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COMPARATIVE QUALITY ASSESSMENT OF COMMERCIAL SUN-DRIED CATFISH (*Clarias garienpinus)* FROM KANO AND WUDIL METROPOLISES, NIGERIA

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ABSTRACT
In Nigeria, fish is highly sought after as a healthy meat option. Unfortunately, most fish are spoilt after harvest due to poor handling and preservation techniques. The traditional methods of fish preservation are fraught with inconsistent product quality sincethe basic methods of drying depend on the locality. This research therefore, comparatively evaluated commercial sun-dried catfish (C. gariepinus) produced within Wudil (WD) and Kano (KN)metropoles for their physico-chemical, microbial and sensory qualities.The results showed that moisture content of dried fish samples from Kano (KN) ranged from 6.60 - 7.80 % and those from Wudil (WD) ranged from 5.00 - 6.70 %. KN-N had the lowest protein content of 57.43 % and WD-4 had the highest (62.34 %).There were significant differences in the pH (5.36 - 5.72) and acid values (4.46 – 5.36) of the dried fish samples at p<0.05. Acid value was highest in WD-3 (5.36mgKOH/g) followed WD-4 (5.25 mgKOH/g) and lowest in KN-N (4.46 mgKOH/g). The heavy metal concentrations of cadmium in all the fish samples ranged from 3.17 to 3.18 mg/kg, except for sample KN-N (0.72 mg/kg). KN-D had the highest Chromium content. The total microbial loads (2.0×10^3 – 4.5×10^4 cfu/g) were within acceptable safety limits. WD-1 and WD-3 had the highest coliform counts (150 MpN). The sensory evaluation showed KN-N (6.53) with the highest scores of acceptability while W-4 (3.73) had the least. The dried catfish samples from the markets had varied quality but were fit for consumption. There is the need for improvement in production, storage and sales environment.
Keywords: Fish, physico-chemical properties, heavy metals, microbial, sensory

1.0 INTRODUCTION

Fish is one of the most important sources of animal protein and has been widely accepted as a good protein source and other essential nutrients necessary for the maintenance of healthy body (Fagbenro *et al*., 2005; Akinneye *et al*., 2007). It is regarded as the healthiest meat option due to its long chain poly-unsaturated fatty acids content which promotes good health and prevent diseases (Ndife, 2016). In Nigeria, fish is highly accepted for its availability, affordability and sensory quality (Ighodaro and Abolagba, 2010; Gulshan *et al*., 2014).

Fish has healthy types of fat that contain omega-3 fatty acids which help to reduce the risk of developing heart disease and other medical problems. Fish intake has also been linked to a lower risk of stroke, depression, and mental decline with age. For pregnant women, mothers who are breastfeeding, and women of childbearing age, fish intake is important because it supplies DHA, a specific omega-3 fatty acid that is beneficial for the brain development of infants (Onwuka, 2014; Ndife, 2016).

However, fish is an extremely perishable commodity and quality loss can occur very rapidly after catch (Ezeama, 2007; Adams and Moss, 2008). Normal micro-flora which was once helpful in the aquatic environment turns harmful, overland and postharvest. These microbes graduate to become pathogenic when environmental factors like temperature and relative humidity in association with bad handling, poor hygiene, and delayed processing and preservation are not adequate (Gram and Dalgaar, 2002; Ighodaro and Abolagba, 2010).

Catfish *(Clarias gariepinus)* is a very important fresh water fish in Nigeria which enjoys wide acceptability in most parts of the country because of the ease of cultivation and its unique taste, flavor and texture (Alfa *et al*., 2014). When the post-harvest is not handled properly, the bio-chemical breakdown of protein and fat content contribute to the quick spoilage of catfish coupled with microbial deterioration (Daramola *et al.,* 2007; Adams and Moss, 2008). Postharvest losses in catfish also manifest in direct physical loss which lead to overall reduction in the fish commercial value (Akinneye *et al*., 2007). Poor quality raw fish can result from poor local methods of catch, mishandling of fish during transportation and storage before processing. Processing can only help slow down the rate of spoilage as using spoilt fish cannot be remedied in the processed product (Okereke *et al*., 2014).

More over heavy metals contaminationin fish and fish products has been a subject of safety concern (Abdulali *et al*., 2012; Rohasliney*et al*., 2014; Olujimi *et al*., 2018). Fish caught from the wild, like ocean, rivers and lakes have been shown to be highly contaminated by heavy metals and other unsafe chemicals. The levels of contamination of the fish depend on the environmental pollutionfrom industrial wastes, mining activities through which the waters traverse (Rohasliney *et al*., 2014) and inorganic feedstocks (Olujimi *et al*., 2018). This has led to the preference for home grown catfish from domestic fish ponds by health-conscious consumers. Organic and inorganic contamination remains agreat food safety challenge in public health (Ezeama, 2007).

