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NUTRIENT EVALUATION OF CHARCOAL AND GAS SMOKED *CLARIAS GARIEPINUS* (BURCHELL, 1822) AND *SAROTHERODUN GALILAEUS* (LINNAEUS, 1758) FROM BAUCHI RIVER (GUBI DAM)

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ABSTRACT

The impact of charcoal and gas smoking on the nutrient composition of African catfish (*Clarias gariepinus*) and tilapia (*Sarotherodun galilaeus*) was studied. The fishes were slaughtered and then gutted, washed, hanged for moisture drip and salted in 70% brine solution and was left for 15 minutes. The samples were divided into two portions. The first portion was smoked with charcoal for 2 hours at ~190^oC. The second portion was smoked under gas powered kiln for 2 hours at ~180^oC. The proximate, minerals, amino acid profile and vitamins of the smoked samples were determined using standard methods. The results revealed that charcoal smoked catfish had significantly high ($p<0.05$) ash (23.34%) and fibre contents while, gas smoked tilapia had significantly ($p<0.05$) high protein (37.30%), fat (23.74%) and energy value (444.99 kcal/10 g). Smoked tilapia were significantly ($p<0.05$) high in potassium, sodium, zinc, iron and copper while smoked catfish were significantly ($p<0.05$) high in magnesium and selenium. Charcoal smoked catfish and tilapia significantly ($p<0.05$) present rises in the percentage contents of leucine, lysine, methionine, phenylalanine, histidine, isoleucine and threonine. Charcoal smoked catfish had significantly ($p<0.05$) high vitamin A (29.32 UI/100 g) while gas smoked had the least content (25.21 UI/100 g). Similarly, charcoal smoked catfish had significantly ($p<0.05$) high vitamin D (3.89 UI/100 g) while gas smoked tilapia had the least content (2.30 UI/100 g). Charcoal smoked fish exhibited high availability of proteins, mineral elements, amino acids and vitamins A and D hence, it should be adopted by local fish processors.

Keywords: African catfish, Tilapia, Smoking methods, Nutrient evaluation

INTRODUCTION

Catfish (*Clarias gariepinus*) holds significant importance as a freshwater fish in Nigeria, gaining wide acceptance across the country due to its distinct taste, flavor, and texture. It is widely distributed and extensively farmed in ponds but is often undervalued (Gabriel *et al.*, 2016). Preservation challenges for fresh fish, particularly in developing countries like Nigeria, have led aquaculturists and food technologists to optimize fish smoking processes to minimize wastage and enhance profitability in both local and international markets (Samuel *et al*., 2010). According to Fafioye *et al*. (2008), there are nearly 1250 species of catfish, valued higher than other fish species of similar size, with common species differentiated by color and external features. *C. gariepinus* is the most commonly domesticated and cultured species.

Tilapias, originating from Africa and the Middle East (El-Sayed, 2006), are robust, prolific, and fast-growing tropical fish. About 70 species of tilapia exist, mostly native to Western African rivers (Adeyeye, 2000), with nine species used in global aquaculture. Breeding has significantly improved the production performance of various breeds and strains (Dey, 2000). Farmed tilapia typically reach market size (600-900 g) within 6-9 months. In 2015, global tilapia production surged to 5.6 million tons (Eknath and Hulata, 2009). Additionally, tilapia farming has enhanced livelihoods in developing countries by increasing household incomes, food security, and nutritional value through higher protein consumption (Fafioye *et al*., 2008).

Fish and fish products rank among the most perishable commodities worldwide, largely due to microbial spoilage, with about one-third of global food production lost annually to this issue (Adeyeye, 2000). Microbial and enzymatic activities are primary causes of spoilage in fresh and lightly preserved seafood. Smoked fish can harbor microbial hazards such as *Listeria monocytogenes, Salmonella spp., Staphylococcus, Escherichia coli*, and *Clostridium botulinum* (Fafioye *et al*., 2008).

Fish smoking, a traditional method aimed at reducing postharvest losses, involves applying heat to remove water and inhibit bacterial and enzymatic activity (Riemersma, 2002). Eyo (2001) noted that smoking not only imparts a desirable taste and odor but also extends shelf life through antibacterial and oxidative effects, pH reduction, color enhancement, and accelerated drying. This ancient preservation technique remains prevalent, especially in third-world communities where up to 70% of the catch is smoked for future use. Smoking, along with salting, spicing, and other methods, enables prolonged preservation by removing moisture essential for bacterial and enzymatic spoilage.

Despite the broad acceptance of smoked fish products, they are prone to deterioration such as rancidity, off-flavor development, and hygroscopicity, which can limit their future use. Traditionally, fish is smoked in pits or on raised smoking "tables," where heat control is challenging. With advancements in aquaculture technology and smoking methods, it is crucial to evaluate the effects of charcoal and gas smoking on the nutritional quality of smoked fish. This evaluation would provide data to further improve the quality of smoked fish products.

MATERIALS AND METHODS

Site of research

Laboratory analyses (proximate, minerals and vitamins A and D) were carried out in the Analytical Laboratory, Nigerian Stored Products Research Institute Ilorin (NSPRI), Kwara

State; while amino acid profille was done in Biochemistry Department, University of Jos.

