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Full Length Research Article

EFFECTS OF CURING METHODS ON QUALITY OF HOT SMOKED FISH (*SARDINA PILCHARDUS*)

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ABSTRACT
Fish are often prone to spoilage because of its high nutrient content which supports the growth of pathogens. Processing methods could influence the quality of smoked fish. This study examined the effect of using different pretreatments on the quality of smoked sardine fish. Fish samples were cured with Brine (A), salt (B), natural spices of nutmeg (C), Clove (D) and commercial *yaji* (E) prior to hot smoking. The nutrient composition, chemical properties, microbial and sensory qualities were evaluated. Results of proximate composition showed a moisture range of 10.46-13.20%, ash (13.81-17.57%), fat (5.81-9.24%), protein (37.61-46.31%) and carbohydrate (17.81-29.57%). Highest potassium value (14.55 mg/100 g) was recorded in dry salted sample (B) while A had the lowest sodium (10.29 mg/100 g). All fish samples were significantly different ($p<0.05$) from each other in mineral content. The low pH (5.15-5.40) and TBA values (2.44-2.53 mg MDA/Kg) obtained are indication that rancidity will not easily occur during storage. Bacteria and fungi count were absent in sample B and very low in other fish samples (2.4×10^3 and 1.8×10^1 CFU/g) respectively. The fish treated with *Yaji* and Brine (E) was most preferred in all the sensory attributes. Curing combined with smoke drying improved the quality and acceptance of fish samples.

Keywords: Fish, curing, spices, brine, smoked, sensory.

INTRODUCTION

Fish (*Sardina pilchardus*) is an excellent source of animal protein due to its high nutritional value, good quality proteins which contains most of the essential amino acids and important minerals such as phosphorus, calcium and magnesium (Chukwu, 2009). Fish are prone to spoilage because of its high nutrient content which supports the growth of pathogens. According to Oyeleye, (2003), proper handling and good storage facilities will enhance keeping quality of smoked fish in Africa. The impact of fish as a food product in developing countries (such as Nigeria) cannot be neglected; as it is one of the major sources of food and income to many people (Ndife *et al*., 2019). More so, small fishes which are often consumed together with its bones are cheap source calcium (Ajai *et al.,* 2019). The nutrient composition of fish species varies from one habitat to another, of which feed intake plays the major role in fish nutrient composition (Oyeleye, 2003).

The broad objective of processing and preservation of fish is to reduce most of the biochemical processes, such as enzymatic, microbial and chemical reactions that aid in fresh fish deterioration, which affects their availability during season and off-season (Akinola *et al*., 2006). Consumers' acceptability of fish is greatly affected by lipids oxidation and microbial proliferation which reduces its nutritional as well as organoleptic qualities (Gomez *et al*., 2011).

Some traditional processing and preservation methods like smoking, drying, salting, frying, fermentation and or combination of these, have been used as attempts to preserve and process fish to improve its shelf stability. Smoke-drying of fish is the most widely practiced method of fish preservation in Nigeria, accounting for 70-80% of fish processing technique.

Different drying techniques have been exploited traditionally to prevent fish spoilage (Akinola *et al*., 2006). The combination of the advantages of dry smoking and curing with different health imparting spices would be a good innovation. In the light of the aforementioned, the aim of this research was to use different techniques to produce cured smoked fish with different local spices and to evaluate the nutrient qualities, chemical properties and sensory acceptance.

MATERIALS AND METHODS

Procurement of raw materials

Fish (sardine fish) for this work and other spice ingredients used were bought from Ndioru market in Umudike, Ikwuano LGA of Abia State, South East Nigeria. Reagents and equipment used were from Food Science and Technology Department, Michael Okpara University of Agriculture, Umudike Nigeria.