The traditional methods of processing catfish are often inefficient and unhygienic, contributing to more contamination of the fish and resulting in substantial post harvest losses in terms of fragmentation, microbial growth, and infestation by flies and beetles, which detract from the overall quality (Akinneye *et al*., 2007). Traditionally fish are preserved by salting, sun drying and smoking. These methods though cheap and handy in hot climes, are fraught with inconsistent qualities as the final product depends on the skill of the processor (Gram and Dalgaar, 2002). More so the methods of processing vary from locality to another depending on the processing culture in place.

This work therefore, examines the quality of the different commercial sun-dried catfish in terms of the proximate composition, chemical characteristics, heavy-metal contamination, microbial content and sensory attributes, that result from the skills of the local processors,location and processing culture, with a view to making useful suggestions in order to improve on the quality and preservation of the fish product.

2.0 MATERIALS AND METHODS

2.1 *Sample collection and preparation*

A total of 8 samples of Catfish *(C. gariepinus)* with average body weight and length of 555±9.60 g and 52.16±3.54 cm respectively that wassourced from local rivers and sun-dried were obtained from 8 different locations, 4 each from Wudil (WD) and another 4 from Kano (KN) metropolis markets. The fish samples were ground into powdery form, packaged inpolythene bags and kept in refrigerator for analysis.

2.2 *Proximate analysis*

The proximate composition of the sausage samples was determined as described by Onwuka (2018); The moisture contentwas by indirect distillation drying method; ash content by the muffle furnace ignition method; fat content through the solvent extraction method in a continuous reflux system using the Soxhlet apparatus. The protein contents were determined by the formal titration method, while the carbohydrate content was determined by recommended mathematical procedure.

2.3 *Chemical properties analysis*

The pH of the samples was recorded using a digital pH meter. The trimethylamine (TMA) value, peroxide value and free fatty acids were determined using the method of AOAC (2005). Briefly: Magnesium oxide was mixed with distilled water containing 2% boric acid into which 2 drops of methyl red indicator was added. The distillate was titrated against 0.1 N H_2SO_4. Thetrimethyleamine (TMA) was calculated in mg/100g. The peroxide valuesof the samples were determined by titrating potassium iodide solution with 0.002 M thiosulphate using starch as indicator. Free fatty acids (%)was determined by mixing the fish sample with 25 ml alcohol into which 1% phenolphthalein indicator has been added and titrated against 0.1M NaOH solution, until a persistent pink colour was obtained.

2.4 *Mineral analysis*

The heavy metals comprising Cd, Cu, Mn, Pb and Cr of the fish samples were determined according to the method described byNielsen (2003). 5g of the sample was weighed in a crucible and then ashed in a muffle furnace at a temperature of 500 ^oC for two hours. To the ashed sample, 10cm^3 of 6M Nitric acid (HNO_3) was added and agitated until a uniform solution was obtained.

This was filtered and distilled water added. Standard curves of the respective metals were used to quantify the elements using Atomic Absorption Spectrophotometer (AAS).

2.5 *Microbiological analysis*

Adapted from APHA (1992), a tenfold dilution of the fish samples was made; from which further dilutions were made. 1ml of each dilution were mixed with appropriate sterile molten media at 45 ^{o}C; Plate count agar (PCA) for total bacteria count; Potato dextrose agar (PDA) for fungi; MacConkey agar for coliforms. 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) and MpN per gram of the sample (MpN/g) for the coliforms.

2.6 *Sensory evaluation*

The protocol described by Iwe (2010) was used. The organoleptic properties of catfish samples were evaluated by 20-member semi-trained panelists, randomly selected from the staff and students of the university. Quality attributes such as appearance, aroma, texture, taste, appearance and general acceptability of the products were scored with a 9-point hedonic scale. The degree of likeness was expressed as: Like extremely 9, neither like nor dislike 5, dislike extremely 1. Like constitute good quality while dislike constitutes poor quality. Neither like nor dislike indicated that the product was neither good nor bad.

2.7 *Experimental design and statistical analysis*

The experimental set-up was of a completely randomized design. All determinations were done in triplicates and their mean values were recorded with standard deviations. The data obtained from the various analyses were subjected to analysis of variances using the statistical package for social sciences (SPSS), version 16.0 for windows. One-way analysis of variance (ANOVA) was used for comparison of the means. Differences between means were considered to be significant at $p<0.05$ using the Duncan multiple range test.

