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# EFFECTS OF SMOKING PROCESSES ON THE NUTRITIONAL VALUE OF CULTURED CATFISH (*Clarias Gariepinus*)

***Olaniyi Alaba OLOPADE[1], Henry Eyina DIENYE[1], Glory Chimburuoma DENSON[1], Vivian Chiemela ONYEKWERE[1]**

[1]*Faculty of Agriculture, University of Port Harcourt, Choba, Rivers State, Nigeria*
olaniyi.olopade@uniport.edu.ng
*Corresponding author
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**Abstract:** This study was designed to determine and compare the effects of smoking processes on the proximal composition, fatty acid profile, minerals, vitamins, total polycyclic aromatic hydrocarbons, and sensory characteristics of cultured Clarias gariepinus. Nine fatty acids were identified from the muscle of fish samples, with all nine fatty acids recorded for both smoked samples (hot and cold), while the raw sample had only eight. Furthermore, the most abundant fatty acids in the smoked samples were palmitic acid, oleic acid, stearic acid, and palmitoleic acid. Vitamins A, D, E, and K were higher in smoked samples than in raw samples, while vitamins B1, B2, and B3 were higher in raw samples than in smoke samples. Raw, cold, and hot smoked samples had significantly different mineral profiles ($p<0.05$). Iron, magnesium, and zinc were found in higher concentrations in the smoked samples examined. Cold smoking had the highest value in terms of total polycyclic aromatic hydrocarbons, followed by hot smoking. The hot sample performed better in terms of color, flavor, tenderness, juiciness, texture, and overall acceptability, according to sensory evaluation results. Based on the results of the study, hot-smoked *C. gariepinus* was nutritionally acceptable.

**Keywords***: Clarias gariepinus, proximal composition, fatty acids, vitamins, minerals, sensory characteristics*

## 1. Introduction

Nigeria is African's second-largest aquaculture producer, with an annual output of about 300, 000 tons dominated by catfish culture [1]. According to the Catfish Association of Nigeria (CAFAN), in 2016, Nigeria produced 370,000 metric tons of fish from aquaculture systems valued at over USD 1.3 billion [2]. The tremendous increase in production will impose additional challenges in the handling, storage, distribution and processing of fish. This is because fish is extremely perishable food especially in hot climates and tropical areas where cold preservation techniques are often missing. Spoilage begins as soon as the fish dies and if fish is not sold fresh, preservation methods should be used to prevent or significanly slow spoilage (loss of quality, edibility or nutritive value) caused or accelerated by micro organisms.

Currently, smoking is the main method of fish preservation in the artisanal sector [3]. Basically, smoking process preserve the fish, enhances flavor and impart good colour to the fish. There are several smoking methods such as hot, cold, liquid and electrostatic [4]. The two commonly used methods in Nigeria are cold and hot smoking. Cold smoking process requires that the fish never reach an internal cooking temperature. Cold smoking

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smokehouse temperatures range from 20 and 30 °C (68 to 86 °F) [5]. In this temperature range, foods take on a smoked flavor but remain relatively moist. Hot smoking temperatures range from 52 to 80 °C (126 to 176 °F) [5]. When food is smoked within this temperature range, it is fully cooked, moist, and flavorful.

Heat effects contribute to changes in the chemical composition and, hence, the nutritional value of processed foods [6]. The degrees of change are related to the species of fish as well as the presence or absence of activators and inhibitors [7]. Thus, the present study attempted to determine the nutritional values of the cultured Clarias gariepinus following hot and cold smoking treatments.

## 2. Matherials and methods

Samples of *Clarias gariepinus* with the average weight and length of sampled fish 881±20.00 g and 47.00±3.56 cm, respectively, were purchased from a fish farm. The fish samples were transported live to the laboratory and divided into three batches: two batches were prepared separately for cold and hot smoking, while the third was sacrificed immediately and analyzed for proximate, fatty acid, mineral, and vitamin compositions**.** The fish were then gutted, rewashed, and then separated into three groups: (i) the first group consisted of raw samples kept at -40 °C until analysis; (ii) the second group consisted of cold smoked samples partially dried for 2 hours in the industrial smoking chamber [8] with the temperature fluctuating between 30 and 35 °C and kept at -40 °C until analysis; and (iii) the third group consisted of a hot smoked sample using an industrial smoking chamber with a peripheral smoke generator [9]. Proximate composition, moisture content, crude protein, fat and ash were determined for wet samples according to standard methods of the Association of Official Agricultural Chemists [10] as follows:

(a). The moisture content was determined by oven drying samples at about 105ºC for about 8 to 10 hours until a constant weight was reached, then cooled in a desiccator and weighed again. The percentage of moisture content was calculated by the following equation: Moisture percentage (%) = (weight lost/original weight of sample) x 100.

