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Quality characteristics of three Hot-Smoked fish species using locally fabricated Smoking kiln

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Abstract
Three fresh water fish species; *Clarias gariepinus*, *Mormyrus rume* and *Heterobranchus longifilis* were subjected to hot smoking using a locally fabricated smoking kiln with a view to determining its efficiency and affordability by peasant fishermen. This will add to the smoking kiln technology and to determine its performance for possible adoption. Loss in weight of the fish samples, temperature, chemical analysis, organoleptic properties and the time it took to properly smoked the fish using charcoal were the parameters used to determine the smoking efficiency. The present samples of the species used in testing the smoking kiln spent 1:30 hours to smoke dry. It was discovered that its performance was efficient because of the faster rate of the dry smoking compared to the already existing fish smoking kilns. The three treatments were subjected to proximate and sensory (organoleptic) analysis. The highest percentage protein content (58.05 $\pm$ 0.64) was recorded in smoked *Heterobranchus longifilis* while the least (54.54 $\pm$ 0.56) was observed in smoked *Clarias gariepinus*. However, no significant difference ($P > 0.05$) was observed between the samples. Sensory evaluation, bacterial count and Total Volatile Bases-Nitrogen of smoked fish samples showed that the quality of the smoked fish decreases with duration of storage. However, all the samples were of acceptable quality for the period of the research. It is hereby suggested that fish should be stored for a short period after smoking to retain its unique taste and flavor. This smoking kiln is hereby recommended to the peasants because of its low cost since it costs approximately #3000 only to fabricate a unit of the kiln.

Keywords: *hot smoking, fabricated, fish species, efficiency, smoking kiln*

1. Introduction
Fish smoking is receiving great attention because of its simplicity and acceptability by consumers. Nowadays, fishermen form the habit of smoking their fish rather than disposing it fresh because it attracts more income. Nigeria is endowed with vast water bodies with varying number of fish species. These species are preserved and processed via distinct means such as drying, frying, freezing, salting, and smoking in order to ensure sustainable supply of fish all year round and to meet up with a post-harvest loss challenges in Nigeria which had reached about 25 to 50 per cent [Ikenweiwe *et al.*, (2010) [1]; Magawata and Oyelese, (2000) [2]; Goulas and Kontominas (2005) [3]].
Khoshmanesh, (2006) [4] and Eyo, (1997) [5] observed that fish is the most perishable of all fresh foods. Immediately fish is out of water deterioration commences due to several factors such as enzymatic activities, bacterial growth, and chemical oxidation of fat which cause rancidity and/or off-flavour. Clucas and Ward (1996) [6] reported that for fish to remain in good quality, it should be preserved, especially in the tropical environment where temperature is so high. Smoking ensures reduction of moisture content which invariably retards the autolytic activity of most bacteria, prevent mould growth, fish discolouration and ultimately increase the shelf-life of the fish and guarantee a sustainable supply of fish during off season in addition to the increase in profit margin of the fisher-folks [Davies and Davies [7]]
Researches on quality of smoked fish products have been conducted by many authors especially in the southern parts of Nigeria; (Ikeweiwe *et al.*, [1]) and (Kumolu-Johnson and Ndimele, 2001) [8]. Reports indicated that fish with a firm texture (which is a characteristic of smoked products) are more preferred to fish with soft texture Clucas and Ward (1981) [6]; Eyo (1997) [5]. Many smoking kilns have been manufactured which are beyond the reach of the peasant of this part of the country where poverty is more pronounced. The present study is aimed at fabricating a locally, cheap and affordable smoking kiln that will be used by fishermen in this locality. This is with a view to coming up with appropriate technology that will improve the existing smoking kiln in order to obtain smoke products that will be most

acceptable to consumers at a lesser cost. Information on smoked products with regards to this environment is not readily available; hence the present study would provide opportunity for obtaining such documented data.