3.0 RESULTS AND DISCUSSION

3.1 *Proximate composition*

The result of the proximate composition of the different fish samples is presented on Table 1.The moisture content of dried fish samples from Kano (KN) metropolis (6.60 - 7.80 %) was higher than those from Wudil (5.00 - 6.70 %). KN-D had the highest moisture content (7.80 %) while WD-1 had the lowest (5.00 %). The moisture content was low in all the fish samples.The values were lower than 17.13 % for oven dried tilapia fish reported by Ogbonnaya (2009). Adequate drying and low moisture creates unfavorable conditions for growth of microorganisms, which would subsequently lead to prolonged shelf life of the fish (Ezeama, 2007).

The protein values of the both Kano (KN) and Wudil (WD) fish samples were high (57.43 – 62.34 %). KN-N had the lowest protein content of 57.43 % and WD-4 had the highest (62.34 %). There was significant difference in the protein content of the dried fish ($p<0.05$). However, the protein contents were lower than 64.10 and 76.53 % reported for oven dried tilapia by Dagne *et al.* (2016) andOgbonnaya (2009). The high protein values could be due to the dehydration of water molecules during the drying process, thus causing aggregation and concentration of protein (Fagbenro *et al.*, 2005).

Sample WD-2 has the highest % lipid (13.70) and sample KN-N had the lowest (10.80 %). There were no significant differences ($p<0.05$) in the fat content of KN-F, WD-2 and WD-3.These values were higher than the range (6.37- 7.01 %) reported by Dagne *et al.*(2016) and close to 20.25 % reported by Ogbonnaya (2009). Fatty fish spoil rapidly due to fat oxidation thereby compromising the freshness of the product (Fuadi *et al.*, 2014). Fish lipids have also been reported to be very rich in health promoting essential fatty acids (EFA), like omega-3 (ω-3) and omega-6 (ω-6) (Yanar, 2007; Ogbonna, 2009; Ndife, 2016).

The ash content of the dried fish ranged from 12.00 to 21.10 %. The % Ash content was highest in KN-N (21.10 %), followed by KN-D (16.00 %) while the lowest was in sample KN-T (12.00 %). This would be regarded as high when compared to similar studies (Ogbonnaya, 2009). The high ash content could have emanated from environmental contamination. The high ash values of the processed fish could also be due to contamination during processing and storage. The % carbohydrate is relatively low in all the samples (4.00 - 8.09 %).Other factors such as fish feeding, post-harvest handling and processing and storage techniques have been reported to affect the nutrient content of fish (Gram and Dalgaar, 2002;Amoo *et al.*, 2007; Msuku and Kapute, 2018).

3.2 *Chemical properties*

The chemical properties of the dried fish samples are shown on Table 2. These chemical characteristics are some of the most critical variables that determine fish quality (AOAC, 2005).Catfish oils are mostly poly-unsaturated oils with reduced stability at elevated temperatures (Ndife, 2016).

The pHis the acidity and alkalinity of a given sample (Onwuka, 2018). The pH of the dried fish samples ranged from 5.36 to 5.72. There was no significant difference in the pH of the samples at $p<0.05$ except for samples WD-1 and WD-4. The pH has a preservative influence on foods (Ezeama, 2007). It could also be an indication of the level of free fatty acids present, which showed their level of deterioration (Onwuka, 2014).

The trimethylamine (TMA) values of the fish samples which ranged from 0-04 to 1.35 mg/100g. The TMA was highest in KN-D (1.35 mg/100g) and lowest in WD-2 (0.04 mg/100g). These results are lower than the range of 2.11 to 2.69 mg/100g reported by Adeyeye *et al.* (2016). The TMA value is an indication to the secondary oxidation products of fish, which may contribute to off-flavours during storage (Onwuka, 2018). The formation of TMA is related to many factors such as differences in species, bacterial growth, processing methods and storage conditions (Onwuka, 2014).

Acid value was found to be the highest in WD-3 (5.36mgKOH/g) followed WD-4 (5.25 mgKOH/g) and lowest value was obtained in KN-N (4.46 mgKOH/g). The acid value is used to quantify the amount of acids present in food products. The degree of acidity is closely related to the value of free fatty acids (FFA). Autolytic deterioration and microbial actons are factors which catalyse lipolytic activites and release acids from glycerides and phospholipids (Onwuka, 2014).