Sample preparation

The ingredients used for pretreatment which comprised of local spices of cloves and African nutmeg) and *yaji* (a local mix of spices) were ground into fine powder using a Moulinex blender. Three hundred grams (300g) of raw sardine fish were weighed, eviscerated to remove all internal organs, filleted and thoroughly washed with clean water and divided into 5 sample batches. A batch of the raw fish fillets was submerged into brine of 50 g of salt in 50 ml of water (sample A). Another batch was cured with 50 g of dry salt only (Sample B). Sample C batch was cured with a mixture of brine (50 ml) and 100 g African nutmeg powder. Sample D was cured in brine with 100 g of clove powder, while sample E was cured in brine with 100 g *yaji* (a local commercial spice mix). The fish sample were cured for 20 minutes each. After which the samples in brines were removed and placed in a sieve-tray to drain. All samples were smoked in a kiln at a temperature of 60-80 ^oC for 7 hours. The samples were allowed to cool to room temperature, kept in a refrigerator for further analysis.

Methods of Analyses

Proximate Analysis

Proximate compositions (moisture, crude fiber, crude fat, crude protein and ash content) were determined using methods described by Onwuka, (2018) while carbohydrate was calculated by difference.

Mineral Analysis
Calcium, Iron, Potassium, Magnesium, Sodium by Atomic Absorption Spectrophotometer according to method of AOAC (2006). One gram of the sample was digested with 20 ml of acid mixture containing 650 ml of conc. HNO_3; 80 ml Perchloric acid PCA 20 ml conc. H_2SO_4) and small quantity of the diluted clear digest was used for atomic absorption spectrophotometer using the filters that match the different elements.

Physico-chemical Properties Analysis
The pH of the samples was recorded using a digital pH meter. Thiobarbituric acid (TBA) value and Peroxide Value (PV) were determined using the methods described by Onwuka (2018).

Microbial Analysis
The microbial analysis was determined using method described by Ezeama, (2007). A tenfold dilution of the fish samples was made; from which further dilutions were made. 1ml of each dilution was mixed with appropriate sterile molten media. Plate count agar (PCA) for total bacteria count; Potato dextrose agar (PDA) for fungi; Incubation period was 48 h at 37 ^{o}C for bacterial and 25 ^{o}C, 72 h for fungal counts. The results were expressed as colony forming unit per gram of sample (cfu/g)

Sensory Evaluation
The fish samples were subjected to sensory evaluation on the following sensory attributes; Appearance, taste, aroma and overall acceptability using a 9 point hedonic scale, with 1 as dislike extremely and 9 as like extremely (Iwe, 2014). Twenty (20) sensory panelists used were semi trained consisting of 15 students and 5 laboratory staff from the Department of Food Science and Technology of Michael Okpara University of Agriculture, Umudike.

Experimental Design and Statistical Analysis
The experimental set-up was a completely randomized design. All determinations were done in triplicates and the results are presented as mean ± standard deviations. The data obtained from the various analyses were subjected to analysis of variance (ANOVA) for comparison of the means. Differences between means were considered to be significant at p<0.05.

RESULTS
Proximate Composition of Cured Smoked Fish
Table 1 shows proximate composition of cured, hot smoked fish samples. Moisture content of the smoked-dried fish ranged between 10.46% (Sample B) to 13.20% (Sample A). There was significant (p<0.05) difference among the samples, however, samples C and D were not significantly different (p>0.05) from each other. Ash content of smoked-dried fish was maximum (17.57%) in Sample D, followed by C (17.21%) while minimum value (14.50) was recorded in E. The fat values of fish samples ranged between 5.81 to 9.24%. Highest fat content (9.24%) was recorded in sample treated with brine and *Yaji* (E), while lest value (5.81%) was recorded for sample A. The protein content was high and ranged between 37.61% in sample A to 46.31% in E. There were significant (p<0.05) differences among the samples. The fiber content was very negligible and was therefore not included in the proximate calculation of carbohydrate content by difference. The carbohydrate of fish samples was least in E (17.81), followed by D (18.77%) and highest in A (29.57%).