2. Materials and Methods

2.1 Construction of the Smoking Kiln

The construction of this smoking kiln wouldn't have been possible without the works of Ikeweiwe *et al.,* [1]. However, due considerations such as economic status and literacy level of the fishermen were born in mind before coming up with a smaller size kiln (when compared to that of Ikeweiwe *et al.,* [1]. The present kiln (Fig. 1) has frame (constructed from galvanized pipes) which supports the body (made up of galvanized iron sheet). The cabinet has an overall length of 25cm and breadth of 15cm. The top of the cabinet is made in form of perforated surface where the fish is placed for smoking. A tray was constructed below the perforated surface which holds the smoking fuel (charcoal). The smoking kiln can be used to smoke up to 5kg of fish at a time. The entire system can be placed under a shade because of the sun or rain.

2.2 Sample Collection and preparation

The three fish species (*Clarias gariepinus, Mormyrus rume* and *Heterobranchus longifilis)* were procured while alive from Kwalkwalawa landing site of River Rima, Sokoto State. These species are common, abundant and widely cherished by the populace. The samples were humanely killed by stunning. All samples were eviscerated and thoroughly washed in clean water. These cleaned samples were then salted and allowed to stay for a period of 15 minutes before laying in the smoking kiln for smoking.

2.3 Smoking Process

The perforated sheet surface was greased with groundnut oil to prevent the fish from sticking unto the sheet. The brined fish were arranged on the perforated sheet and red hot charcoal was placed under the smoking sheet on the fuel tray heat to the fish to enhance smoking (Fig 2.). The fish were smoked within 1:30 hours with smoking temperature range of 60^{O}C and 100^{O}C.

2.4 Determination of Weight Loss

The weight loss was determined using Eq. (1):

Weight loss=initial weight-final weight

The percentage weight loss was determined using Eq. (2):

$$\%\ weight\,loss = \frac{initial\,weight - final\,weight}{initial\,weight} \times 100$$

2.5 Sensory (Organoleptic) Evaluation

The organoleptic evaluation of the smoked samples was carried out using a10 member panelists. Parameters such as flavour, texture, odour, appearance and general taste were used to compare the organoleptic characteristics of the products.

Questionnaires were used by the panelists and scoring was done on a weekly basis. The questionnaires were prepared using a 5 point hedonic scale as suggested by Poste *et al.* (1991) [9]. The points are as outlined below:

Very good	-	5
Good	-	4
Averagely good	-	3
Fair	-	2
Bad	-	1

2.6 Proximate Analysis

After the preparation of the edible parts of the fish samples, the following proximate components; Moisture, crude protein, fat, Ash and nitrogen free extract were analysed according to AOAC, (1996) [10] procedures

2.7 Determination of Shelf Life

The shelf life determination of the smoked fish was carried-out using the bacteriological and total volatile bases nitrogen determinations as described below: The attributes and conditions of the stored fish were assessed regularly at one week interval.

2.8 Bacteriological Assessment

Bacterial count was carried out using standard plate count. 1g of the smoked samples was diluted into 9mls of distilled water (1g:9mls) in sterilized universal tubes for each of the treatments. From this dilution, further serial dilutions were made up by 1ml transfer from tube 1 through tube 5. Plates already prepared were allowed to set before incubating for 24hours and colony counts were carried out on plates.

2.9 Total volatile bases nitrogen (TVBN) Analysis

A 10g sample was washed into the distillation flask and 1gram magnesium oxide was added, followed by two drops of antifoam solution. The Samples were boiled and distilled into 10ml of hydrochloric solution with added indicator in a 500ml conical flask. After the distillation, the content of conical flask was titrated using 0.1 sodium hydroxide.

2.10 Statistical Analysis

Experimental fishes were laid out in a completely randomized design. The data obtained were subjected to analysis of variance (ANOVA) and the means were separated by Duncan's Multiple Range Test (1995) [11], using statistical package for social science (SPSS) Version 16.0 computer software.

3. Results

The results of the weight loss of the samples of the species used in the present research are shown in Table I. Weight loss was higher in samples of *Heterobranchus longfilis* with a value of 56.29% while the least was in *Clarias gariepinus* with a percentage value of 53.85. There were no significant differences ($P > 0.05$) in the weight loss of the three species used in this study.