(b) The ash content was determined by incineration of the samples for 6 h at 500–600 °C in a muffle furnace.

(c) The ash percentage (%) was calculated using the following equation: Ash percentage (%) = (weight of ash/weight of sample) x 100.

(d) Crude protein was detected by the Kjeldahl method [11]

(e) Crude lipid content was determined by the method presented in [12].

The samples (body tissue) were homogenized with a chloroform: methanol (2:1 v/v) mixture before being extracted using the method [12]. After the fat was extracted, it was esterified with 1% $H_2SO_4$ and fatty acid methyl esters were prepared by following the procedure of [13]. Identification and quantification of fatty acids were done using gas chromatography (Hewlett Packard 5890, USA).

(f) The preparation of samples for mineral elements analysis followed a method described by [10]. Approximately 5 g of each sample (wet weight) were placed in a Teflon digestion vessel and double acid digested with nitric acid ($HNO_3$) and perchloric acid ($HCLO_4$). Samples were then analysed for mineral contents of iron (Fe), manganese (Mn), zinc (Zn), potassium (K), calcium (Ca) magnesium (Mg) and manganese (Mn) using the Atomic Absorption Spectrophotometer (Shimadzu AAS, AA-6300).

(g) The sample preparation for vitamin analysis was done as per the method of

[14] were estimated the soluble fat vitamins A, D, E and K and the water soluble vitamins B1, B2, B6, B12 and C by using the high performance liquid chromatography (Merk Hitachi L-74000, USA) following the method [15].
Polycyclic aromatic hydrocarbons (PAHs) in the muscle ware quantified according to [16]. Only solvents with a high degree of purity (98% HPLC) were used; the glass material was washed with ExtranVR, then it was dried for 4 h at 100 C and rinsed with acetone and hexane. The PAHs analysis was performed according to the method described by [17].
After the smoking operation, sensory analyses were performed by using the methods of [18]. Sensory evaluations of the samples from the cold and hot processess were carried out with twenty trained individuals. The panelists evaluated each of the smoked fish for colour, flavour, tenderness, juiciness, texture and overall acceptability. A five-point hedonic scale [19] describing the score of attributes of the smoked fish samples as: very bad (1 point), bad (2 points), satisfactory (3 points), good (4 points), very good (5 points), excellent (6 points) was used**.**

**Statistical Analysis** The descriptive statistics (mean and standard deviation) were conducted while statistical significance of differences ($P < 0.05$) was determined by analysis of variance (ANOVA) with SPSS version 10.0 [20].

## 3. Results and discussion

The proximate composition of fresh and smoked *C. gariepinus* is given in Table 1. Hot smoked samples had significantly higher percentages of crude protein content, crude fat content, ash content, and dry matter than cold smoked and raw samples ($p < 0.05$). Results showed that hot smoked sample had higher protein content (67.84±0.06 %) than the cold smoked sample (53.13±0.06 %), while the raw sample had 17.03±0.06 %. The lipid contents of hot and cold smoked samples were 8.96±0.02 % and 4.41±0.02 %, respectively, while the raw sample was 0.77±0.02 %. The same observation was made on the ash content of the hot smoked samples, which had 7.88±0.02 followed by cold smoked samples (4.01±0.0) and raw samples (1.40±0.02). The lipid contents of hot and cold smoked samples were 8.96±0.02 % and 4.41±0.02 %, respectively, while the raw sample was 0.77±0.02%. The low nutritional quality in raw samples is a result of an inverse relationship between the water content and the content of fatty acids and protein; when the water content increases, the content of other nutrients decreases [21]. The proximate composition of raw and smoked fish analyzed in this study is similar to those obtained for the same species by [22]. In the raw stage, *C. gariepinus* had the highest moisture content (78.07±0.02) followed by cold (21.04±0.02) and hot (4.05±0.02) samples respectively. The main constituent of fish flesh is water, which usually accounts for about 80% of the weight of a fresh white fish fillet [23]. The decrease in moisture content occurring during smoking is the consequence of water loss during this process. Furthermore, nitrogen free extract was significantly higher in cold smoked samples than in hot smoked samples and raw samples ($p < 0.05$).