The free fatty acids (FFA) of the fish samples ranged from 2.23- 2.68 %. KN-N had the highest acid value (2.68 %) while KN-D had the lowest (2.23 %). There were no significant difference in the FFA of the dried fish samples (<0.05). Free fatty acid (FFA) content measures the extent of lipid hydrolysis by lipase action and rancidity is usually accompanied by FFA (free fatty acid formation). The free fatty acid values recorded in this study were comparable to 2.25 % recommended by Codex (1979). High level of FFA is an indication of microbial spoilage activity (Chukwu, 2009; Adams and Moss, 2008).

Peroxide value is commonly used to assess rancidity development (Fuadi *et al.*, 2014; Tenyang *et al.*, 2016). A rancid taste often becomes noticeable at peroxide value of 10 – 20%. Peroxide value was low in all the sun-dried catfish (2.10 – 2.53 %). The peroxide value (PV) of the dried fish samples ranged from 2.10 to 2.53 mEq/kg. Sample KN-N (2.10 mE/kg) had the lowest and KN-T (2.53 mEq/kg) the highest PV values. There was no significant difference in the PV of the fish samples. A maximum level (10 meqO_2/kg) is standard set by Codex (1979) for foods.The peroxide value is used to measure the primary lipid oxidation products of hydroperoxides (Onwuka, 2018). Higher PV showed greater level of fish deterioration.

3.3 *Heavy metals content*

In Table 3, the heavy metal content of dried fish samples are presented. There were significant differences ($P<0.05$) in the heavy mineral composition between the fish sample from Kano (KN) and Wudil (WD). Essential metals like Cu and Mn are required for normal metabolism and body functions (Onwuka, 2014). WD-3 and WD-4 both had the highest Cu values (2.15 mg/kg), followed WD-2 (2.02 mg/kg).The Mn content of the fish was the highest of all the heavy metals evaluated (7.68 – 20.19 mg/kg). The Cu and Mn values obtained are lower compared to those of obtained by Joram and Kapute (2016) for fresh fish. Though essential for body functions, these minerals are required in micro-quantities as overdose can be harmful to humans (Olujimi *et al.,* 2018; Rohaliny *et al.*, 2014).

The result of the non-essential heavy metals showed that Cr value was highest in KN-D (1.26 mg/Kg) and lowest in KN-F (0.08 mg/kg). There was high concentration of cadmium (Cd) in all the fish samples (3.17 – 3.18 mg/kg) except for sample KN-N with 0.72 mg/kg. An uptake of Cd levels above 1.5 to 9.0 mg/day is lethal to humans(Rohaliny *et al.*, 2014). Cd causes impairment of kidney function, poor reproductive capacity, hypertension and tumors (Abdulali *et al.*, 2012; Rohasliney *et al.*, 2014). The lowest Pb content was in WD-1 (0.46 mg/kg) while the highest was found in KN- N (6.73 mg/kg). The KN (1.11 – 1.65 mg/kg) fish samples were lower in Pb than those of WD (1.53 – 3.98 mg/kg). The maximum permissible safe level in fish by WHO (world health organization) is 0.6 mg/kg (Rohaliny *et al.*, 2014). Pb is a non-essential element, which when consumed or inhaled in high doses can lead to poisoning, which is associated with severe health effects. It interferes with similar elements like calcium and zinc.Pb consumption can lead to renal failure and liver damage (Abdulali *et al.*, 2012; Olujimi *et al.,* 2018).

Generally, the fish samples from Wudil (WD) had higher heavy metals than those from Kano (KN-samples). This could be attributed to the environment, as the Wudil River, from where the Wudil fish was sourced is very muddy by nature. Joram and Kapute (2016) reported that some wild sourced fish are more laden with heavy metals compared to home grown fish, depending on the aquatic source. Heavy metals when consumed by human in excess can lead to health problems (Fagbenro *et al.*, 2005; Alfa *et al.,* 2014; Olujimi *et al.*, 2018).

The difference in the mineral contents compared with similar research findings, could be due to geographical place of harvest, seasonal, annual and environmental factors and species of fish (Fagbenro *et al*., 2005; Joram and Kapute, 2016; Tenyang *et al.,* 2016).

3.4 *Microbial content*

From table 4, the total bacteria count was highest in WD-4 (4.5×10^4 cfu/g) followed by WD-3 (3.3×10^4 cfu/g) while the lowest value was in WD-1 (2.2×10^4 cfu/g). The fish samples from Wudil had higher bacteria counts compared to the dried fish from Kano town. The sun-dried fish from the different sources had high microbial load ($2.2 - 4.5\times10^4$) but within acceptable level (5.0×10^5 cfu/g) which are achievable under good manufacturing practice (Ezeama, 2007). The microbial load can be attributed to contamination from the surrounding environment during and after the processing rather than the live fish (Ezeama, 2007; Adams and Moss, 2008).At low moisture (less than 10 %) enzymatic activity of bacteria and yeast are prevented (Ezeama, 2007).

