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PROXIMATE, MICROBIOLOGICAL AND SENSORY PROPERTIES OF SMOKED WILD AND AQUACULTURED CATFISH (*CLARIAS GARIEPINUS*) USING SELECTED AFRICAN WOODS

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ABSTRACT

Fishes are highly perishable protein source which requires further processing to extend shelf life. Wild and aquacultured catfish were smoked using selected African woods; Neem (*Azadirachta indica*), African velvet tamarind *(Dalium guineense*), African Locust bean (*Parkia biglobosa*), Shear butter (*Vitellaria paradoxa*) and African birch wood (*Anogessus leiocarpus*). The catfish sample were immortalize with 4% brine, washed, twisted then smoked for 4 hrs. The samples were analyzed for proximate composition, microbiological quality and sensory properties. The sensory properties was evaluated using a panel of thirty (30) semi-trained panelist using nine (9) point Hedonic scale ranging from (9) refers to like extremely to one (1) refers dislike extremely for appearance, taste, flavor, mouthfeel and the general acceptability. The results obtained were analyzed statistically using Minitab version 17 statistical software for mean and standard deviation. The proximate composition shows that there was a significant difference among the samples at ($P \leq 0.05$), where moisture content ranged from 10.07 – 14.61 %, ash 3.37 – 4.01 %, fat 19.61 – 20.61 %, fiber 0.51 – 0.82 %, protein 48.11 – 55.3 % and carbohydrate content ranged from 9.57 – 16.05 % respectively. The microbial quality of the smoked wild and aquacultured catfish shows that bacterial count ranged from 1.22×10^3 – 7.33×10^3 cfu/g. Whereas, total fungal count ranged from 1.00×10^3 - 4.33×10^3 cfu/g. There was no bacterial growth in sample smoked with neem woods, while control sample smoked in an oven had the lowest fungal count and wild catfish smoked with shear butter wood had the highest fungal count (4.33×10^3) respectively. The sensory properties of smoked catfish shows that appearance ranged from 7.73 - 8.95, flavor 7.73 - 8.20, taste 7.63 - 8.365, aroma 7.66 - 8.23, mouthfeel 7.70 - 8.30 and overall acceptability 7.53 - 8.43 with significant difference at ($P \leq 0.05$) respectively. In conclusion, African woods improves the sensory properties, inhibits microbial growth without altering the proximate composition of smoked catfish.

Keywords: Wild and aquaculture catfish, Smoking, Proximate, Microbiological quality, Sensory

INTRODUCTION

Fish is highly nutritious food which provides all the essential protein required by the body for growth and body development compared with protein obtained from meat, milk or egg (Umar *et al.,* 2018). However, fish falls among the most perishable food commodity, which serves as a suitable media for growth and proliferation of microorganism (Umar *et al.,* 2018). Spoilage may arising from bacterial activity and autolytic spoilage are enormous. Hence, the need for processing of excessive fish harvested through smoking process (Taiwo, 2015).

Fish smoking and its effect had been of interest to many researchers (Ahmed *et al*., 2011; Olayemi *et al*., 2011; Aliya *et al*., 2012; Omodara and Olaniyan, 2012), where smoking accelerates drying (i.e. lowers or removes water activity) to prevent microbial activities thereby extending shelf life (Ndife *et al.,* 2019). Fish smoking is an age long method of processing in Nigeria. However, the process is laborious which is associated with drudgeries (Ayuba *et al.,* 2022).

Wood is extremely complex material with more than 400 volatile compounds identified (Olaniyan, 2012). Wood smoke contains nitrogen oxides, polycyclic aromatic hydrocarbons, phenolic, furans, aliphatic carboxylic acids, tar, carbohydrates, pyrocatechol, pyrogallols, organic acids, bases and certain carcinogenic compounds.

Concentration of different compounds in woods can reach levels considered hazardous for human health, especially when the smoking procedure is carried out under uncontrolled conditions as reported by (Moret *et al.,* 1999). Nitrogen oxides are responsible for the characteristic color, whereas polycyclic aromatic hydrocarbon compounds and phenolic compounds contribute significantly to the unique taste as well as releasing some of the undesirable compounds present in the wood biomass. These chemicals are also most controversial from a health point of view which requires and elaborate study to assess their safety level (Ayuba *et al.,* 2022).

Besides the major combustion products (carbon dioxide and water), wood smoke consists of more distinct organic compounds as reported by Muyela *et al.,* (2012), many of which had been shown to induce acute or chronic health effects when exposed humans (inhaled directly), especially the fine particulate matter, is of concern.

The main aim of this study was to determine the effect of selected wood biomass which includes (Neems woods (*Azadirachta indica*), African velvet tamarind woods *(Dalium guineense*), African Locust bean wood (*Parkia biglobosa*), Shear butter woods (*Vitellaria paradoxa*), African birch woods (*Anogessus leiocarpus*) on the nutritional quality, safety and sensory attributes and shelf-stability of the smoked aquaculture and wild cat fish (*Clarias gariepinus*) samples.

MATERIALS AND METHODS

Samples Used

Freshly harvested Aquaculture and wild cat fish (*Clarias gariepinus),* woods includes; Neem woods (*Azadirachta indica*), African velvet tamarind *(Dalium guineense*), African Locust bean wood (*Parkia biglobosa*), Shear butter woods (*Vitellaria paradoxa*) and African birch woods (*Anogessus leiocarpus*) were used in this study.