Sample Collection

African catfish and tilapia were obtained from Gubi Dam, Bauchi State, Nigeria. The fresh fish were frozen and then transported in a cooler containing ice block to the laboratory for processing and analyses.

Preparation of samples (smoking of fish)

Fish samples were smoked according to modified method described by Adeyeye, *et al*. (2016). The fishes were slaughtered and then gutted, washed, hanged for moisture drip and salted in 70% brine solution and was left for 15 minutes for the brine solution to suck into the tissue. The samples were divided into two portions. The first portion was smoked with charcoal for 2 hours at ~190°C. The second portion was smoked under gas powered kiln for 2 hours at ~180°C. During the two smoking processes, samples were turned at intervals if 5 minutes to ensure even distribution of heat. The smoked fish samples were coded and kept in a desiccator to cool, packaged in Ziploc bags and kept at ambient temperature (28±2°C) for laboratory analyses.

Proximate analysis

The moisture, crude protein, crude fibre, fat, ash and carbohydrate contents of the smoked fish samples were evaluated using AOAC (2009) method.

Mineral determination

The mineral contents of samples were estimated using the method described by AOAC (2009). Each sample (2 g) was transferred into 30 mL crucible and ashed in a muffle furnance at 500°C for 3 hours. The crucibles were removed after the ashing was completed. After cooling, 10 mL of 2 M HCl acid was added and filtered. The contents in each crucible were thereafter transferred into 50 mL volumetric flask and then diluted to 50 mL. The optical density of elements was determined using the Atomic Absorption Spectrophotometer (Shimatsu AA6200). For mercury determination 5 mL of 5 M hydrochloric acid were added to 2 mL of the solution. The concentration was determined as described by AOAC (2009).

Determination of amino acids

The method described by AOAC (2009) was adopted. Amino acid analysis was performed using reverse phase-high pressure liquid chromatography (HPLC) (Buck Scientific BLC 10/11, USA) with a column (15 - 30 cm) packed with very uniform micro-particulate silica (150 nm, flow rate 1 mL/min, SWASTIK Industries, Vadodara, India). The post-column samples were derivatized, and data were integrated using the peak sample chromatography data system (Buck Sci. Chromatopac Data Processor). Tryptophan was determined spectophotometrically after alkaline hydrolysis of the samples.

Determination of vitamin A (retinol)

This method involved chromatographic separation and quantitative determination at 325 nm as described by AOAC (2009). Five gram of the samples were weighed and placed in 100 mL volumetric flasks and homogenized. The samples were saponified with ethanoic and KOH (antioxidant added) for 30 minutes. The samples were transferred to the separatory funnel using H_2O/ETOH and repeatedly extracted with hexane. Extracts and evaporates were combined to dryness under low pressure. Residue was dissolved in mobile phases. The samples were separated and determined by HPLC using MEOH/H_2O, 95/5 (v/v) as the mobile phase. A UV detector set at 325 nm was used to detect the amount of beta-carotene content of the samples and recorded

Determination of vitamin D (ergosterol)

The vitamin D content of the fish samples was determined using the method described by AOAC (2009). Two grams of each sample were extracted with *methanol/dichloromethane* (75:25, v/v) at room temperature in a 1:25 solid to liquid ratio. The extracts were centrifuged at 10,000 rpm for 5 minutes, and the extraction procedure was repeated three times. The total extracts were evaporated to dryness in a *rotavapor* at 40°C. The resulting residue was dissolved in 1 mL of *methanol* and filtered through a 0.4 µm nylon syringe membrane. The resultant solutions were divided into aliquots and promptly injected into the HPLC system. Chromatographic separation was achieved with a BGB Analytic AG *Intertsil* 100A ODS-3 reverse phase column (4.6 x 150 mm, 5 mm, and Knauer). Detection was performed at 280 nm. *Ergosterol* was quantified by comparison of the area of its peak with the calibration curve obtained from the standard. *Cholecalciferol* was used as an internal standard. The result was expressed in mg per 100 g.

Statistical Analysis

The data obtained were in triplicates, and the results were subjected to one-way analysis of variance, expressed as the mean with standard deviation. Differences between means were separated using Duncan's Multiple Range Test with the IBM SPSS Statistics Program, Version 19.0 (Illinois, USA). Significant differences were noted at the 5% level.

RESULTS AND DISCUSSION

Results

Proximate composition of charcoal and gas smoked catfish and tilapia

The proximate composition of charcoal and gas smoked catfish and tilapia is presented in Table 1. The smoking methods used in this study significantly ($p<0.05$) affected the moisture, protein, fat, ash, fiber, carbohydrate, and energy values of the fish. Charcoal and gas smoked catfish had significantly ($p<0.05$) higher moisture content, 9.67% and 10.61%, respectively, while charcoal and gas smoked tilapia had the lowest moisture content (7.43%). Gas and charcoal smoked tilapia had significantly ($p<0.05$) higher protein content, 37.30% and 36.47%, and higher fat content, 23.74% and 23.08%, respectively. However, for ash and fiber, charcoal and gas smoked catfish had significantly ($p<0.05$) higher values, 23.34% and 23.16%; 1.35% and 1.22%, respectively. Gas and charcoal smoked catfish were significantly ($p<0.05$) higher in carbohydrate content, while gas and charcoal smoked tilapia had significantly ($p<0.05$) lower energy values.