The total fungal counts of the fish samples were however more in KN ($5.0\times10^3 - 2.1\times10^4$cfu/g) than in WD ($2.0\times10^3 - 1.0\times10^4$ cfu/g). The fungi count was highest in KN-D (2.1×10^4 cfu/g) and lowest in WD-1 (2.0×10^3 cfu/g). The total fungi count is required not to exceed 1.0×10^5cfu/gin dried fish products (APHA, 1992; Jianadasa *et al*., 2014). All fish samples were within the fungi quality specification. The moisture content is an indicator of the susceptibility of a product to undergo microbial spoilage (Ezeama, 2007; Jianadasa *et al.,* 2014). Fungi are very tolerable to low moisture and thus can thrive well in water activity foods (Ezeama, 2007; Onwuka, 2014).

WD-1 and WD-3 had the highest number of coliform count of 150 MPN/g each. WD-2 had the lowest coliform count (28 MPN). The low coliform count was because of the dry nature of the fish, as coliforms require enough moisture to thrive. The presence of coliforms > 500 MPN/g in fish is considered not acceptable when food safety is considered (Codex, 1979; Jianadasa *et al*., 2014). International commission on microbiological specifications for foods (ICMSF) specified the upper (reject able) level as 1×10^7 cfu/g for fish products (Codex, 1979; Jianadasa *et al*., 2014). The total microbial counts of KN and WD fish samples were below 1.0×10^6cfu/g the acceptability limit for dried fish and are therefore fit for consumption.

3.5 *Sensory evaluation*

The sensory scores of Judges for the dried fish using the nine-point hedonic scale format is presented on Table 5. Organoleptic attributes are very important parameters in fish product quality and pricing (Dagne *et al.,* 2016). There were significant differences ($p<0.05$) in some of the sensory attributes evaluated. KN-T was most preferred in appearance (10.47) followed by KN-N (6.13). Sample KN-D had the lowest appearance score of 4.73. KN samples were generally better than the WD samples. Food colour is a quality indicator of the appearance of foods (Iwe, 2010; Ndife, 2016). It also helps to determine the degree of processing or spoilage level (Onwuka, 2014).

The flavor of the fish samples was evaluated in terms of the taste and aroma attributes. For aroma, KN-N and KN-T had the highest scores of 6.13each. KN- K had highest taste score (6.47) and WD-4 the lowest (3.67).KN samples were significantly different from WD in aroma and taste. Some the local processors from Kano, as matter of culture apply some spices during the process of drying the fish.The flavor of the fish is an indication of the freshness and dryness, and to some extent influence consumer acceptability (Iwe, 2010).

Texture deals with how the sample feels when touched; KN-N (6.20) had the highest textural score, while WD-4 (4.27) had the lowest value. The low texture rating of some of the sun-dried fish samples could be attributed to oil and moisture contents of the catfish. This also boils down to the technique of sun-drying employed. The extent of dried fish texture, toughness, and dryness is greatly influenced by loss of moisture during drying and the effects of protein denaturation (Onwuka, 2014).

In overall acceptability, KN-N (6.53) was considered the best and WD-4 (3.73) had the least acceptability. Generally sun-dried catfish samples from Kano (KN) were more acceptable to the panelists than those from Wudil (WD). The results of the sensory assessment showed that the processing methods used by each locality affected the quality and consumer acceptance of the dried commercial fish.

4.0 CONCLUSION

This study provided information on quality variation of sun-driedcatfish produced and sold in Kano and Wudil towns in Nigeria. Generally, the dried fish were fit for consumption and would be beneficial to human health. However, assessment of the chemical characteristics, heavy metals and microbial contents showed that the conditions for their production, storage and sales need improvement. Overall the Kano fish samples were better than those from Wudil as they were lower in total microbial and heavy metal contents and were also preferred in sensory acceptability.

Proper hygienic condition should be maintained at every step of catching, transportation, processing and marketing by following HACCP steps for the production of good quality fish and fishery products for the consumer. This could be achieved by first educating the local processors on modern fish processing techniques and subsequently enforcing hygienic standards and laws while assisting with sophisticated and modern equipment for harvesting, carriage, processing and storage. Further research should also be conducted to improve on the procedures for sun drying catfish by using solar drying techniques. The essential fatty acid compositions of these dry fish need to be evaluated because of their importance to human health.

REFERENCES

Abdulali, K., Shushaimi-Othman, M. and Ahmad, A. (2012). Analysis of heavy metals in tilapia fish (*oreochromis niliticus*) from four selected markets in selanghor, peninsular Malaysia. *Journal of Biological Sciences* 12(3): 138-145.

