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Comparative Study of the Nutritive and Elemental Composition of Smoked and Raw *Clarias gariepinus* from Three Selected Fish Farms in Ado Ekiti, Ekiti State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Clarias gariepinus is of economic importance in aquaculture due to its rapid growth, omnivorous diet, and potential as food source. It has been widely cultured and dispensed both in raw and smoked forms in various regions to meet the demand for fish protein This study assessed and

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compared the nutritional quality and elemental composition of smoked and raw samples of *Clarias gariepinus*. A total of twelve fish samples were analysed, six raw samples and six smoked samples with two fishes sampled from each farm tagged A, B and C. The Proximate and elemental analysis were done using standard procedures. The result of the study showed that moisture content measured in the raw *Clarias gariepinus* which ranged between (73.074 ± 1.59) % and (71.52 ± 1.83) %. was higher than that of the smoked fish ranging from (26.69±0.03) % to (32.21± 0.02) %. The protein content of smoked fish ranged (43.2±0.02) % to (46.78±0.01) while that of raw fish was between (20.52 ± 1.12) % and (22.15 ± 0.43) %. Similarly, the crude fat, ash, carbohydrate, and fibre content were higher in the smoked fish than raw catfish samples. The elemental composition of both smoked and raw catfish were within the permissible limit of World Health Organization. Arsenic was not detected in the muscle of the raw fish, while cadmium, chromium, lead and magnesium were present in values within WHO permissible limit and similar results was observed for the smoked fish samples. The result of this study presents the possibility of smoked catfish being more nutritious than the raw samples aside from the fact that it has more shelf life than raw fish. Also, both smoked and raw samples of the fish are safe as the values of heavy metal observed were all within the permissible limit of WHO.

Keywords: Proximate; catfish; metals; raw; smoked.

1. INTRODUCTION

Aquaculture is currently gaining worldwide attention due to its significant role in global production of food as well as the need for protein rich diets coupled with the inability of the wild reserves to meet the consumption demand of the populace (Dauda et al., 2018). In Nigeria, as well as in other developing nations, aquaculture has risen to prominence as a strategy for tackling challenges related to food security, augmenting livelihoods, and fostering economic advancement (FAO, 2022). Hence there are increasing number of fish farms across the country striving to meet the ever-increasing demand of fish protein and also to create employment opportunities thus contributing to the nation's economic growth. The choice of *Clarias gariepinus* by most fish farmers could be attributed to its high fecundity, resistance to disease, fast growth rate among its other features. Additionally, catfish is a commonly consumed fish species in Nigeria both in freshly cooked and smoked forms due to its unique taste. The African Catfish *Clarias gariepinus* is distributed widely in Africa ranging from the Nile River Basin to West Africa and Algeria in the North (Solak and Akyurt, 2015). They inhabit freshwater lakes, rivers, swamps and lagoons as well as man-made habitats (Nyamweya et al., 2017). Studies have shown that, the African Catfish is also generally considered to be one of the most successful fish species in tropical aquaculture (Nyamweya et al., 2017). Kwak *et al*. (2016) showed that the ecology of *C. gariepinus* is relatively well studied in some African Lakes including Lakes Victoria and Baringo in Kenya. However, nothing is known about the species in Lake Naivasha apart from recent studies on its length-weight relationships and condition factor in the lake (Keyombe et al., 2015). Proximate evaluations on fish samples have shown that diverse nutrients in fish make it an important nutrient source available easily across the globe. Fish is proven to possess several health benefits, such as anti-oxidation, anti-inflammation, wound healing, neuroprotection, cardioprotection, and hepatoprotection properties (Chen et al., 2021). Fish consumption plays a crucial role in the human diet, providing essential nutrients like protein, omega-3 fatty acids, and vitamins (Maulu et al., 2021). Fish proteins, such as immunoglobins, act as defense agents against viral and bacterial infections and prevent protein-calorie malnutrition (Chen et al., 2021).