Table 1: Proximate composition (%) of cured smoked fish samples

Sample	Moisture	Ash	Fat	Protein	CHO
A	$13.20^{b} \pm 0.28$	$13.81^{e} \pm 0.02$	$5.81^{e} \pm 0.02$	$37.61^{f} \pm 0.04$	$29.57^{e} \pm 0.04$
B	$10.46^{e} \pm 0.08$	$16.16^{c} \pm 0.01$	$6.38^{d} \pm 0.04$	$40.26^{e} \pm 0.01$	$26.74^{a} \pm 0.02$
C	$11.14^{d} \pm 0.02$	$17.21^{b} \pm 0.01$	$7.17^{c} \pm 0.02$	$42.21^{d} \pm 0.01$	$22.27^{b} \pm 0.03$
D	$11.38^{d} \pm 0.004$	$17.57^{a} \pm 0.02$	$8.13^{b} \pm 0.04$	$44.15^{c} \pm 0.07$	$18.77^{c} \pm 0.02$
E	$12.14^{c} \pm 00.2$	$14.50^{d} \pm 0.01$	$9.24^{a} \pm 0.02$	$46.31^{a} \pm 0.01$	$17.81^{d} \pm 0.03$

Values are mean ± standard deviation of determinations in duplicate. Means with different superscript in same column are significantly different (p<0.05); CHO – Carbohydrate

Mineral Content of Cured Smoked Fish
The mineral contents of fish samples is shown in Table 2. The magnesium content ranged from 2.00 (sample A) to 2.11 mg/100 g (D). There were significant (p<0.05) differences in the magnesium content of the smoke-dried fishes. Calcium content was observed to be highest in sample B (fish pre-treated by dry salting) while lowest value was recorded in sample E (fish pre-treated with brine and *yaji*) with values ranging between 25.25 and 25.85 mg/100g. Highest potassium value (14.55 mg/100 g) was recorded in dry salted sample (B) while lowest value (14.10 mg/100 g) was obtained in sample C. There was significant (p<0.05) differences in potassium content of the smoke-dried fishes. Sodium values ranged from 10.29 to 10.72 mg/100 g. The highest sodium content was recorded in sample E (10.72 mg/100 g), while sample A had the lowest (10.29 mg/100 g). All smoked-dried fish samples were significantly different (p<0.05) from each other. Iron content value ranged between 1.56 (C) to 1.71 mg/100g in sample E. There was no observed significant (p>0.05) difference in the samples.

Table 2: Mineral composition (mg/100g) of cured smoked fish samples

Sample	Mg	Ca	K	Na	Fe
A	$2.00^{c} \pm 0.01$	$25.45^{a} \pm 0.07$	$14.45^{a} \pm 0.07$	$10.29^{b} \pm 0.01$	$1.59^{a} \pm 0.01$
B	$2.10^{ab} \pm 0.03$	$25.85^{a} \pm 0.07$	$14.55^{a} \pm 0.07$	$10.33^{b} \pm 0.01$	$1.64^{a} \pm 0.01$
C	$2.08^{ab} \pm 0.01$	$25.60^{a} \pm 0.14$	$14.10^{b} \pm 0.14$	$10.36^{b} \pm 0.01$	$1.56^{a} \pm 0.01$
D	$2.11^{a} \pm 0.01$	$25.40^{b} \pm 0.14$	$14.40^{b} \pm 0.14$	$10.58^{a} \pm 0.07$	$1.65^{a} \pm 0.01$
E	$2.07^{b} \pm 0.01$	$25.25^{b} \pm 0.07$	$14.55^{a} \pm 0.07$	$10.72^{a} \pm 0.01$	$1.71^{a} \pm 0.01$

Values are mean ± standard deviation of determinations in duplicate. Means with different superscript in same column are significantly different (p<0.05)

Chemical Properties of Cured Smoked Fish
Table 3 shows the chemical properties of cured hot smoked fish samples. Thiobarbituric acid (TBA) value was lowest in sample B (2.44 mg MDA/Kg), closely followed by sample C (2.45 mg) and highest in sample A (2.53 mg MDA/Kg). There was significant (p<0.05) difference in the TBA content of fish samples. Peroxide value (PV) was highest (2.33 MEq/Kg) in sample E (fish pre-treated with *Yaji* + brine) and lowest in sample A (2.25 MEq/Kg) pretreated with only brine. There was no significant (p>0.05%) in peroxide values of the smoke-dried fishes. pH value of fish samples ranged from 6.15 in sample E to 6.40 (sample C). There was significant (p<0.05) difference in pH of the products