Tables II and III showed the results of the proximate composition of fish samples before and after smoking. There was a significant increase in the protein and fat content after smoking with moisture being reduced drastically in all the species. The percentage fat contents of the species ranged from 2.13, 3.95 and 2.35 to 9.16, 10.40 and 9.19 before and after smoking for *Clarias, Mormyrus,* and *Heterobanchus,* respectively. Protein percentage recorded increase from fresh to smoked (17.10-54.54, 18.5-57.31, and 18.04-58.05%), while percentage moisture reduction was from 69.20 – 19.13, 66.00 – 17.98 and 69.51 – 17.15 for *Clarias, Mormyrus,* and *Heterobranchus,* respectively.

Table IV shows the result of the organoleptic analysis using taste panelists' assessment. It depicts significant difference ($p < 0.05$) of the taste across the weeks for all the parameters tested (flavor, texture, odour, appearance and general taste). As the storage period increases the taste value tends to reduce.

Bacterial count and total volatile bases Nitrogen (TVBN) were

also assessed and presented in Tables IV and V with a view to determining the palatability and safety of the smoked fish for consumption under storage condition. The results revealed a significant reduction in the bacterial count across the weeks. Though the amount of TVBN increases over time, the values are still within the acceptable range for safe utilization of the products.

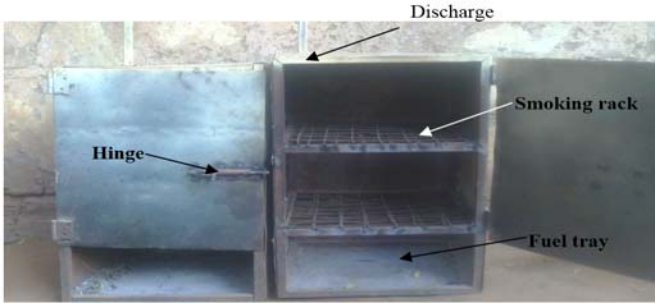

Fig 1: The Locally developed smoking kiln

Fig 2: Fish in the smoking kiln after smoking

Table I: Determination of weight loss from fabricated smoking kiln

Fish species	No. of fish	Initial average weight (g)	Final average weight (g)	Weight loss (%)	Smoking time (h)
Clarias gariepinus	5	325	150	53.85	1:20
Mormyrus rume	5	269	121	55.02	1:00
Heterobranchus longifilis	5	350	153	56.29	1:45

Table II: Proximate Composition of Fishes before Smoking (n = 5/species)

Parameters (%)	*Clarias gariepinus*	*Mormyrus rume*	*Heterobranchus longifilis*
Ash	5.19±0.09	5.04±0.07	5.02±0.01
Fat	2.13±0.01	3.85±0.06	2.35±0.02
Protein	17.10±0.22	18.50±0.13	18.04±0.34
Moisture	69.20±0.27	66.00±0.00	69.51±0.15
Nitrogen Free Extract	6.32±0.10	7.50±0.10	6.06±0.13

Table III: Proximate composition of smoked fish (n = 5/species)

Parameters (%)	*Clarias gariepinus*	*Mormyrus rume*	*Heterobranchus longifilis*
Ash	7.18±0.04	7.41±0.30	7.21±0.10
Fat	9.16±0.12	10.40±0.55	9.19±0.13
Protein	54.54±0.56	57.31±0.97	58.05±0.64
Moisture	19.13±0.54	17.98±0.18	17.15±0.19
Nitrogen Free Extract	8.25±0.15	7.08±0.09	8.40±0.12