Table 1: Proximate Composition of Processed Tilapia and Catfish

	Catfish		Tilapia	
Parameters (%)	**Charcoal smoked**	**Gas smoked**	**Charcoal smoked**	**Gas smoked**
Moisture	$9.67^{b}\pm0.01$	$10.61^{a}0\pm0.08$	$7.43^{d}\pm0.01$	$7.71^{c}\pm0.04$
Protein	$26.31^{b}\pm0.13$	$24.28^{d}\pm0.11$	$36.47^{b}\pm0.00$	$37.30^{a}\pm0.11$
Fat	$12.22^{d}\pm0.16$	$12.83^{c}\pm0.07$	$23.08^{b}\pm0.04$	$23.74^{a}\pm0.04$
Ash	$23.34^{a}\pm0.03$	$23.16^{b}\pm0.06$	$15.86^{d}\pm0.06$	$16.05^{c}\pm0.08$
Fibre	$1.35^{a}\pm0.04$	$1.22^{ab}\pm0.16$	$0.96^{b}\pm0.06$	$0.97^{b}\pm0.02$
CHO	$26.91^{b}\pm0.04$	$27.68^{a}\pm0.00$	$15.97^{c}\pm0.03$	$14.63^{d}\pm0.03$
Energy (kcal/100 g)	$409.75^{c}\pm0.03$	$408.91^{d}\pm0.04$	$441.25^{b}\pm0.04$	$445.99^{a}\pm0.01$

Values represent the Mean ± standard deviation of triplicate determinations. Means sharing the same superscript within a row indicate no significant difference (p>0.05).

Mineral composition of charcoal and gas smoked tilapia

The mineral composition of smoked fish is shown in Table 2. Smoking methods significantly (p<0.05) affected the mineral elements determined. The results revealed that gas and charcoal smoked tilapia were significantly (p<0.05) high in potassium, sodium, zinc, iron and copper while gas and charcoal smoked catfish were significantly (p<0.05) high in magnesium and selenium. Smoked catfish and tilapia had no traces of mercury and cadmium heavy metals. However, charcoal smoked catfish and tilapia had traces of lead 0.01 mg/100 g and 0.02 mg/100 g, respectively.

Table 2: Mineral Composition of Processed Tilapia and Catfish

Mineral (mg/100g)	Catfish		Tilapia	
	Charcoal smoked	**Gas smoked**	**Charcoal smoked**	**Gas smoked**
Potassium	$50.33^{c}\pm0.01$	$50.43^{c}\pm0.07$	$62.22^{b}\pm0.01$	$62.50^{a}\pm0.01$
Sodium	$10.19^{c}\pm0.01$	$10.21^{c}\pm0.01$	$22.21^{b}\pm0.01$	$22.86^{a}\pm0.01$
Magnesium	$76.39^{b}\pm0.01$	$76.99^{a}\pm.01$	$41.23^{d}\pm0.01$	$41.93^{c}\pm0.01$
Zinc	$3.48^{b}\pm0.01$	$3.47^{b}\pm0.01$	$4.98^{a}\pm0.01$	$4.99^{a}\pm0.01$
Iron	$3.49^{b}\pm0.01$	$3.47^{b}\pm0.01$	$6.12^{a}\pm0.01$	$6.13^{a}\pm0.01$
Selenium	$0.08^{a}\pm0.01$	$0.08^{a}\pm0.01$	$0.03^{b}\pm0.01$	$0.04^{b}\pm0.00$
Cupper	$2.37^{b}\pm0.01$	$2.39^{b}\pm0.01$	$6.67^{a}\pm0.01$	$6.68^{a}\pm0.01$
Lead	$0.01^{a}\pm0.01$	ND	$0.02^{a}\pm0.01$	ND
Mercury	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND

Values are Mean ± standard deviation of triplicate determinations. Means with the same superscript in a row are significantly not different (p>0.05).

Amino acid profile of charcoal and gas smoked tilapia

The amino acid profile of processed catfish and tilapia is shown in Table 3. Charcoal and gas processing methods significantly (p<0.05) influenced both the essential and non-essential amino acid profile of the fish. Charcoal smoking in both catfish and tilapia significantly (p<0.05) gave high leucine, lysine, methionine, phenylalanine, histidine, isoleucine and threonine contents over gas smoking methods. The tryptophan content of tilapia was significantly (p<0.05) high and smoking methods had no effects on the concentration. For non-essential amino acids, glutamic acid (14.03 – 14.31 mg/100 g) is the most abundant in catfish while glycine in tilapia (13.01 – 14.25 mg/100 g). Cysteine and tyrosine were least abundant non-essential amino acid in both catfish and tilapia. Charcoal smoking gave significantly (p<0.05) high total amino acid.