**Table 1**

**Promximate composition of raw, cold, and hot smoked samples of *C. gariepinus***

| Promximate composition | Cold Smoking | Hot Smoking | Raw |
|---|---|---|---|
| Crude Protein (%) | 53.13±0.06 [b] | 67.84±0.06 [a] | 17.03±0.06 [c] |
| Crude Fat (%) | 4.41±0.02 [b] | 8.96±0.02 [a] | 0.77±0.02 [c] |
| Ash (%) | 4.01±0.04 [b] | 7.88±0.02 [a] | 1.40±0.02 [c] |
| Moisture (%) | 21.04±0.02 [b] | 4.05±0.02 [c] | 78.07±0.02 [a] |
| Dry matter (%) | 78.97±0.02 [b] | 95.95±0.02 [a] | 21.93±0.02 [c] |
| Nitrogen free extract (%) | 17.42±0.10 [a] | 11.29±0.05 [b] | 2.74±0.04 [c] |

*Means (±SE) with different superscripts along same rows are significantly different (p<0.05).*

The fatty acid profile of raw, cold, and hot smoked *C. gariepinus* is shown in Table 2. The number of fatty acids present in any fish species is quite high, but in this study, nine fatty acids were identified from the muscle of fish samples, with all nine fatty acids recorded for both smoked samples (hot and cold), while raw samples had eight fatty acids. The smoking method used showed a significant change in fatty acid composition, and this is in agreement with the results reported by [24]. Five saturated fatty acids (SFA), two monounsaturated fatty acids (MUFA) and two polyunsaturated fatty acids (PUFA) were identified. This fatty acid pattern was significantly different compared to our earlier study of Danube catfish composition (MUFA>SFA>PUFA) [25]. Generally, palmitic acid, oleic acid, stearic acid, and palmitoleic acid were the most abundant fatty acids in all the three samples. The differences observed between samples of hot, cold, and raw samples were statistically significant ($p < 0.05$). In all the samples (raw, cold, and hot), palmitic acid had the highest percentage composition followed by oleic acid, while lauric acid was the lowest (0.02±0.01 g/100g) in the raw sample, and capric acid was the lowest (0.02±0.01 g/100g) in the smoked fish sample. The high level of palmitic acid in this study could be attributed to the fish diet and the general rearing conditions.

However, smoked *C. gariepinus* had a significantly higher palmitic acid (27.26 ± 5.48 g/100g) than that of the raw sample (1.08±0.01 g/100g). A comparative study by [26] revealed that smoked *Clairas gariepinus* has higher fatty acids than raw *Clairas gariepinus.*

**Table 2**

**Fatty acids profile in *Clarias gariepinus* fillets on raw, cold and hot smoking processes**

| Fatty acid | Hot Smoking | Cold Smoking | Raw |
|---|---|---|---|
| Capric acid C8:0 (SFA) (g/100g) | 0.06±0.01 [a] | 0.02±0.01 [b] | 0.00±0.00 [b] |
| Lauric acid C12:0 SFA (g/100g) | 0.09±0.02 [a] | 0.12±0.01 [a] | 0.02±0.01 [b] |
| Myristic acid C14:0 SFA (g/100g) | 3.94±1.91 [ab] | 5.82±0.03 [a] | 0.30±0.02 [b] |
| Palmitic acid C16:0 SFA (g/100g) | 27.26±5.48 [a] | 32.70±0.03 [a] | 1.08±0.01 [b] |
| Stearic acid C18:0 SFA (g/100g) | 8.24±2.10 [a] | 10.31±0.02 [a] | 0.70±0.02 [b] |
| Palmitoleic acid C16:1 MUFA (g/100g) | 10.75±2.86 [a] | 13.59±0.03 [a] | 0.78±0.01 [b] |
| Oleic acid C18:1MUFA (g/100g) | 13.42±3.77 [a] | 17.17±0.02 [a] | 0.85±0.01 [b] |
| Linoleic acid C18:2 PUFA (g/100g) | 1.22±0.35 [ab] | 1.55±0.02 [a] | 0.35±0.01 [b] |
| Linolenic acid (ω3) C18:3 PUFA(g/100g) | 0.91±0.12 [a] | 1.05±0.02 [a] | 0.15±0.02 [b] |