Elemental analysis has also proven that fishes, beside its healthy contribution can contain certain elements which may not be beneficial to consumer (Hossain et al., 2023). Hashim *et al.* (2014) revealed that the presence of certain heavy metals in fish raises significant concerns due to their potential adverse effects on human health. Numerous studies have shown that heavy metals, including lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As), can accumulate in fish tissues through various sources such as water pollution, industrial activities, and agricultural runoff (Hashim *et al.*, 2014). When consumed, these metals can pose severe health risks, especially when ingested over extended periods or in high concentrations (Jaishankar et al., 2014). In natural water bodies and ponds alike, natural causes and human activities contributes to condition of aquatic habitats. Okwodu *et al*. (2014) conducted research to study the influence of human and industrial activities on the Orashi River and two bony fish (*Clarias gariepinus* and *Tilapia niloticus*), heavy metals such as Copper, Iron and Zinc were found to be present and Zinc was above permissible levels. Ado Ekiti, the capital of Ekiti State, also relies on fish as a dietary staple, making it crucial to comprehend the nutritional composition and presence of heavy metals in commonly consumed fish samples within the area. This study is vital for evaluating its potential advantages and health risks , thereby facilitating the implementation of suitable mitigation strategies.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Ado Local Government Area in Ado-Ekiti, which is the capital and major centre of economic activities in Ekiti State. Ado Ekiti is a town located in Ekiti, south west Nigeria. Both raw and smoked samples of catfish were collected randomly from three different fish farms tagged A, B, C.

2.2 Proximate Analysis

Moisture content: 2.0g of the sample(s) were placed in an oven maintained at 100 - 103°C for 16 hours with the weight of the wet sample and the weight after drying noted. The drying was repeated until a constant weight was obtained. The moisture content was expressed in terms of loss in weight of the wet sample.

Ash content: 2.0g of each of the oven-dried samples in powder form were accurately weighed and placed in crucible of known weight. These were ignited in a muffle furnace and ashed for 8 hours at 550°C. The crucible containing the ash was then removed, cooled in a dessicator and weighed and the ash content expressed in term of the oven-dried weight of the sample.

Protein: The protein nitrogen in 1g of the dried samples were converted to ammonium sulphate by digestion with concentrated H_2SO_4 and in the presence of $CuSO_4$ and Na_2SO_4. These were heated and the ammonia evolved was steam distilled into boric acid solution. The nitrogen from ammonia was deduced from the titration of the trapped ammonia with 0.1M HCl with Tashirus indicator (double indicator) until a purplish pink color was obtained. Crude protein was calculated by multiplying the value of the deduced nitrogen by the factor 6.25mg.

Crude fibre: 2.0g of each sample was weighed into separate beakers, the samples were then extracted with petroleum ether by stirring, settling and decanting 3 times. The samples were then air dried and transferred into a dried 100ml conical flask. 200cm3 of 0.127M sulphuric acid solution was added at room temperature to the samples. The first 40cm3 of the acid was used to disperse the sample. This was heated gently to boiling point and boiled for 30 minutes. The contents were filtered to remove insoluble materials, which was then washed with distilled water, then with 1% HCI, next with twice ethanol and finally with diethyl ether. Finally, the oven-dried residue was ignited in a furnace at 550°C. The fibre contents were measured by the weight left after ignition and were expressed in term of the weight of the sample before ignition.

Lipid content: The lipid content was determined by extracting the fat from 10g of the samples using petroleum ether in a soxhlet apparatus. The weight of the lipid obtained after evaporating off the petroleum ether from the extract gave the weight of the crude fat in the sample.

Carbohydrate: The carbohydrate content of the samples was determined as the difference obtained after subtracting the values of protein, lipid, ash and fibre from the total dry matter.

2.3 Heavy Metal Analysis

Sample digestion: Each sample was homogenized separately and oven dried at 45 ^{0}c -50^0 c prior to digestion. One gram of each sample was measured and placed in a muffle furnace at 450^{O}c-550^{O}c until all carbon contents is removed as evidence by a white ash. Each sample obtained was digested by adding 5ml of 2 MHCL to the ash in the crucible and heated to dryness on a heating mantle. 5ml of 2 MHCL was added again, heated to boil and filtered through what man No. 1 filter paper into a 100ml volumetric flask and was made up with distilled water

Determination of heavy metals: The ash of each sample obtained was digested by adding 5ml of 2 MHCL to the ash in the crucible and heated to dryness on a heating mantle. 5ml of 2 MHCL was added again, heated to boil and filtered through what man No. 1 filter paper into a 100ml volumetric flask and was made up with distilled water. These diluents were aspirated into the Buck 211 Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination.