Table 3: Amino-acid Composition of Processed Tilapia and Catfish

	Cat Fish (g/100 g Protein)		Tilapia Fish (g/100 g Protein)	
	Charcoal smoked	**Gas smoked**	**Charcoal smoked**	**Gas smoked**
***Leucine**	$7.38^{a}\pm0.01$	$7.12^{a}\pm0.01$	$7.36^{a}\pm0.01$	$6.71^{b}\pm0.72$
***Lysine**	$8.31^{a}\pm0.01$	$5.76^{d}\pm0.01$	$7.70^{b}\pm0.14$	$7.26^{c}\pm0.01$
***Methionine**	$2.83^{b}\pm0.01$	$2.24^{d}\pm0.01$	$2.90^{a}\pm0.01$	$2.79^{c}\pm0.01$
***Phenylalanine**	$4.06^{b}\pm0.01$	$3.71^{c}\pm0.01$	$4.27^{a}\pm0.01$	$3.71^{c}\pm0.01$
***Histidine**	$2.22^{a}\pm0.01$	$2.02^{c}\pm0.01$	$2.25^{a}\pm0.01$	$2.16^{b}\pm0.01$
***Isoleucine**	$4.07^{a}\pm0.01$	$2.86^{b}\pm0.01$	$3.93^{ab}\pm0.60$	$3.8^{ab}\pm0.14$
***Threonine**	$4.69^{a}\pm0.01$	$4.09^{c}\pm0.01$	$4.43^{b}\pm0.01$	$4.10^{c}\pm0.14$
***Tryptophan**	$0.72^{b}\pm0.01$	$0.59^{b}\pm0.01$	$3.28^{a}\pm0.01$	$3.20^{a}\pm0.14$
***Valine**	$5.01^{a}\pm0.01$	$4.31^{b}\pm0.01$	$4.16^{b}\pm0.01$	$3.9^{c}\pm0.14$
Aspartic acid	$9.54^{a}\pm0.01$	$7.50^{c}\pm0.14$	$8.99^{a}\pm0.62$	$8.87^{b}\pm0.01$
Cysteine	$0.71^{c}\pm0.01$	$0.79^{b}\pm0.01$	$0.86^{a}\pm0.01$	$0.72^{c}\pm0.01$
Glutamic acid	$14.03^{b}\pm0.03$	$14.31^{a}\pm0.01$	$6.76^{c}\pm0.01$	$6.09^{d}\pm0.01$
Glycine	$7.96^{c}\pm0.01$	$5.09^{d}\pm0.01$	$14.25^{a}\pm0.01$	$13.01^{b}\pm0.01$
Proline	$5.74^{a}\pm0.20$	$4.26^{b}\pm0.01$	$4.27^{b}\pm0.01$	$4.05^{b}\pm0.01$

Serine	5.89^{a}±0.01	4.29^{b}±0.01	3.85^{c}±0.01	3.30^{d}±0.01
Tyrosine	3.08^{a}±0.01	2.41^{b}±0.01	0.90^{c}±0.01	0.80^{d}±0.01
Alanine	6.13^{a}±0.02	4.57^{d}±0.02	5.83^{b}±0.01	5.22^{c}±0.01
Arginine	6.55^{a}±0.01	3.98^{d}±0.01	5.84^{b}±0.01	5.41^{c}±0.01
Total amino acid (TAA)	99.11^{a}±0.01	79.9^{d}±0.14	91.86^{b}±0.01	85.25^{c}±0.01

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are significantly different (p < 0.05).
Key: * = Essential amino acids

Vitamins A and D contents of charcoal and gas smoked catfish and tilapia
The vitamin A and D contents of processed catfish and tilapia are shown in Table 4. Smoking methods significantly (p<0.05) influenced their concentrations. Charcoal smoked catfish had significantly (p<0.05) high vitamin A (29.32 UI/100 g) while gas smoked had the least content (25.21 UI/100 g). Similarly, charcoal smoked catfish had significantly (p<0.05) high vitamin D (3.89 UI/100 g) while gas smoked tilapia had the least content (2.30 UI/100 g).

Table 4: Vitamin Composition of Processed Tilapia and Catfish

	Catfish		Tilapia	
	Charcoal smoked	**Gas smoked**	**Charcoal smoked**	**Gas smoked**
Vitamin A (UI/100 g)	29.32^{a}±0.01	25.21^{d}±0.01	26.21^{c}±0.01	27.00^{b}±0.00
Vitamin D (UI/100 g)	3.89^{a}±0.01	3.33^{b}±0.01	2.60^{c}±0.14	2.30^{d}±0.08

Values are Mean ± standard deviation of triplicate determinations. Means with the same superscript in a row are significantly not different (p>0.05).

