	8.67±0.62a	1.08±1.24a	0.98±0.12a	2.22±0.36a
	Drum	8.78±0.88a	1.92±1.62b	1.02±0.42a	3.60±0.24b
14 Days	Oven	9.24±0.42a	3.62±0.34a	1.68±0.26a	2.62±0.84a
	Drum	22.82±0.66b	7.02±0.48b	2.84±0.82b	8.08±0.62b
28 Days	Oven	10.02±0.22a	4.98±0.26a	1.94±0.82a	2.84±0.96a
	Drum	25.62±0.32b	8.48±0.22b	3.96±0.34b	8.62±0.02b
42 Days	Oven	14.06±0.98a	6.14±0.62a	2.04±0.62a	3.96±0.44a
	Drum	29.62±0.98b	12.94±0.74b	4.82±0.72b	9.24±0.08b

*TVB-N, total volatile basic nitrogen, * PV, peroxide value, *TBAR, thiobarbituric acid,
* TMA-N, trimethylamine nitrogen. Mean value with different superscript in the same column for each parameter are significantly ($P<0.05$) different

Microbiological Evidence

The study's findings showed that, over the course of storage, there were more microorganisms on the wet weight and sample smoked with perforated kiln (smoked) than on the fabricated smoking kiln sample (oven-dried). This result shows that total viable counts (TVC), yeast and mold 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 $2.45±0.34x10^3$cfu/g and $2.64±0.04x10^2$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.

Table 3: Microbiological safety and shelf life of African catfish, C*larias gariepinus* under storage condition

Storage time	Sample	TVC x 10^3 (cfu/g)	YMC X 10^2 (cfu/g)
1 Day	Fresh (Control)	4.28±0.44	3.24 ± 0.02
	Oven	1.34±0.22^a	1.18±0.06^a
	Drum	2.45±0.34^b	2.64±0.04^b
14 Days	Oven	1.48±0.42^a	2.02±0.04^a
	Drum	6.86±0.38^b	3.64±0.02^b
28 Days	Oven	1.52±0.64^a	2.47±0.22^a
	Drum	22.23±0.86^b	48.46±0.46^b
42 Days	Oven	2.45±0.54^a	3.88±0.64
	Drum	365.62±7.84^b	*

Mean± standard deviation, * completely covered with mould (mouldy)
*TVC implies total viable counts. YMC implies yeast and mould count.
*cfu implies colony forming units

Discussion

According to Belton *et al*. (2014) [33], protein content is regarded as a crucial instrument for assessing the biochemical and physiological criteria of a particular organism because crude proteins are vital for regular bodily function, growth, and maintenance of body tissue. Upon smoking, the study's highest crude protein value was found to be indicative of the largest amount of dry matter present in all fish samples, when compared to the values of other metrics.

Recent research on catfish (*Clarias gariepinus*) by John *et al.* (2017) [34] and Mrigal (Cirrhinus mrigala) by Neeta *et al.* (2020) [35] indicates a noteworthy decline in protein content while stored at room temperature. The increase in fat content after smoking and further decrease with increase in storage time in sample smoked with fabricated smoking kiln compared to sample smoked with drum kiln which shows high fat content may be related to potential fat loss from the oven's high temperature, as noted in studies by Ahmed *et al.* (2011) [3] and Omoruyi *et al.* (2017) [14].

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. Idah *et al.* (2013) [36] reported that one of the things that make fresh fish's muscle deteriorate more quickly is moisture. This research supports the findings of Oparaku and Mgbenka (2012) [37], who found that fish that have been thoroughly dried and have had their moisture content reduced to 25% (wet basis) will not be affected by spoilage organisms like mold. If the fish is further dried to a moisture content of 15%, mold growth will stop and the fish's shelf life will increase. The moisture content that was noted in this study following smoking was also noted in Aiyeloja and Akinrotimi, (2021) [4] on assessment of the effect of smoking on the proximate composition of specific marine fish species.

One of the most popular methods for determining the quality of seafood is to utilize the total volatile basic nitrogen (TVB-N) value shown in table 2. An essential factor in assessing the freshness of fish items is the TVB-N value. Fish age and sex, capturing region, season, and species all influence TVB-N value. Total volatile nitrogen bases (TVB-N) were found to be below the recommended maximum levels of 35 mg N/100 g for smoke fish, indicating that the raw material samples used in this experiment were of good quality. The results of this study showed higher values for TVB-N values after smoking for the two methods adopted and over storage time (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 findings of this investigation support those of Ikutegbe (2014) [12] and John *et al*. (2017) [34], who found that smoking processes affected the TVB-N content of sample goods. This general term encompasses the measurement of volatile basic nitrogenous compounds linked to seafood spoilage, such as ammonia (produced by the deamination of amino acids and nucleotide catabolites), dimethylamine (produced by autolytic enzymes during frozen storage), trimethylamine (produced by spoilage bacteria), and other volatile compounds.