*Means (±SE) with different superscripts along same row are significantly different (p<0.05)*

The vitamin compositions of smoked and raw samples of *C. gariepinus* are presented in Table 3. The smoked samples (cold and hot) were statistically significantly higher ($p < 0.05$) than in the raw sample. In this study, vitamin A displayed high content in both raw and smoked study samples. Hot smoked samples had higher levels of vitamins A (45.32±0.03), D (0.63±0.01), E (0.88±0.01), and K (0.35±0.01) than cold smoked samples. Vitamins A (27.22±0.04), D(0.38±0.01), E (0.64±0.01) and K (0.23±0.02), while raw samples had the lowest levels of vitamins A (12.70±0.03), D (0.16±0.01) E (0.31±0.02) and K (0.14±0.01).

**Table 3**

**Vitamin content in Raw and smoked *C. gariepinus***

| Vitamins | Hot | Cold | Raw |
|---|---|---|---|
| Vitamins B1 (mg/100g) | 0.04±0.01 [b] | 0.08±0.01 [b] | 0.12±0.01 [a] |
| Vitamins B2 (mg/100g) | 0.01±0.00 [c] | 0.02±0.00 [b] | 0.03±0.00 [a] |
| Vitamins B3 (mg/100g) | 0.91±0.02 [c] | 1.35±0.01 [b] | 1.70±0.01 [a] |
| Vitamine A(ug/100g) | 45.32±0.03 [a] | 27.22±0.04 [b] | 12.70±0.03 [c] |
| Vitamins D(ug/100g) | 0.63±0.01 [a] | 0.38±0.01 [b] | 0.16±0.01 [c] |
| Vitamins.E(ug/100g) | 0.88±0.01 [a] | 0.64±0.01 [b] | 0.31±0.02 [c] |
| VitaminsK(ug/100g) | 0.35±0.01 [a] | 0.23±0.02 [b] | 0.14±0.01 [c] |

*Means (±SE) with different superscripts along same rows are significantly different (p<0.05)*

There were significant differences ($p < 0.05$) in vitamin B2 and B3 contents between hot, cold, and raw samples, with the raw values having the highest values followed by the cold and hot samples, respectively. The Vitamin B1 content of the raw was higher than that of the smoked samples (hot and cold) ($P<0.05$). *[27]* reported that the smoking method had a significant reduction in the vitamin content of some smoked fish samples. This could be due to the temperature of smoking, as some vitamins are heat unstable. Smoke particles can react with nutrients in fish meat and may lead to loss of important nutrients and antioxidants [28].

The mineral compositions of raw, cold and hot smoked *C. gariepinus* are given in Table 4. There was generally a significant difference ($p<0.005$) in the mineral profile between the raw, cold, and hot smoked fish samples, with the cold smoked fish samples having the highest mineral values than the hot and raw samples. Similar changes in the content of essential nutrients in thermally treated fish were reported by [29]. Iron, magnesium, and zinc were more abundant in the fish samples analysed than calcium, potassium, phosphorus, sodium, magnesium, and iron. The mineral content in this study followed the same pattern with the records for the cold smoked samples followed by the hot and raw samples, respectively. Fresh fish contains a significant amount of minerals in general, but processed fish, such as dried fish, have higher values [30].

The total polycyclic aromatic hydrocarbon of the raw, cold, and hot smoked *C.gariepinus* is presented in Table 5. The result shows that there are significantly different ($p<0.05$) across the various samples. It was observed that cold smoking had the highest value, followed by hot smoking. The results of this study revealed that cold smoking had a higher mean value than hot smoking, while no value was recorded for the raw sample. The direct contact of the product with combustion gases is definitely an important source of PAH contamination [31].

Fish samples with a shorter smoking time generated unexpectedly higher PAH concentrations than those with a longer smoking time [32].