Table IV: Sensory evaluation of smoked fishes

Parameters	*Clarias gariepinus*	*Mormyrus rume*	*Heterobranchus longifilis*
1st Week			
Flavor	4.80±0.13^{a}	4.50±0.22^{a}	4.80±0.13^{a}
Texture	4.70±0.21^{a}	4.40±0.27^{a}	4.90±0.10^{a}
Odour	4.60±0.22^{a}	4.30±0.26^{a}	4.80±0.13^{a}
Appearance	4.50±0.27^{a}	4.10±0.28^{a}	4.70±0.15^{a}
General taste	4.90±0.10^{a}	4.40±0.31^{a}	4.80±0.20^{a}
2nd Week			
Flavor	4.70±0.15^{a}	4.40±0.27^{a}	4.50±0.31^{a}
Texture	4.60±0.31^{a}	4.40±0.22^{a}	4.40±0.31^{a}
Odour	4.50±0.17^{a}	4.20±0.25^{a}	4.40±0.16^{a}
Appearance	4.50±0.22^{a}	4.00±0.30^{a}	4.60±0.16^{a}
General taste	4.60±0.16^{a}	4.00±0.30^{a}	4.50±0.22^{a}
3rd Week			
Flavor	4.40±0.16^{a}	4.00±0.15^{a}	4.40±0.16^{ab}
Texture	4.50±0.17^{a}	3.80±0.20^{b}	4.40±0.16^{a}
Odour	4.50±0.17^{a}	4.30±0.15^{a}	4.40±0.16^{a}
Appearance	3.90±0.41^{b}	2.90±0.23^{bc}	3.80±0.44^{b}
General taste	4.40±0.22^{a}	3.40±0.34^{b}	4.50±0.17^{a}
4th Week			
Flavor	3.70±0.21^{b}	3.40±0.22^{b}	3.80±0.20^{b}
Texture	3.70±0.26^{b}	2.90±0.23^{c}	3.90±0.23^{b}
Odour	3.50±0.31^{b}	3.00±0.26^{b}	3.80±0.25^{b}
Appearance	3.30±0.40^{bc}	3.10±0.31^{b}	3.70±0.30^{b}
General taste	3.70±0.37^{b}	3.50±0.34^{b}	3.70±0.30^{b}
5th Week			
Flavor	2.90±0.23^{c}	2.30±0.15^{c}	2.80±0.25^{c}
Texture	3.10±0.28^{b}	2.20±0.13^{c}	3.40±0.31^{b}
Odour	2.90±0.23^{c}	2.00±0.15^{c}	3.00±0.30^{c}
Appearance	2.90±0.28^{c}	2.60±0.22^{c}	3.00±0.30^{c}
General taste	3.00±0.40^{c}	2.70±0.34^{c}	3.10±0.38^{c}

Means of each parameter with the same alphabet(s) in the same column are not significantly different (p>0.05).

Table V: Mean weekly bacterial count

Weeks	Species	Mean count	Standard (cfu/g)
1	*Clarias gariepinus*	28^{a}	2.8 x 10^{6}
	Mormyrus rume	32^{a}	3.2 x 10^{6}
	Heterobranchus longifilis	29^{a}	2.9 x 10^{6}
2	*Clarias gariepinus*	25^{b}	2.5 x 10^{6}
	Mormyrus rume	28^{b}	2.8 x 10^{6}
	Heterobranchus longifilis	27^{ab}	2.7 x 10^{6}
3	*Clarias gariepinus*	25^{b}	2.5 x 10^{6}
	Mormyrus rume	27^{bc}	2.7 x 10^{6}
	Heterobranchus longifilis	25^{b}	2.5 x 10^{6}
4	*Clarias gariepinus*	20^{c}	2.0 x 10^{6}
	Mormyrus rume	25^{c}	2.5 x 10^{6}
	Heterobranchus longifilis	22^{c}	2.2 x 10^{6}
5	*Clarias gariepinus*	18^{d}	1.8 x 10^{6}
	Mormyrus rume	21^{d}	2.1 x 10^{6}
	Heterobranchus longifilis	17^{d}	1.7 x 10^{6}
	SE	0.499	
	F-Value	14.348*	

Table VI: Mean total volatile bases (MgN/100g)

Species	Storage period (weeks)				
	1	2	3	4	5
Clarias gariepinus	7.54	7.61	8.40	10.15	11.00
Mormyrus rume	11.20	14.00	16.10	16.82	19.60
Hetrobranchus longifilis	11.22	11.80	13.25	14.15	16.80
SD	2.141	3.246	3.893	3.570	4.386
Sig.	ns	Ns	ns	ns	Ns

4. Discussion

Weight losses observed in the experiment was due to the evaporation of water content of fish, which depends on the temperature of the heat source, the higher the temperature, the faster the drying (smoking) rate. Davies and Davies (2009) [7] and Osuji (1997) [12] made a similar observation that the weight loss of the smoked fish was a result of the drying or dehydration effect from the burning charcoal. Dehydrating temperature can be easily controlled by the air vents by the side of the combustion chamber and by the distance of the fish from the source of heat, which control rate of weight loss. Smoked fish from the fabricated smoking sheet were easily identified from the fact that it was firmer when chewed and had a characteristic golden-brown colour.