3.4 Statistical Analysis

The means and the standard deviations were calculated and recorded using Microsoft excel 2013 version.

3. RESULTS

3.1 Proximate Analysis of *Clarias gariepinus*

Moisture content: The moisture content of all the smoked fish samples as presented in Table 1 ranged from (26.69±0.03) % to (32.21± 0.02) % while the raw fish had the moisture content ranging between (73.074 ± 1.59) % and (71.52 ± 1.83) % as presented in Table 1.

Ash content: The ash content of smoked *Clarias gariepinus* ranged from (3.08±0.01) % to (3.73±0.01) % as presented in Table 1 while ash content of raw *Clarias gariepinus* from the three locations ranged between (1.186 ± 0.04) % and (1.764 ± 0.42) % as shown in Table 1.

Fat content: The fat content of smoked ranged from (11.44±0.01) % to (11.53±0.02) % in all the fish sampled as represented in Table 1 while fat content of raw *Clarias gariepinus* from the three locations ranges between (2.335± 0.26) % and (2.879 ± 0.23) % as presented in Table 1.

Fibre content: The fibre content of smoked catfish ranged from (2.26 ±0.01) % to (2.50±0.01) % in all the fish samples as presented in the Table 1. while the fibre content of raw *Clarias gariepinus* was between 0.00 and (0.068 ± 0.04) %.

Protein content: The protein content of smoked fish samples ranged from (43.2±0.02) % to (46.78±0.01) % in all the fish samples as presented in the Table 1. sample A has the highest protein content and sample B has the lowest protein content. The protein content of raw *Clarias gariepinus* from location A to C is presented in Table 1. The protein content from the three location ranges from (20.518 ± 1.12) % to (22.152 ± 0.43) %. Fish samples from location C (22.152 ± 0.43) % contain the highest protein composition while the protein content is least in in samples from location A (20.518 ± 1.12) %.

Carbohydrate content: The Carbohydrate content for smoked fish ranged from (4.12±0.02) % to (8.04±0.01) % in all the fish samples as presented in the Table 1. sample B has the highest Carbohydrate content and sample C has the lowest Carbohydrate content. there was a significant difference in A, B and C. The carbohydrate content of raw *Clarias gariepinus* for the three locations are presented in Table 1. The carbohydrate content from the three locations ranges from (1.917 ± 0.66) % to (2.067 ± 0.63) %. Samples from location C contain higher carbohydrate composition (2.067 ± 0.63) % while sample from location A contain the least (1.917 ± 0.66) %.

3.2 Heavy Metal Analysis of *Clarias gariepinus*

Arsenic (As): Arsenic was not detected in the muscle of the raw samples as presented in Table 2. while in the smoked samples, A had values higher than the recommended limit. However, the liver and gills of the raw samples presented 0.08 and 0.01ppm respectively. Smoked muscle samples B and C presented values that were below the permissible limit of WHO as presented in Table 2 while the raw liver and gills for samples B and C presented values within the permissible limit except for gills of sample B which showed 0.06ppm.

Cadmium (Cd): The value of cadmium measured in smoked sample B was (0.01±0.00) ppm but not detected in samples A and C as presented in Table 2. while the value of cadmium measured for raw samples was between 0.00 to 0.08 parts per million as presented in Table 2. The Table 2 showed that gill had the highest value of cadmium compared to the liver and muscles.

Chromium (Cr): The value of chromium measured in the smoked fish sample presented in Table 2 it ranged from (0.03±0.00) ppm to (0.09±0.00) ppm. Samples A and B had values higher than the permissible limit while C was lower while the concentration of chromium in raw catfish samples from the different locations ranged from (0.00 ± 0.00) to (0.05 ± 0.07) ppm. The raw muscle of sample B presented values which is above the permissible limit as presented in Table 2.