Discussion
Proximate Composition of Fish Samples
Protein is the most important nutrient component that fish supplies to the human body. The high protein content (24.28 – 37.30%) in this study is in line with the report of Olopade *et al*. (2013). Fish with a protein content of more than 20% are categorized as high protein (Omojowo *et al*., 2009). Protein content in the processed fish increased with decreasing moisture which may have been lost during drying resulting in increase in protein concentrations. The protein content of charcoal smoked catfish (26.31%) is higher than gas smoked (24.28%). Similarly, Omozokpia *et al*. (2015) also reported that protein contents increased with decrease in moisture content. However, the protein contents of tilapia fishes in this study 36.47% and 37.30% for charcoal and gas smoked, respectively are lower than that 48.87%, 49.40% and 64.90% after 15 hours of smoke-drying tilapia fishes at 50ºC, 60ºC and 70ºC, respectively (Idah and Nwankwo, 2013). In addition, Sainani and Kapute (2017) reported higher protein (64.3%) in Lake Malawi tilapia processed by using fireless cooker and roasting. The variations could be attributed to feeding practice, species difference and management practice. Norambuena *et al*. (2016) reported that high fat content in solar dried fish is a good dietary attribute but may also cause storage problems due to the susceptibility of fish oils to spoil, hence, the need to exercise care during handling. The fat content of charcoal and gas smoked tilapia in this study 23.08% and 23.74%, respectively are higher than 8.90% reported by Katola and Kapute (2017) in smoked-dried Mozambique tilapia. To rationalize the level of fat in processed fish Aberoumad and Pourshafi (2010) reported that the lower the percentage of water, the greater the fat content. The low fat contents of charcoal smoked catfish and tilapia compared to gas smoked catfish and tilapia may have been due to excessive heat and temperature generated by the charcoal which also caused reduced moisture content and destruction of fat molecules in the fish. Also, the decrease in lipid content could be explained by oxidation and break down of crude fat into other components due to oxidation of poly-unsaturated fatty acids contained in the fish tissue to products such as peroxides, aldehydes, ketones and free fatty acids (Daramola *et al.,* 2007; Holma and Maalekuu, 2013).

The ash contents of processed tilapia obtained in this study compare favourably to 14 - 17% in Mozambique tilapia (Katola and Kapute, 2017) and 14 - 21% in Nile tilapia (Idah and Nwankwo, 2013). The concentrations of minerals and trace elements that contribute to the total ash contents are known to vary in fish depending on their feeding behaviour, environment, ecosystem and migration even within the same area (Arannilewa *et al*., 2005). The values obtained in this study also agree with 16.1% for salted, fermented and sun-dried tilapia by (Abdel-Baki *et al*., 2011). More so, minerals are not generally destroyed by heating. This may explain lower percentage loses in the ash contents of the fish dried by charcoal and gas methods.
Charcoal and gas smoking methods had no effect on the fibre content of both catfish and tilapia; however, catfish had higher fibre than tilapia. The results of this study agree with (Idah and Nwankwo, 2013) who reported a range of 0.71 – 1.35% in tilapia fish dried at 50ºC, 60ºC and 70ºC.
It is noteworthy that carbohydrate contents of fresh fish are lower than that of dried ones. This may be due to the concentration of nutrients with moisture loss. Thus, the carbohydrate values of both charcoal and gas-dried are expected. This is in line with several reports by Chukwu and Shaba (2009); Odiko and Obirenfoju (2017); Idah and Nwankwo (2013); Fafioye *et al*. (2008).
Fish is low in calorie and in high protein making it a choice food combination for weight loss in obese persons. The values obtained in this study (408.91 - 445.99 kcal/100 g) indicate that smoked-dried catfish and tilapia are good and potential caloric protein sources which can supply energy. Charcoal and gas smoked tilapia were significantly (p<0.05) higher in energy than charcoal and gas smoked catfish. Fafioye *et al*. (2008) reported that the caloric content of eight fresh water fish were between 564.61 - 593.42 kcal/100 g; while, Norambuena *et al*. (2016) recommends an energy intake of 450 – 600 kcal per day. Thus, values obtained in this study are within the US/RDA recommendations (Norambuena *et al*., 2016).

Minerals composition of smoked catfish and tilapia
The mineral and heavy metal compositions of catfish and tilapia dried using gas and charcoal drying methods are shown

on Table 2. The potassium contents of smoked catfish and tilapia fish recorded in this study are in agreement with the result of Abdulkabir *et al.* (2010) who reported 69.74 mg/100 g potassium in catfish and 54.06 mg/100 g potassium in tilapia. The result also showed that, charcoal is a better drying source of heat when it comes to maintaining the potassium content. The recommended body's daily need for potassium is 350 mg/day (Ghosh *et al*., 2008). Potassium content in excess of the RDA has been reported to be the prime cause of hyperkalemia, a condition that affects the human kidney (Cranney *et al*., 2007). Although, the amount of potassium recorded in the fish does not meet the RDA, it is a significant contributor of potassium to human diet.

The sodium contents in this study are in agreement with Edward *et al*. (2013) who reported similar results on the mineral and heavy metal contents of fish harvested from Odo-Ayo river in Ado-Ekiti. When compared with the RDA, the sodium contents of catfish and tilapia analysed in this study are high enough to provide all the health benefits associated with the consumption of sodium and at the same time low enough to prevent the occurrence of high blood pressure and cardiovascular diseases (De Henauw *et al*., 2007) which are the risk factors of sodium consumption.

The magnesium contents of dried catfish in this study agree with the report of Akinola *et al*. (2006). Minerals have different lethal temperatures during processing. The lost might be due to the intensity of the heat during smoking process. Akinola *et al.* (2006) reported drying by solar as a heat source to have imparted higher drying temperatures on the fishes, thus creating more room for mineral lost than charcoal. Magnesium in the body maintains a normal nerve and muscle function, supports a healthy immune system and regulate heart beat (Akoto *et al*., 2014). A recommended 53 mg/day of magnesium is required to exert the above listed health benefits (Akoto *et al*., 2014) and reading from the results of this study, catfish from both the two fish contained enough magnesium to cater for the body needs.