The quality, shelf life, and acceptability of smoked fish are all at risk, hence the food safety organizations advised evaluating the pH, TVBN, PV, and TBARS levels (El-Lahamy *et al*., 2019) [11]. It is evident that throughout the storage days, the TBARS values grew gradually and considerably ($P<0.05$); moreover, the rate of increase in the TBARS value in the sample smoked with perforated drum kiln (smoked) was higher than the rate of increase in the fabricated smoking kiln (oven-dried). This study's result is consistent with that of Domínguez *et al.* (2019) [9] and Shaban *et al.* (2021) [38], who found that the formation of certain TBA-reaction substances during the storage period and fish lipid autoxidation were the causes of the observed increases in TBARS values with increased storage. 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) [18] who observed increase in TBA value of Grass Carp (*Ctenopharyngodon idella*) fillets after smoking. The initial TBAR value of 0.52±0.02 mg MA/kg (fresh condition) indicates that post-mortem treatment may have minimized lipid oxidation. According to this finding, the oven-dried and smoked sample's TBAR slightly rose during smoking (Table 2) and the ensuing storage times. At 48 days of storage, the smoked sample showed the most rise. The partial drying of the fish and the enhanced oxidation of unsaturated fatty acids brought on by smoking may be the causes of the increase in TBAR value during smoking and storage. This outcome also agreed with findings published by Mohamed and Atef (2012) [18], who noted that smoking increased the TBA value of grass carp (*Ctenopharyngodon idella*) fillets.

The main measure of fat oxidation (rancidity) is the peroxide value (Adeyemi *et al*., 2013) [1]. Results (table 2) shows that the preservation method raised the peroxide values in both smoked and oven-dried products as storage lengthened. The peroxide readings often fall between 20 and 40 meq O2/kg ml/kg, which indicates early spoiling. Neeta *et al*. (2020) [35] observed that fish acquire a rotten flavor and smell when the peroxide value exceeds 10–20 meq O2/kg.

Base on these findings, it can be concluded that the sample smoked in drum kiln surpassed the permitted limit of spoilage, whereas the values of oven-dried sample maintain acceptable limit.

Ammonia is mostly produced as a byproduct of protein degradation, while TMA is a reduction product of trimethylamine oxide (TMAO) during spoilage. Along with ammonia, trimethylamine (TMA) is one of the volatile amines that can be employed as a spoilage index (Da Silva, 2002) [39]. In comparison to the value of 5.00 mgN/100 g for doubtful quality provided by the U.S.F.D.A., the values obtained in the sample that was oven-dried were lower (range 2.22±0.36-3.96±0.22 mgN/100 g) compared to smoked sample (Da Silva, *et al*., 2008) [40]. Trimethylamine is connected to fat and is what gives rotten fish its distinct fragrance.

The sample smoked in the oven had a lower level of trimethylamine, indicating that the fish samples were of high quality and that the rate of fish protein degradation was low. There is proof that the two smoking methods used in this investigation lower the fish's microbial load (Table 3). The outcome also demonstrates that longer storage times for smoked samples result in higher microbial burdens on fish.

According to Table 3, the smoked sample has a short shelf life (28 days). The results of this investigation are consistent with the findings of Dutta *et al.* (2018) [10], who found that, because hot smoking kills nearly all microorganisms except for some harmful bacteria, the fish is cooked and dried at high temperatures. The study found that the microbial values of oven-dried products decreased and then gradually increased over time. These findings could be attributed to a number of obstacles, such as a drop in pH, a decrease in water activity, prolonged exposure to high temperatures, an increase in salt content, and the phenolic content's bactericidal and antioxidant effects, which increase with smoking time (Odeyemi *et al*., 2020) [20].

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) [38] findings that hot-smoked sagan fish was more acceptable and of higher quality than cold-smoked fish. The sample smoked in a drum kiln may have more moisture, which could encourage the growth of germs and cause the microbial loads to rise quickly throughout the storage time. This was in line with the findings of Ekelemu *et al.* (2021) [41], who showed that microbial loads rose with storage time.

Conclusion

The result of this findings 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. As a result, the current study shows how important it is to apply drying and smoking treatments to fish samples in order to preserve and extend their shelf life. Additionally, it helps to maintain the fish's customer acceptability and appeal while extending its shelf life. For a 42-day storage period, the total viable and mold are low and within an acceptable range in the oven-dried sample. Thus, the current study shows that the processes of smoking and drying fish samples are very important for maintaining and extending the fish's shelf life. Additionally, it helps to maintain the fish's customer acceptability and appeal while extending its shelf life. Extended ambient storage of drum kiln samples, beyond 14 days, should be discouraged as it will lower the overall quality and acceptability of the product.

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