Table 3: Chemical properties of cured smoked fish samples

Sample	TBA (mg MDA/g)	PV (MEq/Kg)	pH
A	$2.53^{a} \pm 0.01$	$2.25^{a} \pm 0.01$	$5.35^{a} \pm 0.07$
B	$2.44^{b} \pm 0.01$	$2.28^{a} \pm 0.01$	$5.35^{a} \pm 0.07$
C	$2.45^{ab} \pm 0.01$	$2.30^{a} \pm 0.01$	$5.40^{a} \pm 0.00$
D	$2.48^{ab} \pm 0.01$	$2.26^{a} \pm 0.01$	$5.25^{b} \pm 0.07$
E	$2.51^{a} \pm 0.01$	$2.33^{a} \pm 0.01$	$5.15^{bc} \pm 0.07$

Values are mean ± standard deviation of determinations in duplicate.
Means with different superscript in same column are significantly different
(p<0.05; TBA – Thiobarbituric acid; PV – Peroxide Value

Microbial Quality Cured Smoked Fish
The microbial quality of cured hot smoked fish is presented in Table 4. The smoked-dried fish pretreated with some selected natural preservatives showed reduced total viable microbial counts. The control sample A had the highest bacteria count (2.4×10^3 cfu/g) while sample D (fish pre-treated with *Yaji* + Brine) had the lowest bacteria count (1.4×10^3 cfu/g). However, sample B (dry salting) showed no presence of bacteria and fungi. Fungal counts were only observed in Sample A (1.8×10^1 cfu/g) and D (1.5×10^1 cfu/g)

Table 4: Microbial Content (cfu/g) of cured smoked fish samples

Sample	Bacteria count	Fungal count
A	2.4×10^3	1.8×10^1
B	Nil	Nil
C	1.1×0^2	Nil
D	1.4×10^2	1.5×10^1
E	1.8×10^2	Nil

Values are means of microbial counts

Sensory Quality Cured Smoked Fish
Table 5 shows the sensory evaluation scores of cured smoked fish products. The appearance attribute of the smoke-dried fishes ranged from 7.05 to 7.95. Samples A (7.05) and B (7.33) without spices pretreatments were the least preferred by the panelists, which translates to "Like moderately." Samples C, D and E were not significantly (p<0.05) different in appearance. The best scores for taste and aroma were recorded in sample E (Yaji and brine) with scores of 8.05 and 7.90 respectively, which translates to 'like very much." Sample A was least preferred for taste (6.14) and aroma (6.24). The most accepted fish sample E (Yaji and brine) had a score of 8.33. This was closely followed by D (7.86). The least accepted were samples A (brine only) and B (dry salting) with overall acceptance scores of 6.95 and 7.12 respectively.

Table 5: Sensory scores of cured smoked fish samples

Sample	Appearance	Taste	Aroma	Acceptability
A	$7.05^c \pm 1.75$	$6.14^c \pm 1.59$	$6.24^c \pm 1.26$	$6.95^c \pm 1.02$
B	$7.33^b \pm 1.20$	$7.24^b \pm 0.83$	$7.38^b \pm 0.74$	$7.12^c \pm 0.86$
C	$7.71^a \pm 0.72$	$7.57^a \pm 0.75$	$7.19^b \pm 1.08$	$7.71^b \pm 0.72$
D	$7.67^a \pm 0.97$	$7.05^b \pm 0.80$	$7.48^{ab} \pm 0.87$	$7.86^b \pm 0.79$
E	$7.95^a \pm 0.97$	$8.05^a \pm 0.86$	$7.90^a \pm 1.09$	$8.33^a \pm 1.02$

Values are mean ± standard deviation of determinations in duplicate. Means with different superscript in same column are significantly different (p<0.05).