Samples procurement and identification

The aquaculture catfish were purchased from 'Fari-Fari farms, Warawa local Government area, Kano State. While the wild cat fish were purchased from Hadejia, Jigawa state, Nigeria. The samples were identified by a fishery specialist, Department of fishery, forestry and wildlife, Aliko Dangote University of Science and Technology (ADUSTECH), Wudil. The woods were purchased in Gaya Emirate Council, Gaya Local Government Area, following a method of (Eyo, 2001).

Study area

The smoking processing of wild and aquacultured catfish (*Clarias gariepinus*) samples were prepared prior to smoking in Food Processing Laboratory using smoking kiln set a temperature of 72±5 ^{o}C. while, the wood biomass were processed (cut) into chunks as a source of cresols, While, the samples were prepared in Food Analysis Laboratory for proximate and microbiology quality of the samples, while the sensory evaluation were carried out in the sensory testing room for their Appearance, Taste, Aroma, Flavor, Texture and the overall acceptability, in Aliko Dangote University of Science and Technology.

Sample preparation

A total number of fifteen (30) matured wild catfish and aquacultured sample with an average weight of 10kg ±100g and one kilogram for control sample were purchased following a method of (Ayeloja *et al.,* 2015), where wild and aquacultured catfish were smoked with an average of 4.5 kg of wood chunks per 1 kg each (Kwaghvihi *et al.,* 2020). The catfish sample was immortalized / stunt using 4g dissolved salts, washed, rinsed in cleaned water and the tail was twisted into the head to form a ring shape for better smoking. The prepared samples were dipped in brine solution and then allowed to stand for 30 minutes before smoking process commenced by arranging the samples in a pre-heated smoking kiln for 3-4 hrs (Ndubueze, 2021).

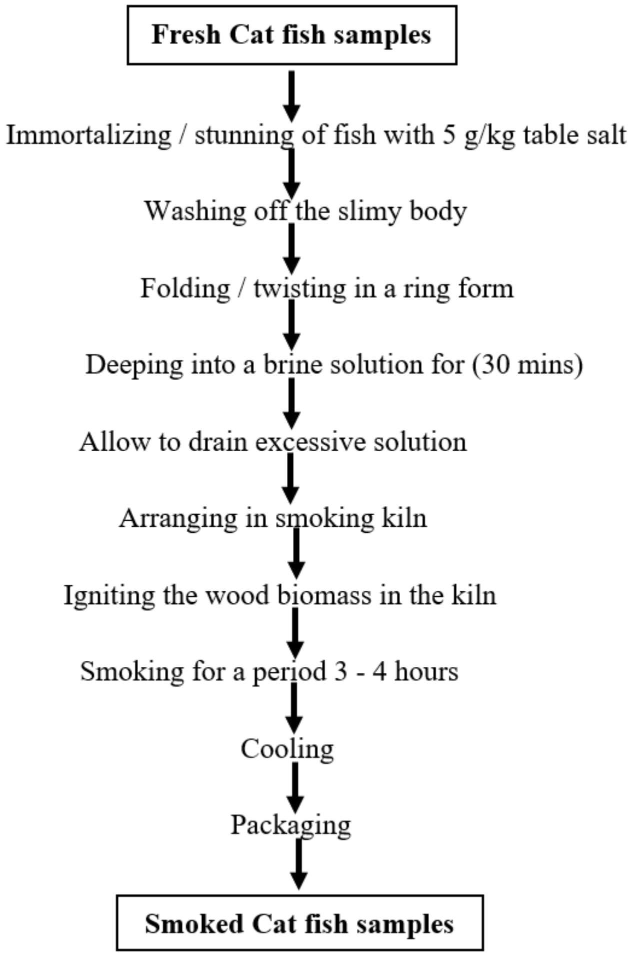

Figure 1: Flow Chart for Smoking Catfish (*Clarias gariepinus*) samples
Source: (Ayeloja *et al.,* 2015).

MATERIALS AND METHODS

Determination of proximate composition of smoked cat fish samples.

The determination of moisture, fat, ash, protein, fibre and carbohydrate content were analyzed according to the method of (Onwuka, 2018 and AOAC, 2010).

The percentage moisture content were determined by the method described by Onwuka, (2018). A pre-dried petri dish was weighed and recorded as (W_1) and 5g of the sample smoked catfish sample were weighed in the dish as (W_2).the sample were oven dried at (105 ^{o}C) for 3 hrs and the reweighed as w3 then allowed to cooled down in a desiccator and weigh. This process were repeated for triplicate measurement and calculated using the following equation.

% moisture = $\frac{[(W2-W3}{W2-W1)]} \times 100$

The percentage ash content were analyzed following a method of Onwuka, (2018), where pre-dried cleaned crucible was weighed as (W_1), five grams (5 g) of smoked catfish sample was weighed out accurately recorded as (W_2). The smoked samples were transferred into pre-heated muffle furnace set at temperature of (550 ^oC) for 4 hrs until turned to grey color. Ashed samples was re-weighed and recorded as (W_3). The percentage ash content were calculated using the equation below;

$$\%\ ASH = \frac{[(W3-W2}{W2-W1)]} \times 100$$

The protein content of the smoked catfish were analyzed using digestion, distillation and titration as described by (AOAC, 2010), were 2 g of the sample was digest sing 1 kjeldahl catalyst tablet, 15 ml concentrated H_2SO_4 were added and then digested for 4 hours until a clear solution is obtained. The digest were distillated with 20 ml boric. The distillation will be within for 15 mins and the distillate will be titrate with 0.05 N HCl (AOAC, 2010).

% Total Nitrogen = Titre Value x Atomic mass of Nitrogen x Normality of HCl used x 4

Therefore, the crude protein content will be determined by multiplying the percentage Nitrogen by a constant factor of 6.25 i.e. % crude protein = % N x 6.25.