**Table 4**

**Raw and smoked mineral compositions of *C. gariepinus***

| Minerals | Hot | Cold | Raw |
|---|---|---|---|
| Manganese (mg/kg) | 125.91±0.02 [b] | 268.36±0.02 [a] | 101.55±0.02 [c] |
| Calcium% | 0.46±0.00 [b] | 0.79±0.00 [a] | 0.13±0.00 [c] |
| Phosphorus % | 0.26±0.00 [b] | 0.42±0.00 [a] | 0.09±0.00 [c] |
| Magnesium% | 0.19±0.00 [b] | 0.24±0.00 [a] | 0.09±0.00 [c] |
| Potassium % | 0.22±0.00 [b] | 0.41±0.00 [a] | 0.10±0.00 [c] |
| Sodium % | 0.18±0.00 [b] | 0.31±0.00 [a] | 0.09±0.00 [c] |
| Iron(mg/kg) | 137.83±0.02 [b] | 235.65±0.01 [a] | 112.70±0.02 [c] |
| Zinc(mg/kg) | 23.48±0.02 [b] | 37.91±0.02 [a] | 12.07±0.02 [c] |

Means (±SE) with different superscripts along same rows are significantly different ($p<0.05$)

**Table 5**

**Total polyaromatic hydrocarbon concentrations in the raw, cold, and hot smoked *C. gariepinus***

| Sample | Total polyaromatic hydrocarbon (mg/kg) |
|---|---|
| Cold smoking | 0.03±0.00 [a] |
| Hot smoking | 0.01±0.00 [b] |
| Raw | 0.00±0.00 [c] |

*Means (±SE) with different superscripts along same column are significantly different ($p<0.05$)*

The organoleptic characteristics of hot and cold smoked samples of *C. gariepinus* are presented in Tables 6 and 7.

The result shows that there is no significant difference ($p>0.05$) across the various samples.

The panelists' assessment rated the hot smoking higher than the cold smoking in terms of colour (1.75±0.50 vs.1.40±0.55), flavour (1.75±0.96 vs.1.40±0.55), tenderness (1.75±1.50 vs. 1.40±0.89), texture (1.75±1.50 vs. 1.40±0.55). Also, in terms of overall acceptability and juiceness scores, hot smoking was also rated higher (1.75±0.96) than cold smoking (1.40±1.14). Therefore, the hot smoking process presented better results for organoleptic traits. Food colour helps to determine quality, degree of processing or spoilage level [33].

**Table 6**

**Sensory evaluation of smoked *C. gariepinus* by sensory panelist**

| Variables | Cold | Hot | t-value | p-value |
|---|---|---|---|---|
| Colour | 1.40±0.55 | 1.75±0.50 | -0.99 | 0.36 |
| Flavour | 1.40±0.55 | 1.75±0.96 | -0.70 | 0.51 |
| Tenderness | 1.40±0.89 | 1.75±1.50 | -0.44 | 0.68 |
| Juiciness | 1.40±1.14 | 1.75±0.96 | -0.49 | 0.64 |
| Texture | 1.40±0.55 | 1.75±1.50 | -0.49 | 0.64 |
| Overall acceptability | 1.40±0.55 | 1.75±1.71 | -0.44 | 0.68 |

*Not significantly different ($p>0.05$)*

The result of the T test in Table 7 showed that there was no significant difference in cold and hot smoking samples as determined by the sensory panelists**.** However, the hot smoked fish was more appreciated than cold smoked.

**Table 7**

**Differences between cold and hot smoked *C. gariepinus* by sensory panelist**

| Variables | Mean | Std. Deviation | t-value | p-value |
|---|---|---|---|---|
| Cold smoking | 3.91 | 0.15 | -1.63 | 0.14 |
| Hot smoking | 4.07 | 0.20 | | |

*Not significantly different (p>0.05)*

## 4. Conclusion

In conclusion, both hot and cold smoking processes had significant effects on proximal composition, fatty acids, vitamins, and mineral contents, in line with the findings of this study.

The nutritional value of catfish was also highly improved by hot smoking as compared to cold smoking, and a comparison of the hot and cold smoking methods of C. gariepinus demonstrates that the hot method is preferable due to its superior organoleptic characteristics. Polycyclic aromatic hydrocarbons were found to be less than 0.01 ppb for both cold and hot smoking, indicating that they are safe to consume.

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