DISCUSSION
Moisture content of cured smoked fish (10.46-13.20) were lower than that of raw fish (70-84%).The use of salt together with either sun drying or smoking could significantly reduce moisture as well as spoilage of fish from the action of enzymes and bacteria (Ajai *et al.,* 2019). Moisture content is an important attribute in food processing and preservation because many biochemical and physiological changes depends very much on it (Ndife *et al.,* 2022). The higher ash value in the smoked-dried fish may be due to moisture loss from heat processing, and to some extent from wood ash contamination during smoking. Bille and Shemkai, (2006) and Ndife *et al.* (2019) reported that smoking significantly increased ash in dagga fish and sun dried catfish (12.00-21.10%). It has been reported that fat increases with heat processing resulting from reduction in moisture content (Akintola *et al*., 2013). Fat levels reported in this study were lower than those reported for other processed fish species. Chukwu, (2009) reported 28.0% for Kiln smoked Tilapia (Oreochromis niloticus) and 21.2% fat for catfish (*Clarias gariepinus*). Fish species with more than 20% fat content are considered fatty (Ndife *et al.,* 2019). Increased fat in human diet provides and sustains energy in the body [16]. Fat is also important for normal functioning of the brain which is made up of nearly 60% fat (Wardlaw, 2004). Higher levels of protein than recorded in this study (37.61-46.31%) have been reported for whole fish (49.5%) by Msusa *et al.* (2017) and sundried catfish (57.43-62.34 %) (Ndife *et al.,* 2019). It is widely reported that smoke drying increases protein, attributed to concentration in the proteins resulting from dehydration (Oparaku and Mgbenka), 2012). Protein levels reported in this study are nevertheless, relatively lower than those reported for other species such as *Tilapia* (Fapohunda and Ogunkoya, 2006). The low carbohydrate content of fish samples confirmed that fish is sought after for their protein and unsaturated fat values. Factors such as fish feeding, post-harvest handling and processing and storage techniques have been reported to affect the nutrient content of fish (Oyeleye, 2003; Ajai et al., 2019; Ndife *et al.,* 2019).

The spice pretreated smoked-dried fish C, D and E, had higher level of these minerals compared to the un-pretreated sample A. The high concentrations of these elements can be attributed to the additives used prior to smoking. Ajai *et al.* (2019) reported higher mineral values for dried fishes. Calcium is an important element in most physiological functions, involving heart muscles, skeletal system and cell membrane (Wardlaw, 2004). Higher potassium (14.55%) to sodium (10.58%) contents as recorded in the fish samples is necessary for optimal body fluid and blood functions. However, consuming too little potassium and much sodium can raise the blood pressure. Increase intake of potassium can lower blood pressure and may help prevent strokes. However, extremely high sodium intake has been associated with fluid retention, leading to hypertension, heart failure and instant death. Generally, most of the mineral analysed are within the recommended limits (Wardlaw, 2004).

Thiobarbituric acid (TBA) measures secondary lipid oxidation compounds formed during drying (Cakli *et al*., 2006; Onwuka, 2018). The high Thiobarbituric acid value obtained for fish samples could be due to combined effects of temperature and exposure time, resulting in formation of secondary oxidation compounds during the drying process. Ali *et al.* (2011) reported similar increase in Thiobarbituric value of smoked-dried and sun-dried of different fish species. Thiobarbituric values above 4 mg MDA/kg indicates a loss of product quality (Cakli et al., 2006), because the fat has degraded to non-metabolizable aldehydes which is not suitable for consumption. The values obtained for Thiobarbituric acid for pretreated smoked-dried fishes in the study were within the limit (3-4 mg MDA/kg) acceptability (Ndife et al., 2022). Peroxide value is an indication of initial stage of the oxidative changes in food products and is influenced prolonged heat treatment, exposure to light and oxygen resulting in oxidation of fatty acids. A peroxide value of 10-15 meq of O_2 /kg of lipid indicates rancidity (Ndife *et al.,* 2022). The peroxide values recorded in this study were within the acceptable limit indicating that the products will keep well during storage. Chabbouh *et al.* (2011), reported a decrease in pH in dried salted beef. High pH values favour growth of bacteria.