The crude protein content of the sample will be calculated as showing below, where,

$$\%\ N = \text{NHCl} \times \frac{acid\ volume}{g\ of sample} \times \frac{14\ g\ N}{mol} \times 100$$

Crude fat were determined using Soxhlet extraction method as described by (Onwuka, 2018). Where two grams (2 g) of dried sample was weighed into thimbles free from fat in an extractor and 200 ml of N-Hexane was added then allowed to run in the apparatus set for 3 - 4 hrs with continuous siphoning. After the extraction was completed, the hexane residue were evaporated off in a hot air oven at 100 ^oC for 30 mins, the allowed to cool down and then weighed. The fat content were calculated using the equation below;

$$\text{Fat} = \frac{weight\ of\ flask + fat}{weight\ of\ sample} - \text{x } 100 \text{ g}$$

Determination of CHO by Difference

The carbohydrate content of the smoked catfish (*Clarias gariepinus*) sample were calculated by difference using the following formula:

% available carbohydrate = 100 - (% moisture + % Protein + % fat + % Ash) (Onwuka, 2018).

Microbiological Analysis

Preparation of Nutrient Agar Medium

All media's were prepared following the manufacturer's guide, where twenty three gram (23 g) of nutrient agar were measured and dissolved in 1 litre of distilled water, boiled with frequent stirring and finally sterilized by autoclaving at 121 ^oC for 15 mins as described by (Onwuka, 2018), and 49 g of potato dextrose agar (PDA) were measured into 1 litre conical flak and dissolved in 1 litre distilled water then sterilized at 115 ^oC for 10 mins and the bring to temperature of 47 ^oC. It was supplemented with anti-biotic (chloramphenicol solution) in a ratio of 1:25 to suppress the bacterial growth as reported by (Onwuka, 2018). One gram (1g) of peptone powder were prepared by dissolving into 1000 ml distilled water (i.e. 0.1 %), then dispensed into dilution bottles and then sterilized at 121^oC for 15 mins.

Enumeration of Viable Bacterial count

Viable count for mesophilic bacteria were carried out, the serial dilution method were carried out following a method described by Daniel *et al.,* (2013). One (1 g) of the smoked cat fish samples were mixed with ninety nine 99 ml (0.1 % peptone water. The homogenate solution gave the dilution of 10^{-1}. This procedure were repeated up to the fifth dilution factor of 10^{-5}. One (1) ml of each dilution was pipetted into separate corresponding petri-dish in duplicates. About 15 ml of nutrient agar (NA), Potato dextrose agar (PDA) were cooled to 45 ^oC then poured in to each plate (Onwuka, 2018). The plate were rotated on a flat surface and allowed to solidify. The petri-dish were then inverted and s. Plates containing between 30-300 colonies were selected and counted. While, the potato dextrose agar were incubated at 25 ^oC for 3-5 days. The number obtained were multiplied by the dilution factor. This gave the number of total bacterial colony forming unit per gram of smoked cat fish sample, (Cfu/g) of the smoked cat fish as described by (Daniel, *et al.,* 2013). N= n/vd

Where;

N= the number of bacterial colony per gram of sample. n= Number of colonies counted. V= volume of sample used. d= dilution factor.

Sensory Evaluation

The sensory evaluation of smoked catfish samples were evaluated for appearance, taste, flavor, mouth feel and the general acceptability. The smoked catfish samples were compared with control samples smoked in an oven. A semi-trained panelists consists of (30) thirty male and Female who were pre-trained based on the smoked fish to difference the sensory attributes for the study were employed. The test room were prepared with colored dim light to prevent bias between the samples and each samples were presented in a partitioned cubicle to avoid interference between the panelists response to samples. A nine (9) point Hedonic scale ranging from (9) means like extremely to one (1) meaning dislike extremely were used as a scale of preference (Onwuka, 2018). The data obtained were further subjected to statistical analysis for mean and standard deviation and means were separated using least significant difference.

Statistical Analysis

Data's obtained were analysed in triplicates measurement except sensory evaluation which involved (30) panelists. The data generated were analyzed using Minitab (Version 17) Statistical software for mean standard deviation. Means and standard deviation were calculated among the samples from values obtain from the analysis as described by Aremu *et al.,* (2013); Onwuka, (2018). Analysis of variance (ANOVA) result were used to compare the values obtained and the level of significance were considered significant at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of Smoked Catfish

Table 1. presents the results of proximate composition of wild and aquacultured smoked catfish samples smoked with indigenous wood biomass such as (shear butter, *Tamarindus*, locust bean, neem and African birch woods) respectively and the control sample were smoked – dried in an oven to as control sample compared with the samples evaluated for effect of the wood biomass on the quality of smoked catfish samples. The results revealed that there was a significant difference among the samples in terms of moisture content ranged from (10.07 – 14.61 %) in sample WSA and WSN, ash content ranged from (3.37 – 4.01 %) in sample WSL to CON where there was a significant difference at ($P \leq 0.05$) level of probability among the samples. The result of crude fat content of (wild and aquaculture) catfish samples ranging from (19.61 – 20.61 %) were aquacultured catfish smoke with African birch wood coded ASA had the highest mean value compared with sample CON had the lowest mean value as indicated the table 1. The results of fiber content of catfish smoked with

selected indigenous wood biomass ranged from (0.51 – 0.82 5 %). The crude protein content of wild and aquacultured smoked catfish samples ranged from (48.11 – 55.3 %). Similarly, the carbohydrate content analyzed by difference had a mean value ranged from (9.57 – 16.05 %) respectively.