Table 1. Proximate Composition of Raw and Smoked *Clarias gariepinus*

Vendors	Fish form	Moisture	Ash	Fat	CHO	Protein	Fibre
A	Raw	73.07 ±1.59	1.76 ±0.42	2.71 ± 0.68	1.92± 0.66	20.52 ± 1.12	0.02 ± 0.25
	Smoked	26.69 ±0.03	3.08±0.01	11.44±0.01	6.73±0.02	46.78±0.01	2.26 ±0.01
B	Raw	71.52 ±1.83	1.57 ±0.42	2.88 ± 0.23	2.04 ± 0.59	21.93 ± 1.93	0.07 ± 0.04
	Smoked	32.15±0.02	3.28±0.02	10.86 ±0.01	8.04±0.01	43.20 ±0.02	2.42±0.01
C	Raw	72.26 ±1.27	1.19 ±0.04	2.34 ± 0.26	2.07 ± 0.63	22.15 ± 0.43	0.00±0.00
	Smoked	32.21±0.02	3.73±0.01	11.53±0.02	4.12±0.02	45.82 ±0.01	2.50±0.01

A= Samples from Iyin Road; B= Samples from Egbewa area; C= Samples from Housing Annex. Values are presented in mean ± standard deviation; CHO = Carbohydrate

Table 2a. Heavy Metal Composition of Raw *Clarias gariepinus*

Vendors	Fish Organs	As (ppm)	Cd (ppm)	Cr (ppm)	Mg (ppm)	Pb (ppm)
A	GILL	0.08 ± 0.01	0.01 ± 0.00	0.17 ± 0.02	30.91 ± 2.56	0.02 ± 0.00
	LIVER	0.01 ± 0.00	0.00 ± 0.00	0.04 ± 0.08	17.88 ± 0.04	0.01 ± 0.00
	MUSCLE	ND	0.00 ± 0.00	0.10 ± 0.03	17.52 ± 3.15	0.01 ± 0.00
B	GILL	0.06 ± 0.01	0.02 ±0.00	0.09± 0.01	34.50 ±2.68	0.03 ± 0.04
	LIVER	0.01 ± 0.00	ND	0.02 ± 0.00	22.78 ± 1.41	0.02 ± 0.00
	MUSCLE	0.04± 0.04	0.05 ± 0.07	0.06 ± 0.01	22.48 ± 0.98	ND
C	GILL	0.10 ± 0.01	0.02 ± 0.00	0.21 ±0.00	39.51 ± 0.91	0.08 ±0.10
	LIVER	0.02± 0.01	0.01 ± 0.02	0.05 ± 0.02	26.28 ± 1.36	0.03 ± 0.00
	MUSCLE	ND	0.00 ± 0.00	0.11 ± 0.03	23.85 ± 2.02	ND
	WHO LIMIT	0.05	0.01	0.05	150	0.05

Table 2b. Heavy Metal Composition of Smoked *Clarias gariepinus* (Muscle)

Samples	As (ppm)	Cd(ppm)	Cr(ppm)	Mg (ppm)	Pb(ppm)
A	0.09±0.003	ND	0.08±0.01	16.51±0.01	0.01
B	0.021±0.011	0.01±0.00	0.09±0.002	14.06±0.01	ND
C	0.001±0.00	ND	0.03±0.00	15.89±0.01	ND
WHO	0.05	0.005	0.05	150	0.05

A – Catfish samples from Agric olope B – Catfish samples from Omisanjana C – Catfish samples from GRA
As – Arsenic Cd – Cadmium Cr – Chromium WHO: World Health Organization ppm: parts per million ND: not detected
Values are presented in Mean ± standard deviation

Magnesium (Mg): The value of magnesium measured in the smoked fish sample presented in Table 2b it ranged from (14.06±0.01) ppm to (16.51±0.01) ppm while the concentration of magnesium in raw catfish samples from the different location as presented in Table 2a ranged from (17.52 ± 3.15) % to (23.85 ± 2.02) % which is below the permissible limit.