It is evident from the results of microbial analysis obtained in this study that the different pre-treatment of smoked-dried fish seems to have anti-microbial effects. This agrees with the report of Amuneke *et al.* (2015) that spice extracts was effective in reducing microbial load in the stored fish. Kiin-Kabari *et al.* (2011) also showed that *Piper guineensis, Myristica monodora and Xylophia aethiopicum* had preservation potentials by retarding growth of microorganisms in stored fish (*Clarias gariepinus*). Similarly, Relekarm *et al.* (2014) reported low microbial counts in dried ribbon fish *(Lepturacanthus savala).* This further corroborates the result of this study. The levels of microbial contamination in the fish samples are minimal, therefore, are fit for consumption, as it is below the tolerable limit for bacteria (2.5×10^5-1.0×10^8 cfu/g) and Fungi (1.0×10^4) growths in meat products and will improve shelf the stability of cured smoked fish (Ndife *et al*., 2019). The low microbial loads could be attributed to the actions of salt, heat, smoke and natural spices used in the processing.

Sample E with Yaji and brine treatments had the highest appearance score (7.95) while samples A (7.05) and B (7.33) without spice pretreatments were the least preferred by the panellists. This shows that curing with addition of spice had positive influence on smoked fish appearance. Physical appearance is an important feature of food samples (Onwuka, 2018), hence this is crucial in quality evaluation. The High scores for taste and aroma by sample E, pretreated with brine and Yaji, a commercial local mix of spices and flavorings, could be the reason for its preference. Aroma are volatile odours perceived from the foods (Iwe, 2014). However, all the smoke-dried products were liked very much (7.12-8.33) by the panelists in terms of general acceptability, except for the sample A which was liked moderately with score of 6.95. This shows that curing with spices combined with smoke drying improved the sensory quality and acceptance of fish samples.

Conclusion

The study showed the effectiveness of different curing methods on hot smoked fish. The pretreatment of the fish samples with selected natural spices prior to smoking helped retained most of the nutrients evaluated, coupled with good chemical properties as shown by low Thiobarbituric acid (TBA) and Peroxide values. The fish products quality increased significantly but differed in terms of overall organoleptic acceptability. It is therefore, recommended to pretreat fish with these natural spices prior smoke-drying in order to improve overall quality and consumer's acceptance.

REFERENCES

Ajai, A.I., Inobeme, A., Nwakife, N. and Abubakar, N. A. (2019). Proximate and essential mineral composition of fresh and smoked catfish and beef sold in Minna, Niger State. *FUW Trends in Science & Technology Journal*, *4* (2): 569 – 571.

Akinola, O. A., Akinyemi, A. A. and Bolaji, B. O. (2006). Evaluation of traditional and solar fish drying systems towards enhancing fish storage and preservation in Nigeria. *Journal of fisheries International Pakistan,* 3(4): 44 – 49.

Ali, A., Ahmadou, D., Mohamadou, B., Saidou, C. and Tenin, D. (2011). Influence of traditional drying and smoke-drying on the quality of three fish species (*Tilapia nilotica, Silurus glanis and Arius parkii*) from Lagdo Lake, Cameroon. *Journal of Animal Veterinary Advances,* 10(3): 301-306.

Amuneke, K. E., Oguntade O. R., Ikeogu F. C. and Nomeh U. A. (2015). Effect of natural preservatives on the organoleptic characteristics and storage stability of smoked *Heterotis niloticus*. *Journal of Tropical Agriculture, Food, Environment and Extension*, 19(2):31 - 35.

AOAC. (2006). Official Methods of Analysis, 18th Edition. Association of Official Analytical Chemists, Washington D.C, USA. 864 – 889.

Bille, P. G. and Shemkai, R. H. (2006) Process development, nutrition and sensory characteristics of spiced-smoked and sun-dried Dagga fish (*Rastrineobola argentea*) from lake Victoria, Tanzania. *African Journal of Food Science, 6*: 1-12.