Table 1: Proximate Composition of Smoked Cat Fish

Sample	Moisture (%)	Ash (%)	Crude Fat (%)	Fibre (%)	Protein (%)	NFE (CHO)
CON	$13.81^{b}\pm0.00$	$4.01^{a}\pm0.04$	$19.63^{d}\pm0.00$	$0.77^{a}\pm0.01$	$51.89^{c}\pm0.09$	$9.87^{d}\pm0.11$
WSW	$10.71^{g}\pm0.05$	$3.42^{d}\pm0.00$	$19.67^{d}\pm0.01$	$0.51^{d}\pm0.01$	$49.61^{d}\pm0.99$	$16.05^{a}\pm0.94$
WST	$12.93^{c}\pm0.14$	$3.83^{b}\pm0.02$	$20.39^{b}\pm0.14$	$0.57^{c}\pm0.01$	$48.80^{de}\pm0.73$	$13.55^{b}\pm0.82$
WSL	$10.40^{h}\pm0.17$	$3.37^{d}\pm0.08$	$20.02^{c}\pm0.01$	$0.64^{b}\pm0.04$	$49.78^{d}\pm0.24$	$15.73^{a}\pm0.42$
WSN	$14.61^{a}\pm0.00$	$3.72^{c}\pm0.08$	$19.61^{d}\pm0.09$	$0.55^{c}\pm0.03$	$48.31^{de}\pm0.52$	$13.15^{b}\pm0.60$
WSA	$10.07^{i}\pm0.02$	$3.99^{a}\pm0.09$	$19.95^{c}\pm0.01$	$0.82^{a}\pm0.02$	$55.36^{a}\pm0.49$	$9.57^{d}\pm0.47$
ASS	$11.92^{d}\pm0.07$	$3.92^{a}\pm0.04$	$20.02^{c}\pm0.00$	$0.56^{c}\pm0.01$	$52.81^{bc}\pm0.81$	$10.75^{c}\pm0.83$
AST	$9.24^{j}\pm0.14$	$3.90^{a}\pm0.08$	$20.53^{ab}\pm0.02$	$0.58^{c}\pm0.01$	$53.29^{b}\pm0.60$	$12.44^{bc}\pm0.63$
ASL	$11.41^{e}\pm0.00$	$3.77^{c}\pm0.04$	$20.55^{ab}\pm0.17$	$0.74^{a}\pm0.01$	$53.84^{b}\pm0.52$	$9.72^{d}\pm0.52$
ASN	$14.03^{b}\pm0.03$	$3.73^{c}\pm0.05$	$20.47^{ab}\pm0.04$	$0.68^{b}\pm0.02$	$47.34^{e}\pm0.41$	$13.66^{b}\pm0.45$
ASA	$11.03^{f}\pm0.02$	$3.84^{b}\pm0.04$	$20.61^{a}\pm0.01$	$0.62^{b}\pm0.01$	$48.11^{de}\pm0.14$	$15.67^{a}\pm0.04$

The result are mean standard deviation (±SD) of triplicates measurements. The samples in same column with different superscript are significantly different at ($P\leq0.05$) level of probability.

Key:
Con = Control sample: Aquaculture catfish smoked in an oven; WSW= Wild Catfish smoked with Shear butter woods; WST= Wild Catfish smoked with *Tamarindus* woods; WSL= Wild Catfish smoked with locust bean woods; WSN = Wild Cat fish smoked with neem woods; WSA= Wild Catfish smoked with African birch woods; ASS= Aquaculture Catfish smoked with Shear butter woods; AST= Aquaculture Cat fish smoked with *Tamarindus* woods; ASL= Aquaculture Catfish smoked Locust bean woods; ASN= Aquaculture Catfish smoked with neem woods and ASA= Aquaculture Catfish smoked with African birch woods.

Total viable Bacterial and fungal Count in smoked Catfish samples

Table 2, revealed the results of microbiological quality of catfish samples smoked with selected wood biomass such as; shear butter, tamarind, locust bean, neem and African birch were carried out, where the smoked wild catfish were coded WSW, WST, WSL, WSN and WSA respectively. While, the aquacultured smoked catfish were coded; ASS, AST, ASL, ASN and ASA meanwhile, CON referred to the control sample smoked in an oven. The results showed that the total viable bacterial count ranged from ($1.22\text{x}10^{3}$ – $7.33\text{x}10^{3}$ cfu/g), where sample CON and WSW had no viable count among the samples analyzed. The trend showed a slight increase in total viable bacterial count. The result obtained revealed that the total viable bacterial count from the smoking point had a very low viable count which indicates the effect of the wood biomass on lowering the water activity thereby increasing the storage time. The results obtained showed that the total viable bacterial count in smoked wild and aquacultured catfish samples were below the standard acceptable for bacterial count ($8.5\text{x}10^{6}$ cfu/g) for smoked fish products set by (FAO, 2017).