Adams, M. R. and Moss, M. O. (2008). Food Microbiology, 3rd ed. Thomas Graham House, Science Park, Cambridge, UK.

Adeyeye, S. O., Oyewole, O. B., Obadina, A. O., Omemu, A. M. and Adebayo-Oyetoro, A. O. (2016). Effect of smoking methods on quality, microbial and chemical safety of traditionally smoked silver catfish (*Chrysichthys nigrodigitatus*). *Pacific Journal of Science and Technology* 17(1): 258-270.

Akinneye, J. O., Amoo, I. A. and Arannilewa, S. T. (2007). Effect of drying methods on nutritional composition of three species of fish. *Journal of Fishery International* 2(1): 99.-103.

Alfa, Y. M., Nda-Umar, U. I., Salihu, A. B. and Nma, N. Y. (2014). Proximate composition and mineral components of some species of fish sold in Bida market. *International Journal of Current Research in Chemistry and Pharmaceutical Sciences* 1(8): 19-24.

Amoo, I. A., Akinneye, J. O. and Arannilewa, S. T. (2007). Effect of drying methods on the nutritional composition of three species of fish (*Bonga sp. Sardinella sp. and Heterotis niloticus*). *Journal of Fishery International*2: 99-103.

AOAC, (2005). Official Methods of Analysis, 18th ed. Association of Official Analytical Chemists International, Maryland, USA.

APHA. (1992). Compendium of methods for the microbiological examination of foods, 4thed. American Public Health Association, Washington DC, USA.

Chukwu, O. (2009). Influences of drying methods on nutritional properties of tilapia fish (*Oreochromis nilotieus*). *World Journal of Agriculture Science* 5(2), 256–258.

Codex (1979). Recommended International Code of Practice for Smoked Fish. Codex Alimentarius-1, Volume 9, CAC/RCP 25-1979. Codex Alimentarius Commission, Food and Agriculture Organisation, Rome.

Dagne, T., Mitiku, G., Solomon, A. and Getachew, B. F. (2016). Effect of drying method and pre-treatments on nutritional value and sensory quality of fish (*Oreochromis niloticus, Pylodictiso livaris and Cyprinuscarpio*) species commonly used in Gambella region. *Turkish Journal of Agriculture, Food Science and Technology* 4(1): 22-30.

Daramola, J. A., Fasakin, E. A., Adeparusi, E. O. (2007). Changes in physicochemical and sensory characteristics of smoke-dried fish species stored at ambient temperature. *African Journal Food Agriculture Nutrition and Development* 7(6): 1684-5358.

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

Fagbenro, O., Akinbulumo, O., Adeparusi, O. E. and Raji, A. A. (2005). Flesh yield, waste yield proximate and mineral composition of four commercial West African fresh water food fishes. *Journal of Animal and Veterinary Advance* 4(1): 848-85.

Fuadi, I., Suseno, S. and Ibrahim, B. (2014). Characterization of fish oil from mackerel (*scomber japonicus*) canning by product. *Asian Journal of Agriculture and Food Science* 2(3): 227-233.

Gram, L. and Dalgaard, P. (2002). Fish spoilage bacteria problems and solutions. *Current Opinion Biotechnology* 13: 262-266.

Gulshan, A. L., Subhash, C. C., Mohajira, B., Farzana, B. F. and Mosarrat, N. N. (2014). Comparative study of quality of three different Bangladeshi smoke-dried lean fishes using salt and turmeric stored at refrigeration temperature (4 ^{o}C). *American Journal of Food Science and Technology* 2(6): 2009-2015.

Ighodaro, H. E. and Abolagba O. J. (2010). The acceptance of package smoked-dried fish cured (*Clarias gariepinus*) in Benin City. *Journal of Field Aquatic Studies* 4(1): 32-39.58.

Iwe, M.O. (2010). Handbook of Sensory Methods and Analysis, Rojoint Communication Services Ltd. Enugu, Nigeria.

Jianadasa, K., Ginigaddarage, P. and Ariyawansa S. A. (2014). Comparative quality assessment of five types of selected fishes collected from retail market in Sri lanka. *American Journal of Food Science and Technology* 2(1): 21-27.

Joram, A. and Kapute, F. (2016). Sensory evaluation of wild-captured and pond-raised tilapias in Malawi.*Africa Journal of Food Science*10(10): 238-242.

Msuku, L and Kapute, F. (2018). Effect of smoking and sun drying on proximate composition of diplotaxodon fish species (*Ndunduma*) from lake malawi, Malawi. *African Jurnal Food Agricultue Nutrition and Devevelopment*18(1):13009-13018.