The zinc contents of smoked catfish and tilapia fish revealed that both the two processing methods had no effect on them. The RDA for zinc is 5 mg/day (Adebowale *et al*., 2008). The results of this study showed that the two fish types adopted contain enough zinc which will provide the body with its daily need. The values of iron obtained agree with the report of (Abolagba and Melle, 2008). Iron helps the body in the manufacture of haemoglobin and blood clothing and its RDA is 15 mg/day (De Henauw *et al*., 2007). The iron contents of both fish are low and these fish cannot be relied on as the sole source of iron.

Selenium is a mineral that occurs naturally in certain foods. It is not produced in the human body but it is needed for proper thyroid and immune system function. Catfish and tilapia have low selenium levels 0.08 mg/100 g and 0.01 mg/100 g, respectively. De Henauw *et al*. (2007) revealed that 0.5 mg/day of selenium is good enough for proper thyroid and immune system functioning. The amounts of selenium found in the two fish were lower than the recommended; thus, artificial selenium fortification is required where the fish are to be depended on as the sole source of the mineral.

Copper is an essential mineral nutrient for the body and together with iron, it enables the body to form red blood cells, promote the formation of health and strong bones and teeth as well as promote proper nerves and immune function and iron absorption (Abolagba and Melle, 2008). This implies that Cu has the capacity to withstand the temperature thresholds of the two smoking methods adopted. The RDA for copper is 10 mg/day. Therefore, the fish most especially tilapia can substantially complement other food sources of copper.

Lead, mercury and cadmium are heavy metals in the environment whose accumulation in the human body causes health issues like kidney stones, renal failure and other fatal health complications (Abolagba and Melle, 2008). Heavy metals poisoning is mostly from water which makes fish a major source of concern. While no mercury and cadmium deposits were detected in catfish and tilapia, low doses of lead were recorded in charcoal smoke catfish (0.01 mg/100 g) and tilapia (0.02 mg/100 g). These results imply that, the charcoal used for drying contained lead particles that were deposited on the fishes during the drying process. However, the level is within the recommended safe level of 0.02 mg/day. This finding confirms the the safety of charcoal as heat source for drying consumable food products. It is always advisable to remove the skin of smoked fish products to avoid the effects of long time accumulation of toxic compounds in the body.

Amino acid profile of charcoal and gas smoked catfish and tilapia

In this study, *leucine* and *lysine* are the essential amino acids with the highest concentrations, ranging from 6.71 to 7.38 mg/100 g and 5.76 to 8.31 mg/100 g, respectively. *Glutamic acid* and *aspartic acid* were the non-essential amino acids with the highest concentrations, ranging from 6.07 to 14.31 mg/100 g and 7.50 to 9.54 mg/100 g, respectively.

Essential amino acids are those that cannot be synthesized by the body and must be obtained from the diet. The concentrations of *lysine* and *leucine* exceed the 6.3 g/100 g content of the reference egg protein, indicating that the fish samples are good sources for fortifying weaning foods. The ranges of *lysine* and *leucine* found in this study align with Aremu and Ekunode (2008), who reported 7.80 mg/100 g and 7.36 mg/100 g, respectively, in electric oven-dried African catfish. However, Idah and Nwankwo (2013) reported that smoking causes some decrease in the availability of *lysine* and that the loss is proportional to the temperature and duration of smoking. Thus, the temperature and duration of charcoal smoking may have minimized the reduction of *lysine* and *leucine*. The variation in amino acid contents may reflect the impact of the two smoking methods used. The results imply that tilapia fish have higher concentrations of *methionine*, *phenylalanine*, and *tryptophan* than catfish, and both smoking methods influence their concentrations.

Glutamic acid was the highest non-essential amino acid in this study. The *glutamic* content of gas-powered smoked catfish (14.31 mg/100 g) was higher than that of charcoal-powered smoked catfish (14.03 mg/100 g). This amino acid is one of the most abundant in both fish (Saad and Alim, 2015) and legumes (Vadivel and Janardhanan, 2005; Ade-Omowaye *et al*., 2015; James *et al*., 2020). *Cysteine* exhibited the lowest amino acid contents, ranging from 0.71 to 0.86 g/100 g. The low levels of sulfur-containing amino acids (*cysteine* and *methionine*) in this study align with values ranging from 0.86 to 2.78 mg/100 g and 0.56 to 4.65 mg/100 g, respectively, in eight underutilized legumes (plant protein foods) (James *et al*., 2020).

Belitz *et al*. (2009) showed that overheating in traditional smoking methods can reduce the availability of essential amino acids (*methionine*, *tryptophan*, and *lysine*). According to Chavan *et al*. (2008), smoking also decreases the more soluble proteins like myofibrillar and sarcoplasmic contents and increases the amount of insoluble protein. Additionally, heating protein fish can cause loss of nutritional value through amino acid destruction, protein denaturation, and the Maillard reaction (Abraha *et al*., 2018). It can be deduced that the heat treatments used that is charcoal and gas did not cause negative changes in the amino acid concentrations of catfish.

Effects of charcoal and gas smoking on vitamin content of catfish and tilapia

Vitamin A is positively correlated to good vision, bone and muscle growth and has effects on many body functions such as gene transcription, reproduction, maintenance of healthy epithelial tissue embryonic development and haematopoiesis. Also, it has an immune function and protects the skin and the body. Charcoal smoked catfish had the highest value (29.32 mg/100 g). This was followed by gas smoked tilapia (27 mg/100 g) while gas smoked catfish had the least value (25.21 mg/100 g). This result imply that smoking methods have significant influence on vitamin A contents of catfish and tilapia with charcoal smoking having favourable effect on catfish while gas smoking had positive influence on tilapia.