Table 2: Total viable Bacterial and fungal Count in Catfish Smoked

Sample	Total Bacterial count (cfu/g)	Fungal count (cfu/g)
CON	No Growth	$1.00^{cd}\times10^{3}\pm1.57$
WSW	No Growth	$4.33^{a}\times10^{3}\pm0.52$
WST	$7.33^{a}\times10^{3}\pm1.03$	$1.20^{c}\times10^{3}\pm1.20$
WSL	$2.33^{bc}\times10^{3}\pm0.57$	$3.03^{ab}\times10^{3}\pm1.05$
WSN	$4.33^{b}\times10^{3}\pm0.08$	No Growth
WSA	$5.00^{ab}\times10^{3}\pm1.61$	$2.33^{b}\times10^{3}\pm1.51$
ASS	$6.67^{ab}\times10^{3}\pm1.11$	$1.26^{c}\times10^{3}\pm1.04$
AST	$7.30^{a}\times10^{3}\pm10.2$	$1.90^{bc}\times10^{3}\pm1.55$
ASL	$1.27^{c}\times10^{4}\pm1.11$	$2.00^{b}\times10^{3}\pm1.00$
ASN	$1.33^{c}\times10^{3}\pm1.15$	$1.80^{bc}\times10^{3}\pm1.00$
ASA	$5.66^{ab}\times10^{3}\pm1.15$	$2.20^{b}\times10^{3}\pm1.76$

The result are mean standard deviation (±SD) of triplicates measurements. The samples in same column with different superscript are significantly different at ($P\leq0.005$) level of probability.

Key:
Con = Control sample: Aquaculture catfish smoked in an oven; WSW= Wild Cat fish smoked with Shear butter woods; WST= Wild Cat fish smoked with Tamarindus woods; WSL= Wild Cat fish smoked with locust bean woods; WSN = Wild Cat fish smoked with neem woods; WSA= Wild Cat fish smoked with African birch woods; ASS = Aquaculture Cat fish smoked with Shear butter woods; AST = Aquaculture Cat fish smoked with Tamarindus woods; ASL= Aquaculture Cat fish smoked Locust bean woods; ASN = Aquaculture Cat fish smoked with neem wood and ASA= Aquaculture Cat fish smoked with African birch woods.

Sensory Properties of Smoked Catfish

Table 3 present the results of sensory attributes of smoked catfish samples which includes appearance, flavor, taste, aroma, mouth feel and the overall acceptability respectively. The results revealed that there were significant difference among the samples evaluated by (30) semi trained panelists. The results showed that the appearance ranged from (7.73 - 8.95) in sample ASL to CON with a significant difference at (P≤0.05) level of probability. The result showed that flavor attributes of the smoked catfish samples ranged from (7.73 - 8.20) in sample WST to sample WSW. Where sample CON, WSW, ASS, WSL, ASL, ASN, WSA and ASA where significantly the same at (P≥0.0) and most preferred by the panelists, followed by sample WSL (7.83) to the lowest mean score value in sample WST and WSN (7.73 and 7.76) respectively. The taste attributes ranged from (7.63 - 8.36), and the aroma attributes of the smoked catfish samples analyzed for (wild and aquaculture) ranged from (7.66 - 8.23). The results mouth feel ranged from (7.70 - 8.30) and the overall acceptable by the panelists which ranged from (7.53 - 8.43) respectively.

Table 3: Sensory Evaluation of Smoked Catfish Analyzed

Sample	Appearance	Flavor	Taste	Aroma	Mouth feel	Overall Acceptability
CON	$8.95^{a}\pm0.00$	$7.93^{a}\pm0.90$	$8.33^{a}\pm0.80$	$8.16^{a}\pm0.69$	$8.16^{a}\pm0.87$	$8.06^{ab}\pm0.78$
WSW	$8.40^{ab}\pm0.77$	$8.20^{a}\pm0.80$	$7.93^{ab}\pm0.74$	$8.13^{a}\pm0.86$	$8.30^{a}\pm075$	$8.33^{a}\pm0.66$
WST	$8.13^{bc}\pm0.18$	$7.73^{b}\pm0.74$	$8.36^{a}\pm0.76$	$8.03^{ab}\pm0.76$	$8.03^{b}\pm0.76$	$8.23^{a}\pm0.77$
WSL	$7.96^{bc}\pm0.66$	$8.00^{a}\pm0.87$	$7.63^{b}\pm0.71$	$7.93^{b}\pm0.04$	$8.03^{b}\pm0.66$	$7.90^{ab}\pm0.84$
WSN	$8.16^{bc}\pm0.83$	$7.76^{b}\pm0.77$	$7.88^{ab}\pm0.81$	$7.90^{b}\pm0.71$	$7.76^{c}\pm0.97$	$7.53^{b}\pm0.68$
WSA	$7.83^{bc}\pm0.95$	$8.06^{a}\pm0.58$	$8.13^{ab}\pm0.81$	$8.23^{a}\pm0.81$	$8.00^{a}\pm0.74$	$8.16^{a}\pm0.83$
ASS	$8.23^{bc}\pm0.81$	$8.13^{a}\pm0.77$	$7.96^{ab}\pm0.61$	$8.16^{a}\pm0.83$	$8.16^{a}\pm0.74$	$8.40^{a}\pm0.77$
AST	$8.20^{bc}\pm0.80$	$7.83^{ab}\pm0.83$	$8.26^{a}\pm0.82$	$8.23^{a}\pm0.67$	$7.86^{bc}\pm0.73$	$8.43^{a}\pm0.72$
ASL	$7.73^{c}\pm0.78$	$8.10^{a}\pm0.75$	$7.86^{ab}\pm0.62$	$8.03^{ab}\pm0.80$	$8.00^{b}\pm0.87$	$7.93^{ab}\pm0.64$
ASN	$8.03^{bc}\pm0.76$	$8.03^{a}\pm0.85$	$7.63^{b}\pm0.85$	$8.06^{a}\pm0.82$	$7.70^{c}\pm0.75$	$8.00^{ab}\pm0.83$
ASA	$8.03^{bc}\pm0.76$	$7.93^{a}\pm0.86$	$8.13^{ab}\pm0.73$	$7.66^{c}\pm0.80$	$8.10^{a}\pm0.80$	$8.23^{a}\pm0.67$

The result are mean standard deviation (±SD) of thirty (30) measurements. The samples in same column with different superscript are significantly different at (P≤0.005) level of probability.