Ndife, J. (2016). Functional Foods: Basics, Ingredients and Applications. Amotes Link Services and Publishers, Kaduna, Nigeria.

Nielsen, S. S. (2003). Food Analysis Laboratory Manual. 3rd ed. Kluwer Academic Plenum Publishers, New York.

Okereke, A. N., Okpara, J. Y. and Ogumuka, S. O. (2014). Comparative nutritional composition of smoked catfish (*clarias gariepinus*) produced from NIOMR smoking kiln and local cut drum oven. *American Journal of Food Technology* 9(7): 377-381.

Olujimi, O., Abubakar, R., Fabusoro, E., Sodiya, C., Ojo, O., and Towolawi, A (2018). Levels of heavy metals in local milk and cheese and phthalate esters in cheese by pastoralists in ogun and oyo states Nigeria. Nigerian Food Journal 36(1): 12-20.

Onwuka, G. I. (2014). Food Science and Technology, Naphtali Prints, Somolu Lagos, Nigeria.

Onwuka, G.I. (2018). Food Analysis and Instumentation: Theory and Practice, 2nd ed. Napthali Prints. Shomolu, Lagos, Nigeria.

Ogbonnaya, C. (2009). Influence of drying methods on nutritional properties of tilapia fish. *World Journal of Agricultural Sciences* 5(2): 256-258.

Rohasliney, H., Tan, H. S., Noor, Z and Tan, P. Y. (2014). Determination of heavy metals in fishes from lower reach of Kelantan river, kelatan, Malaysia. *Tropical Life Science Research* 25(2): 21-39.

Tenyang, N., Ponka, R., Tiencheu, B., Djikeng, F. and Womeni, H. (2016). Proximate composition, fatty acid and mineral contents of four freshwater fish from Maga lake (far north region of Cameroon). *American Journal of Food Science and Technology* 4(3): 64-69.

Yanar, Y. (2007). Quality changes of hot smoked catfish (*Clarias gariepinus*) during refrigerated storage. *Journal of Muscle Food* 18: 391-400.

Table 1: Proximate content of sun-dried catfish (%)

Sample	Moisture	Protein	Lipid	Ash	Carbohydrate
KN-N	7.50±0.42[a]	57.43±0.77[a]	10.80±0.28[a]	21.10±0.14[a]	3.12±0.78[a]
KN-F	6.90±0.42[a]	59.61±0.78[a]	12.20±0.28[ab]	13.20±0.69[b]	8.09±2.6.2[ab]
KN-T	6.60±0.28[a]	60.71±0.77[a]	11.40±0.85[a]	12.00±0.57[bc]	6.80±1.19[a]
KN-D	7.80±0.57[a]	58.52±0.2.32[a]	12.00±0.56[a]	16.00±0.28[bd]	5.68±1.47[a]
WD-1	5.00±0.57[b]	60.66±0.71[a]	12.40±1.13[a]	14.80±0.57[bced]	6.64±1.13[a]
WD-2	5.00±0.28[b]	58.52±0.77[a]	13.70±0.14[ab]	14.20±0.68[fde]	6.89±0.49[a]
WD-3	6.70±0.14[ab]	60.00±2.32[ab]	13.20±0.28[ab]	15.40±0.28[bcgdef]	4.00±2.18[ab]
WD-4	5.90±0.42[bc]	62.34±0.00[a]	12.30±0.14[ab]	15.40±0.57[bchdef]	4.06±0.00[a]

Values are mean ± standard deviation;Column with different superscript are significantly different ($p<0.05$); KN-Kano; WD-Wudil

Table 2: Chemical properties of sun-dried catfish

Sample	pH	TMA (mg/100g)	FFA (%)	AV ((MgKOH/g)	PV (mEq/kg)
KN-N	5.57±0.01[b]	0.75±0.14[a]	2.23±0.04[a]	4.46±0.08[a]	2.10±0.15[a]
KN-F	5.65±0.01[b]	0.66±0.35[a]	2.36±0.06[b]	4.72±0.12[b]	2.28±0.25[a]
KN-T	5.71±0.01[b]	1.04±0.06[a]	2.51±0.01[b]	5.02±0.0[b]	2.53±0.18[a]
KN-D	5.65±0.01[b]	1.35±0.07[b]	2.63±0.04[b±]	5.25±0.06[a]	2.41±0.15[a]
WD-1	5.36±0.01[a]	0.53±0.25[b]	2.26±0.06[a]	4.51±0.01[a]	2.11±0.15[a]
WD-2	5.47±0.01[b]	0.04±0.06[a]	2.24±0.05[a]	4.47±0.09[b]	2.41±0.13[a]
WD-3	5.57±0.01[ab]	0.73±0.11[a]	2.68±0.02[b]	5.36±0.06[a]	2.48±0.04[a]
WD-4	5.72±0.01[a]	1.25±0.06[b]	2.27±0.04[b]	5.25±0.06[b]	2.28±0.04[a]