The high heat intensity produced by the charcoal was responsible for the smoky flavour, sweet fragrance which is generally eugenol, syringaldehyde and acetosyringon. These are important for hot-smoked products. The fabricated smoking kiln can be used by both farmers and elites, because of the hygiene and aseptic way of handling the smoke products.

4.1 Proximate composition

The highest moisture content recorded in *Heterobranchus longifilis* was not unexpected because of the species variation in chemical composition. Similar reports by Osuji (1997) [12], Salan *et al.*, (2006) [13] and Bilgin *et al.*, (2008) [14] also confirmed the present results of the moisture content of the same species. The significant moisture reduction found in smoked *Clarias gariepinus* was due to species variation coupled with the heat the fish samples were subjected to during the hot smoking process. This has reduced fish deteriorating agents from acting on the tissue which will ultimately render the fish unsafe for human consumption. This observation is in agreement with the findings of Kumolu-Johnson and Ndimele (2001) [8] and Salan *et al.*, (2006) [13] who reported that spoilage of fish resulting from the action of enzymes and bacteria can be slowed down by the addition of salt as well as reduction in moisture through sun drying or smoking. The percentage crude protein in smoked fishes was higher than the values in the fresh fishes. This is because of the inverse relationship that exists between moisture and protein and moisture and fat. As moisture decreases, the protein content tend to become more concentrated thereby making its percentage increases. Similar results for chemical composition of smoked fish have been reported in previous studies of Goulas and Kontominas (2005) [3] and Bilgin *et al.*, (2008) [14]. Doe and Olly (1983) [15] reported that smoking resulted in concentration of nutrients like crude protein and fat, moisture content of the smoked fishes was significantly ($P<0.05$). Processing method, quality of feed given to the fish and storage are some of the factors responsible for differences in proximate composition of smoked fish (Abdullahi *et al.*, (2001) [17]; Akinola (2006) [18].

4.2 Sensory (Organoleptic) Assessment

Some sensory (organoleptic) parameters like flavour, texture, appearance, odour and taste were examined on weekly basis and their results are presented in Table III. The differences in the sensory parameters measured over a period five weeks were significant ($p<0.05$). However, there was no significant difference ($p>0.05$) in these parameters within first three weeks after smoking, but significant changes were observed from 4th and 5th weeks. This indicates that shorter storage duration enhances and maintains the quality of the fishes in contrast to longer storage period. This agrees with the finding of Bilgin *et al.*, (2008) [14]. In all the sensory qualities examined, all the smoked fishes scored above average, which indicates that the products were still be acceptable 35 days after smoking.

4.3 Bacterial count and Total Volatile Bases

In Tables IV and V, quality assessment in terms of bacterial count and TVB were presented in order to determine the safety of the products. The smoking of fishes is expected to reduce the bacterial counts, thereby enhancing the quality; it was observed that as the storing period progresses the bacterial level reduces in all the species tested which confirms the efficiency of this local method of fish preservation. The TVB values of all the species have not reached the limit of 35mg/100g after 5 weeks of storage period and this further confirms the quality of the fishes smoked with the fabricated smoking kiln. The findings of this study are in agreement with the result of Magawata and Faruk (2014) [19].

5. Conclusion

This present study was able to establish/come-up with a locally manufactured simple and portable smoking Kiln which can be affordable to the peasant fishermen inhabiting this part of the country.

The smoked fish from the fabricated smoking kiln have a longer shelf-life than those from the commonly used drum oven. It took over 5 weeks for mould to appear but the texture still remains intact, because of the fact that the water content has reduced greatly, inhibiting bacterial growth. The time spent in smoking is also a factor that must be considered. An average of 1:30 hours is enough for the species to be properly smoked so that the protein content is not denatured and the golden-brown colour is retained. The average percentage weight loss obtained during the test for the three fish species were 53.8, 55.6, and 56.5 respectively.

6. Recommendation

This smoking Kiln has the efficiency to smoke, roast any fish for preservation or instant human consumption. Therefore, it is recommended that product developers can purchase this kiln for the purpose of adding value to their products. Further studies is hereby recommended regarding the extension of period of storage of the smoked fish products using this kiln with a view to knowing the maximum period it could stay without spoiling.

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