Key:

CON = Control sample: Aquaculture catfish smoked in an oven; WSW= Wild Catfish smoked with a Shear butter woods; WST= Wild Catfish smoked with Tamarindus woods; WSL= Wild Cat fish smoked with locust bean woods; WSN = Wild Catfish smoked with neem woods; WSA= Wildcat fish smoked with African birch woods; ASS= Aquaculture Cat fish smoked with Shear butter woods; AST= Aquaculture Cat fish smoked with Tamarindus woods; ASL= Aquaculture Cat fish smoked Locust bean woods; ASN= Aquaculture Cat fish smoked with neem woods and ASA = Aquaculture Cat fish smoked with African birch woods

Discussion

Proximate composition of smoked wild and aquacultured catfish samples

The proximate composition of smoked wild and aquacultured catfish samples presented in Table 1. Revealed that moisture content obtained in all the samples were below the maximum permissible limit which ranged from WSA – WSN range within (10.07 – 14.61 %), which agreed with the finding reported by Peter, (2015) which is low enough to prevent deterioration during storage under optimum storage condition. Umar (2018) reported different of chemical compounds such as; proteolytic, lipolysis and microbiological spoilage such as; microbial proliferation were encouraged at high moisture content above 15 %.

The crude protein, fat and carbohydrate (NFE) content showered a significantly different at (p≤0.05) where crude protein had a mean value of (55.36 %) in wild smoked catfish coded WSA and fat content had the highest percentage mean value of (20.61 %) in sample ASA in aquaculture smoked catfish samples. This could be attributed due to change in temperature difference generated between (40 -70 °C), because each wood biomass generate different amount of heat within the smoking chamber and the smoke composition varies, hence, best smoked catfish were achieved with low moisture content among samples with complex aerosol during pyrolysis. The results of proximate composition obtained in this study revealed that moisture, fat and ash content presented in table 1) and the fat content were high enough to triggers rancidity during storage which disagree with the finding of Peter, (2015); Adebowale *et al.* (2008) reported that, the range of moisture, fat and ash content of Nigerian smoked catfish to be (7.16 - 10.71, 1.58 - 6.09 and 9.21 - 12.16 %), respectively, which may be attributed due to the nature of the sample used, preparation as well as the mode of smoking techniques used.

The low crude fiber value recorded in the samples is due to the fact that animal products are significantly low in dietary fibre content as reported by Olopade *et al.* (2013). In this study, the crude protein had the highest quantity of dry matter in all the parameters analyzed. This is in line with work conducted by (Umar *et al.,* 2018; Kumolu-Johnson *et.al* (2009) which reported that protein forms the largest quantity of dry matter in smoked catfish and thus, smoked. Hence, *C. gariepinus* could serve as a good source protein rich enough to prevent malnutrition among children and adult.

The type of wood biomass commonly used in northern Nigeria with best outcome, their composition, effect on the quality of fish were considered to impact the quality offend product; hence this study investigates the impact of the wood biomass on the proximate composition of the smoked catfish which indicates a significant increase in protein and fat content with a significant decreased in moisture content which in turn lowers the rate of microbial activities (Huda *et al.,* 2010). Ogbonnaya and Shaba (2009) reported that there were no significant effect of smoking processes on the proximate composition of smoked catfish. In this study, the variations observed in proximate compositions of wild and aquacultured catfish smoked with different wood biomass (shear butter, tamarind, locust bean, Neem and African birch) woods may be due to composition of the smoke from individual wood biomass, aerosol compounds generated, temperature variables and time taken and not because of difference in species of the catfish samples used. Hence, essential smoking techniques parameters such as duration, air humidity and temperature could affect the efficiency of smoking and the quality of the end products (Olopade *et al*., 2013) and hence, could attributes some changes. In addition, the variations in the nutritional value of *Clarias gariepinus* smoked with different wood biomass may be due to the storage techniques, durations and the environmental factors. Therefore, According to this study, it is recommended that smoking process decrease water activity in smoked catfish tissue significantly by increasing the dry matter and enhancing the protein content (Peter, 2015; Ahmad *et al.,* 2011).

Microbiological quality of Catfish Smoked with Selected Indigenous Wood Biomass

This study assessed the microbiological quality of smoked catfish (wild and aquaculture) samples using selected indigenous wood biomass such as; (shear butter, tamarind, locust bean, Neem and African birch woods) for their effect on microbial growth and proliferation during storage. The results revealed that woods contained different volatile compounds which play an active role against viable bacterial and fungal growth due to aerosol generated during smoking, as well as their effect on the microbial quality of the catfish which revealed that the total count were significantly below the expected level for smoked fish products.