Cakli, S., Kilinc, B., Dincer, T. and Tolasa, S. (2006). Comparison of the shelf life of MAP and vacuum packaged hot smoked rainbow trout (*Onchoryncus mykiss). European Food Research and Technology,* 224(1):19-26.

Chabbouh, M., Hajji, W., Hadj Ahmed, S.B., Farhat, A., Bellagha, S., and Sahli, A. (2011). Combined effects of osmotic dehydration and convective air drying on Kaddid meats: Kinetics and quality. *Drying Technol*ogy, 29(13), 1571-1579.

Chukwu, O. (2009). Influences of drying methods on nutritional properties of Tilapia fish (*Oreochromis niloticus). World Journal of Agricultural Sciences* 5(2): 256-258.

Ezeama, C. F. (2007). Food Microbiology: Fundamentals and Applications. Natural Prints Ltd., Lagos. Pp.196.

Fapohunda, O. and Ogunkoya, M. (2006). Effect of Smoke-drying on the Proximate composition of *Tilapia zilli, Parachanna obscura* and *Clarias gariepinus* obtained from Akure, Ondo-State, *Nigeria. Animal Research International*, 3:478-480.

Gomez, E, J., Gomez-Guillen, M. C., Montero, P., Sopelana, P. and Guillen, M. D. (2011). Oxidative stability, volatile components and polycyclic aromatic hydrocarbons of cold-smoked sardine (*Sardine pilchardus*) and Dolphin fish (*Corphaena hippurus*). LWT - *Food Science Technology, 44:* 1517-1524.

Iwe, M. O. (2014). Handbook of Sensory Methods and Analysis. 2nd Edition, Rejoint Communication Services Ltd, Uwani- Enugu. Pp 70-72.

Kiin-Kabari, D. B., Barimalaa, I. S., Achinewhu, S. C. and Adeniji, T. A. (2011). Effects of extracts from three indigenous spices on the chemical stability of smoke dried cat fish (*Clarias lazera*) during storage. *African Journal of Food, Agriculture and Nutritional. Development,* 11: 1-9.

Kumolu-Johnson, C. A, and Ndimele, P. E. (2001). Effect of salting, brining and sun drying on the shelf-life of *Clarias gariepinus*. *Journal of Research and Review in Science*, 2:21-25.

Msusa, N., Likongwe J., Kapute F., Mtethiwa A. and Sikawa D. (2017). Effect of processing methods on proximate composition of gutted fresh Mcheni (*Rhamphochromis* species) from Lake Malawi. *International Food Research Journal*, 24(4):1513-1518.

Ndife, J, Ahmad T. B, Dandago M. A and Gambo A. (2019). Comparative quality assessment of commercial sun dried catfish (*Clarias garienpinus*) from Kano and Wudil metropolises, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 12(1): 132-140.

Ndife, J., Onwuzuruike U. A., Ebeleagu, S. B. and Okwunodulu N. I. (2022). Influence of meat type on processed meat (Kilishi) quality. *FUDMA Journal of Sciences*, 6(2):160-168.

Oparaku, N. F. and Mgbenka, B. O. (2012). Effects of electric oven and solar dryer on a proximate and water activity of *Clarias gariepinus* Fish. *European Journal of Scientific Research,* 81(1):139 -144.

Onwuka, G.I. (2018). Food Analysis and Instrumentation: Theory and Practice. 2nd Edition. Napthali Publishers, Lagos, Nigeria, Pp. 140 – 146.

Oyeleye, O. (2003). Traditional fish processing Nigeria: A critical review. *Nutrition and Food Science,* 46 (3): 321-335.

Relekarm, S. S., Joshi, S. A., Gore, S. B. and Kulkarni, A. B. (2014). Effect of improved drying methods on biochemical and microbiological quality of dried small head ribbon fish, (*Lepturacanthus savala*). *International Journal of Fisheries and Aquatic Studies,* 1(5), 60-66.

Wardlaw, G. M. (2004). Perspectives in Nutrition. 6th Edition. McGram Hill Co., New York, U.S.A