Vitamin D is responsible for a wide range of functions including calcium absorption and homeostasis with the role in bone mineralization particularly in relation to rickets and osteomalacia (Norman, 2008). An increase vitamin D status is linked to significant morbidity and mortality risk reduction. It is worth noting that fish is considered a good source of vitamin D, therefore, fish tissue meets the recommended dietary intake for vitamin D (Norman, 2008).

CONCLUSION

This study demonstrated that the ash and fibre contents of charcoal smoked catfish were the highest. However, in protein, fat and energy values gas smoked tilapia exhibited high superiority. In mineral elements, selenium was more abundant in charcoal smoked catfish; while, K, Na, Zn, Fe and CU were highest in gas smoked tilapia. The amino acids and vitamins A and D contents of charcoal smoked catfish were higher compared to smoked tilapia. Further study on the accumulation of heavy metals on the skin and tissue of smoked fish is needed.

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REFERENCES

Abdel-Baki, A.S., Dkhil, M.A. and Al-Quraishy, S. (2011). Bioaccumulation of some heavy metals in tilapia fish relevant to their concentration in water and sediment of Wadi Hanifah, Saudi Arabia. *African Journal of Biotechnology*, 10(13):2541-2547

Aberoumad, A. and Pourshafi, K. (2010). "Chemical and proximate composition properties of different fish species obtained from Iran". *World Journal of Fish and Marine Sciences*, 2(3), 237-239.

Abolagba, O.J. and Melle, O.O. (2008). Chemical composition and keeping qualities of a scaly fish tilapia, *Oreochromis niloticus* smoked with two energy sources. *Afr. J. Gen. Agric*. 4(2):113-117.

Abraha, B., Admassu, H., Mahmud, A., Tsighe, N., Shui, X.W. and Fang, Y. (2018). Effect of processing methods on nutritional and physico-chemical composition of fish: a review. *MOJ Food Processing and Technology*, 6(4):376–382.

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

Ade-Omowaye, B.I.O., Tucker, G.A., Smetanska, I. (2015). Nutritional potential of nine underexploited legumes in South West Nigeria. *Int. Food Res. J.*, 22 (2): 798–806.

Adeyeye E. I. (2000). Amino acid composition of three species of Nigerian fish: *Clarias anguillaris, Oreochromis niloticus* and *Cynoglossus senegalensis*. *Food Chem*., 113(1): 43-46.

Adeyeye, S. A. O., Oyewole, O. B., Obadina, A. O., Omemu, A. M., Adeniran, O. E, Oyedele H. A and Olugbile, A. (2016). Effect of smoking methods on microbial safety, polycyclic aromatic hydrocarbons and heavy metal concentrations of traditional smoked fish from Lagos State, Nigeria. *Journal of Culinary Science and Technology,* 14 (2): 91- 106.

AOAC. (2009). Official Mmethods of Aanalysis of Aassociation of Oofficial aAnalytical Cchemists. Washington, DC (17th ed.). Washington, DC, USA.

Akinola, O.A., A.A. Akinyemi and B.O. Bolaji, (2006). Evaluation of traditional and solar drying systems towards enhancing fish storage and preservation in Nigeria Abeokuta local government as a case study. *J. Fisheries Int.*, 1: 44-49. DOI:10.3923/jfish.2006.44.49

Akoto, O., BismarkEshun, F., Darko, G. and Adei, E. (2014). Concentrations and Health Risk Assessments of Heavy Metals in Fish from the Fosu Lagoon. *International Journal of Environmental Research*, 8(2): 403-410.

Arannilewa, S.T., S.O. Salawu, A.A. Sorungbe1 and B.B. Ola-Salawu, (2005). Effect of frozen period on the chemical, microbiological and sensory quality of frozen tilapia fish (*Sarotherodun galiaenus*). *Afr. J. Biotechnol*., 4: 852-855.

Aremu, M.O. and Ekunode, O.E. (2008). Nutritional evaluation and functional properties of *Clarias lazera* (African catfish) from river Tammah in Nasarawa State, *Nigeria. Am J Food Technol.,* 3(4): 264-74.

Belitz, H. D., Grosch, W., and Schieberle, P. (2009).Food Contamination In H. D. Belitz, W. Grosch, A. and P. Schieberle (Eds.), Food Chemistry (4th edn, 467–496). Berlin: Springer-Verlag.

Berge, G.M., B. Hatlen, J.M. Odom and B. Ruyter. (2013). Physical treatment of high EPA Yarrowia lipolytica biomass increases the availability of n-3 highly unsaturated fatty acids when fed to Atlantic salmon. *Aquacult. Nutr*., 19:110–121.

Chavan, S., Dudhmal, D., Kannewad, P. and Pathan, K. (2008). Traditional Methods of Fish Processing by Fisher Tribes in Godavari River Basin, (MS) India. *Scientific Research Reporter*, 5(2):192-197.