The microbiological quality of the smoked catfish were carried out on the samples produced showed a minimal total viable bacterial and fungal count ranged from (1.33×10^3 – 1.27×10^4 cfu/g) and fungal count ranged from 1.00×10^3 – 4.33×10^3 cfu/g) where the microbial count were significantly (Ezeamna, 2007) which implies the effectiveness of the woods against microorganism coupled with moisture removal with no bacterial growth found in sample CON and WSW with indicates the antibacterial effects of shear butter woods as well as the antifungal effect of neem woods with no fungal count in sample WSN which revealed that the wild catfish had the lowest microbial activities compared with the aquacultured smoked catfish which could be attributed due to handling, the level of initial contaminant or exposure laboratory, (Umar *et al.,* 2023). The result obtained were similar with the study conducted by (Abolagba and Uwagbai, 2011), where freshwater catfish smoked with Neem wood experienced low microbial spoilage compared with locust bean, tamarind and African birch woods. The result may be attributed due to the fact that these woods possess bioactive compounds which are transferred to the end product during smoking, hence deterring the growth and activities of microorganism during storage. In contrast to the work conducted by Adeyeye *et al.,* (2015), the microbial growth in the summer season among smoked catfish were high due to high humidity and frequent rainfall coupled with lack of modified atmospheric packaging for the smoked catfish which indicates a seasonal variation as reported by (Agbon *et al.,* 2002).

Sensory attributes of smoked catfish

The sensory properties of catfish samples smoked with selected indigenous wood biomass which includes; shear butter, tamarind, African locust bean, neem and African birch woods evaluated for their consumer preference. The results of appearance, taste, aroma, and texture of smoked catfish smoked with tamarind woods were more preferred than other wood used. The result obtained were in agreement with similar work conducted by Olopade *et al.,* (2013). The results revealed that catfish *(Clarias gariepinus*) samples smoked with Neem wood (*Azadirachta indica*), had the lowest mean score value in terms of appearance and texture as the result correlate with the report of (Lekoso *et al.,* 2020). This was in contrast to the work conducted by Adebowale *et al*. (2008), where fish smoked with neem wood maintained lowest mean score value for appearance, this may be attributed due to low burning intensity of the wood caused by its high moisture retention (Adeogun and Adebisi-Adelani, 2016). However, all the mean scores for taste, aroma / flavor in this study were above average for all wood samples used.

Consumer preference on smoked catfish samples produced from different types of wood biomass showed that shear butter and African birch wood samples gave the highest mean score for all the sensory attributes (Olopade *et al.,* 2013) and highly recommended in terms of consumer preference. Although, some panelists preferred to tamarind and locust bean wood because of its bright color and appearance, where the best appearance of smoked catfish is characterized by its surface color, which is golden brown. Umar *et al.,* (2018) explained that carbonyl compounds have a major influence on the color which means smoked product color are due to the interaction between the carbonyl amino groups through the Mallard reaction.

The different types of wood's produced different complex chemical composition, which is a mixture of structural volatile and non-volatile compounds with different sensory characteristics, such as phenol, guaiacol and syringol and their derivatives (Daniel, *et al.,* 2023) used in creating the unique golden color, shiny looks of smoked catfish as well as the distinctive flavor, taste and aroma of the smoked catfish (Adebolwae *et al.,* 2013).

CONCLUSION

According to the findings of this article, smoked catfish with (shear butter, tamarind, locust bean, neem and African birch woods) were effective in improving the organoleptic properties of the samples, more effective against viable bacterial and fungal growth by lowering the moisture content. The result showed that wild and aquacultured catfish smoked with neem, tamarind and shear butter woods were preferred in terms of sensory and microbiological quality assessed suggesting that all the woods used does not affect the proximate composition of the smoked catfish, thereby maintain its nutritional quality under a controlled moisture content. Therefore, it can be concluded that selected indigenous wood biomass could be used in smoking of both wild and aquacultured catfish with acceptable consumer preference, low microbial load without altering the proximate composition under a regulated processing condition. Hence, there is need to carry out bacterial characterization of pathogenic microorganism to improve safety aspect and effect of wood biomass on health.

REFERENCES

Abolagba, O.J. and Uwagbai, E.C. (2011). A comparative analysis of the microbial load of smoke-dried fishes (*Ethmalosa Fimbriata* and *Pseudotolithus Elongatus*) sold in Oba and Koko Markets in Edo and Delta States, Nigeria at Different season. *Australian Journal of Basic and Applied Sciences*, 5: 544-550.

Adebowale, B. A., Dongo, L. N., Jayeola, C. O. and Orisajo, S. B. (2008). Comparative quality assessment of fish (*Clarias gariepinus*) smoked with cocoa pod husk and three other different smoking materials. *Journals of Food Technology,* 6:5-8.

Adeogun, M and Adebisi-Adelani, O. (2016). Linkage between indigenous fish processing practices and sustainable fisheries development: A case study of Northern Nigeria. *African Journal of Applied Research* 2(2):73–83.

Adeyeye, S.A.O., Oyewole, O.B., Obadina, A.O and Omemu, A.M. (2015). Evaluation of Microbial Safety and Quality of Traditional Smoked Bonga Shad (*Ethmalosa frimbriata*) Fish from Lagos State, Nigeria. *Pacific Journal of Science and Technology* 286(1):286–94.

Agbon, A.O., Ezeri, G.N.O., Ikenwiewe, B.N., Alegbleye, N.O and Akomolade, D.T. (2002). A comparative study of different storage methods on the shelf life of smoked current fish. *Journal of Aquatic Sciences,* 17(2): 134-136.

Ahmed, A., Dodo, A., Bouba, A., Clement, S. and Dzudie, T. (2011). Influence of traditional drying and smoke-drying on the quality of three fish species (*Tilapia nilotica*, *Silurus glanis* and *Ariu sparkii*) from Lagdo Lake, Cameroon. *Journals of Animal and Vetnary Advance*. 10(3): 301-306.

AOAC, (2010). Official method of analysis of the association of analytical chemists. (18th edition). AOAC, International, Washington DC. Retrieved online: https://www.Sciepub.com

Aremu, M. O., Namo, S. B., Salau, R. B., Agbo C. O. and Ibrahim H. (2013). Smoking Methods and Their Effects on Nutritional Value of African Catfish (*Clarias gariepinus*). *The Open Nutraceutical Journal*, 6: 105-112.