Lead (Pb): Lead was not detected in almost all of the smoked samples as presented in Table 2b while for raw samples lead was detected only in samples from location A, the total mean value was observed to be (0.008 ± 0.004) % Table 2a and it is below the permissible limit by WHO.

4. DISCUSSION

Clarias gariepinus is fish species commonly consumed in Nigeria both in smoked and freshly cooked forms. The proximate analysis of the fish species presents the nutrient composition of the two different forms. Moisture content measured in the raw *Clarias gariepinus* which ranged between (73.074 ± 1.59) % and (71.52 ± 1.83) %.was higher than that of the smoked fish ranging from (26.69±0.03) % to (32.21± 0.02) % which could be attributed to the dehydration process of the smoked fish. A low moisture content as shown in the smoked catfish reflects its ability to be more preservable (Ali et al., 2018) than the raw fish as moisture presents a suitable breeding ground for microorganisms which can cause deterioration of the fish. Alternately, Ash, fibre, protein and carbohydrate content was quite higher in smoked fish samples than the raw fish samples. The higher ash content could be attributed to the high drying temperature during the smoking procedure (Olayemi et al., 2011) and could also be as a result of high mineral component of the Fish species (Liu et al., 2019). The Fibre content recorded was within the range of (2.26 ±0.01) % to (2.50±0.01) % which was quite lower than what was reported by Namaga *et al*. (2020) for males and females of *C. gariepinus* which recorded 3.5 -4.5 %. The protein content of smoked fish ranged (43.2±0.02) % to (46.78±0.01) which was within the range of the values reported by Namaga *et al*. (2020) but lower than the values reported by Ikyo *et al*., 2022 which was (66.11 to 68.97) %. Based on the report of the study, smoked fish appear to be more nutritious than the raw fish samples also coupled with longer shelf life it presents due to lower moisture content. However, according to FAO (2012), the composition of a particular species often appears to vary from one fishing ground to another, and from season to season, but the basic causes of changes in composition are usually variation in the amount and quantity of food that the fish eats and the amount of movement it takes. It further stressed that when fish are overcrowded, there may not be enough food to go round, thus intake will be low and composition will change accordingly. Chemical composition of fish flesh is regarded as reliable predictor of its flesh quality, nutritional value, physiological state and habitat (Ravichandran *et al.*, 2011). Also, Okonjo and Enoma (2007) suggested that the differences in the percentage protein contents between the fish raised in pond and those raised in the river could be as a result of the fact that fishes raised in fish ponds are constantly being fed with highly quality food in addition to the presence of zooplankton in ponds which is natural source of protein. The proximate components of the fish flesh combine to form the nutritional profile which give a first indication about the fish's commercial standard that are required for food regulations.

The elemental composition of *C. gariepinus* showed similar range of values both for smoked and raw fish samples. The concentrations of Cr and Mg across the three samples (A, B and C) exceeds the limit values of 0.05 as recommended by World Health Organization (2013) and Standard organization of Nigeria for each of the metals. Although the concentration of trace metals in catfish from this study were lower than those reported by Indrajit *et al.* (2011). According to Muiruri *et al*. (2013), the low levels of Pb may as well pose fear of poisoning since low levels are also known to be toxic. It is obvious that fish muscles are capable of bioaccumulation of heavy metals which may pose danger to fish consumers. Generally, the concentrations of the selected heavy metals in catfish which were raised in fish pond C were lower than the values observed in the two other samples. This could be as a result of the proper and regular monitoring of the fish ponds and partly to the fact that effluents from industries can't flow directly into these fish ponds. This could also be as a result of the released of toxic effluents into the water system as well as the continuous release of CO_2 in moving vehicles. According to Muiruri *et al*. (2013), weathering of soil and rocks as well as a variety of anthropogenic activities are two independent factors that result into the presence of heavy metals in water.

5. CONCLUSION

The result from the study showed that the moisture content of smoked fish sample assessed were much lower than the protein content, hence smoked fish may be considered to be more proteinous than the freshly cooked fish. Also, the heavy metal composition was below the WHO standard limit which proves that the process of smoking does not introduce heavy metals into the fish and that the fish reared in ponds are relatively safer than those in the wild which are mostly predisposed to pollutant.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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