Values are mean ± standard deviation;Column with different superscript are significantly different ($p<0.05$); KN-Kano; WD-Wudil ; TMA-Trimethylamine ; FFA-Free Fatty Acids; AV-Acid Value; PV-Peroxide Value

Table 3: Heavy metal content of sun-dried catfish (mg/kg)

Sample	Cd	Cu	Pb	Mn	Cr
KN-N	0.72±0.01[d]	0.18±0.03[c]	6.73±0.16 [c]	7.68±0.15[c]	0.85±0.03[c]
KN-F	3.22±0.10[b]	0.11±0.02[c]	1.65±0.10[b]	13.46±±0.19[b]	0.12±0.01[b]
KN-T	3.32±0.12[b]	1.84±0.13[b]	1.49±0.13[b]	13.60±0.13[b]	0.19±0.02[b]
N-D	3.17±0.10[c]	0.53±0.01[c]	1.11±0.03[b]	20.15±0.20[a]	1.26±0.10[a]
WD-1	3.18±0.13[c]	0.70±0.02[c]	0.46±0.01[d]	19.26±0.21[a]	0.66±0.01[c]
WD-2	3.40±0.10[b]	2.02±0.13[a]	1.53±0.12[b]	21.05±0.30[a]	0.49±0.02[c]
WD-3	3.97[a]±0.12	2.15±0.14[a]	3.98±0.10[a]	18.18±0.16[a]	0.90±0.03[b]
WD-4	3.81[a]±0.13	2.15±0.10[a]	3.97±0.14[a]	20.19±0.21[a]	0.38±0.01[c]

Values are mean± standard deviation; Column with different superscript are significantly different ($p<0.05$); KN-Kano; WD-Wudil; Cd-Cadmium; Cu-Copper; Pb-Lead; Mn-Manganese; Cr-Chromium

Table 4: Microbial content of sun-dried catfish

Samples	Bacterial counts (cfu/g)	Fungi counts (cfu/g)	Coliform counts (MpN/g)
KN-N	3.0×10^4	5.0×10^3	93
KN-F	3.1×10^4	9.0×10^3	75
KN-T	2.8×10^4	5.0×10^3	120
KN-D	2.8×10^4	2.1×10^4	93
WD-1	2.2×10^4	2.0×10^3	150
WD-2	3.3×10^4	4.0×10^3	28
WD-3	3.0×10^4	1.0×10^4	150
WD-4	4.5×10^4	4.0×10^3	75

MpN-Most Probable Number;KN-Kano; WD-Wudil

Table 5: Sensory evaluation of the sun-dried catfish

Sample	Appearance	Aroma	Taste	Texture	Acceptability
KN-N	6.13 ± 1.13^a	6.13 ± 0.83^a	6.47 ± 0.74^a	6.20 ± 0.78^a	6.53 ± 0.52^a
KN-F	5.20 ± 0.77^a	5.80 ± 0.86^a	4.40 ± 1.30^a	4.80 ± 1.45^a	5.80 ± 0.68^a
KN-T	10.47 ± 1.82^a	6.13 ± 0.83^a	5.67 ± 1.35^a	4.87 ± 1.55^a	5.47 ± 1.06^b
KN-D	4.73 ± 1.23^a	5.13 ± 1.30^{ab}	5.13 ± 1.30^a	5.27 ± 1.21^a	4.60 ± 0.91^b
WD-1	5.00 ± 1.77^a	4.33 ± 1.54^{ab}	4.67 ± 1.39^b	5.20 ± 1.01^a	4.53 ± 0.99^b
WD-2	4.93 ± 1.34^a	3.80 ± 1.26^b	4.67 ± 1.39^b	5.0 ± 1.36^a	4.67 ± 1.05^b
WD-3	5.27 ± 1.23^a	3.80 ± 1.86^b	4.53 ± 1.36^b	4.53 ± 1.55^b	4.00 ± 1.25^b
WD-4	5.33 ± 1.05^a	3.53 ± 2.26^b	3.67 ± 1.35^b	4.27 ± 1.62^b	3.73 ± 1.16^a

Values are mean±standard Deviation; Column with different superscript are significantly different ($p<0.05$); KN-Kano; WD-Wudil