Ayeloja, A.A., Jimoh, W.A., Shitu, M.O and Batatunde, B.O. (2020). Effect of frozen storage on microbial load of hybrid hetero-Clarias, Clarias gariepinus and *oreochroms nilotticus*. *Journal of Agriculture and Forestry.* 4(1): 285-288.

Ayuba, A.B., Josaiah I.A, Okouzi S.A, Ibrahim Y, Bankole I.O, Oluborode G.B, Ngwu, E.O, M I.A, Aliyu R and Abugwu N. P (2022). Comparative assessment of catfish (*Clarias gariepinus*) smoked with briquettes and firewood *International Journal of Engineering Applied Sciences and Technology,* 7, (*6*): 271-276

Daniel, E.O., Ugwueze, A.U and Igbegu, H.E. (2013). Microbiological Quality and Some Heavy Metals Analysis of Smoked Fish Sold in Benin City, Edo State, Nigeria. *World Journal of Fish and Marine Sciences* 5 (3): 239-243, 2013

Eyo, A.A. (2001). Fish Processing Technology in the Tropics. A Text Book, University of Ilorin Press. 403pp.

Ezeama, C.F. (2007). Food Microbiology: Fundamentals and Applications. Natural Prints Ltd. Lagos, Nigeria. Pp: 85-94

Huda, N., Deiri, R. S and Ahmed, R. (2010). Proximate, color and amino acid profile of Indonesians traditional smoked catfish. *Journals of Fish and Aquaculture Sci*ence, 5:106-112.

Kumolu-Johnson, N. F., Aladetohun, C. A. and Ndimele, A. (2010). The effect of smoking on the nutrient composition of the African cat fish (Clarias gariepinus). *African Journal of Biotechnology*, 9:73-76.

Kwaghvihi, O. B., Akombo, P. M. and Omeji, S. (2020). Effect of wood smoke on the quality of smoked -fish. *Mediterranean Journal of Basic and Applied Science*. 4(*2*): 72-82.

Lekoso, T, Edison, I and Ikhsan, M.N. (2020). The effect of different variety of fire woods on smoking of selais catfish (*Cryptopterus bicirchis)*. The 8th International and National Seminar on Fisheries and Marine Science. IOP Conf. Ser.: Earth Environ. Sci. 430 012002

Mayomi I. and Olokor J. O. (2014). Monitoring the land-use and vegetation cover changes in the Kainji Lake Basin, Nigeria (1975-2006). *African Journal of Environmental Science and Technology*, 8(*2*):129–142.

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

Ndubueze, I.K., Ogbunugafor, H.A and Oladejo, A.A. (2021). Effect of Smoked and Oven-dried Catfish (*Clarias gariepinus*) on hematological Parameters, Liver and Antioxidant Enzymes of fish - Wistar Rats. *European Journal of Nutrition and Food Safety 13(5): 3-13,*

Ogbonnaya, C and Ibrahim, M.S. (2009). Effects of drying methods on proximate compositions of catfish (*Clarias gariepinus*). *World Journal of Agricultural Sciences* 5(1):114-116.

Olayemi, F.F., Adedayo, M.R., Bamishaiye, E.I. and Awagu, E.F. (2011). Proximate composition of catfish (*Clarias gariepinus*) smoked in Nigerian Stored Products Research Institute (NSPRI) developed kiln. *International Journals of Fisheries and Aquaculture*. 3(*5*): 96-98.

Olopade, O. A., Taiwo, I. O. and Agbato, D.A. (2013). Effect of Traditional smoking Method on nutritive values and organoleptic properties of *Sarotherodon galilaeus* and *Oreochromis niloticus*. *International Journal of Applied Agricultural and Apicultural Research,* 9 (1&2): 91-97.

Omodara, M.A., Olaniyan, A.M. (2012). Effects of pretreatments and drying temperatures on drying rate and quality of African catfish (*Clarias gariepinus*). *Journals of Biology, Agriculture and Healthcare* 2(*4*): 1-11.

Onwuka, G.I. (2018). Food Analysis and Instrumentation: Theory and Practice, 2nd ed. Napthali Prints. Shomolu, Lagos, Nigeria. Pp: 222-348.

Peter, T. O. (2015). Nutritional Values of Smoked *Clarias Gariepinus* from Major Markets in Southwest, Nigeria. *Global Journal of Science Frontier Research: D Agriculture and Veterinary* Volume 15 Issue 6 Version 1.0. Pp: 34 – 42

Sérot, T., Baron, R., Knockaert, C. and Vallet, J. L., (2004). Effect of smoking processes on the contents of 10 major phenolic compounds in smoked fillets of herring (*Cuplea-harengus*). *Food Chemistry*, 85(*01*): 111-120.

Taiwo, P. O. (2015). Nutritional Values of Smoked Clarias Gariepinus from Major Markets in Southwest, Nigeria. *Global Journal of Science Frontier Research*, 15(*6*): 34- 42

Umar F., Oyero J. O., Ibrahim S.U., Maradun H. F and Ahmad M. (2018a). Sensory evaluation of African catfish (*Clarias gariepinus*) smoked with melon shell briquettes and firewood, *International Journal of Fisheries and Aquatic Studies*. 6(*3*): 281-286.

Muyela, B., Shitandi, A. and Ngure, R. (2012). Determination of benzo[a]pyrene levels in smoked and oil fried Lates niloticus. *International Food Research Journal*, 19(4): 1595-1600.