Chukwu, O. and Shaba, I.M. (2009). Effects of Drying Methods on Proximate Compositions of Catfish (*Clarias gariepinus*). *World Journal of Agricultural Sciences*, 5: 114-116.

Cranney, A., T. Horsley, S. O'Donnell, H. Weiler, L. Puil, D. Ooi, S. Atkinson, L. Ward, D. Moher, D. Hanley, M. Fang, F. Yazdi, C. Garritty, M. Sampson, N. Barrowman, A.

Tsertsvadze, and V. Mamaladze. (2007). Effectiveness and safety of vitamin D in relation to bone health. *Evid. Rep. Technol. Assess*., 158: 1–235.

Daramola, J.A., Alao, F.O., Osofero, S.A. and Wemimo, O.O. (2017). Assessment of the Microbial and Sensory Qualities of Smoked African Catfish (*Clarias gariepinus*). *Journal of Agriculture and Environmental Sciences*, 3(1): 11-22.

De Henauw, S., J. Van Camp, G. Sturtewagen, C. Matthys, M. Bilau, N. Warnants, K. Raes, M. Van Oeckel, and S. De Smet. (2007). Simulated changes in fatty acid intake in humans through n-3 fatty acid enrichment of foods from animal origin. *J. Sci. Food Agric*., 87: 200–211.

Dey, M.M. (2000). The impact of genetically improved farmed Nile tilapia in Asia. *Aquaculture Economics and Management*, 4(1-2): 107-124.

Edward, J.B., Idowu, E.O., Oso, J.A. and Ibidapo, O.R. (2013). Determination of heavy metal concentration in fish samples, sediment and water from odo-ayo River in Ado-Ekiti, Ekiti-State, Nigeria. *Int. J. Environ. Monitoring Analysis*, 1(1):27-33.

Eknath, A.E. and Hulata, G. (2009). Use and exchange of genetic resources of Nile tilapia (Oreochromis niloticus). *Reviews in Aquaculture,* 1(3-4): 197-213.

El-Sayed A.F.M. (2006). *Tilapia culture* UK: CABI Publishing

Eyo, A.A. (2001). Fish processing Technology in the Tropics. Published by National Institute for Freshwater Fisheries Research (NIFFR), P.M.B. 6006, New Bussa, Niger State, Nigeria.

Fafioye, O.O., Olurin, K.B. and Sowunmi, A.A. (2008). Studies on the physico-chemical parameters of Omi water body of Ago-Iwoye, Nigeria. *African Journal of Biotechnology*, 4 (9):1022-1024.

Gabriel, G. B., Miracle, U., Abdulkarim, I. A., James, S., Masato, E., Yutaka, H. and Sadiku, S. O. E. (2016). Nutrient utilization and haematological indices of Clarias gariepinus fingerlings fed varying inclusion levels of fermented flamboyant (*Delonix regia*) seed meal in concrete tanks. International Journal of Applied Sciences, 1:1-42-53.

Ghosh, A.K. and S.R. Joshi. (2008). Disorders of calcium, phosphorus and magnesium metabolism. *J. Assoc. Phys. India*, 56: 613– 21.

Holma, A.K. and Maalekuu, B.K. (2013). Effect of traditional fish processing methods on the proximate composition of red fish stored under ambient room conditions. *American Journal of Food and Nutrition*, 3: 73-82.

Idah, P.A. and Nwankwo, I. (2013). Effects of Smoke-Drying Temperatures and Time on Physical and Nutritional Quality Parameters of Tilapia (*Oreochromis niloticus*). *International Journal of Fisheries and Aquaculture*, 5: 29-34.

James, S., Nwabueze, T. U., Onwuka, G. I., Ndife, J. and Usman, M. A. (2020). Chemical and nutritional composition of some selected lesser known legumes indigenous to Nigeria. *Heliyon*, 6 (2020) e05497.

Katola, A. and Kapute, F. (2017). Nutrient composition of solar dried and traditionally smoked *Oreochromis mossambicus* (Peters, 1852). *International Food Research Journal*, 24(5): 1986-1990.

Norambuena, F., Rombenso, A. and G. M. Turchini. (2016). Towards the optimization of performance of Atlantic salmon reared at different water temperatures via the manipulation of dietary ARA/EPA ratio. *Aquaculture*, 450: 48–57.

Norman, A.W. (2008). From vitamin D to hormone D: Fundamentals of the vitamin D endocrine system essential for good health. *Am. J. Clin. Nutr*., 88: 491S–499S.

Odiko, A.E. and Obirenfoju, J. (2017). Proximate composition and mineral contents of different brands of canned fishes marketed in Edo state Nigeria. *International Journal of Fisheries and Aquaculture Research*, 3(2):30-38.

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 and 2): 91-97.

Omojowo, F.S.I., Garba, L. and Ihuahi, J.A. (2009). Comparative Assessment of Potassium Sorbate and Sodium Metabisulphite on the Safety and Shelf Life of Smoked Catfish. *Nature and Science,* 7: 10-17.

Omozokpia, J. A., A. I. Ajai, M. M. Ndamitso, J. O. Jacob, A. Akoma and E. Tanko (2015). Heavy Metals Accumulation in Water, Sediments and Catfish (*Clarias gariepinus*) from Two Fishing Settlements along River Kaduna in Niger State, Nigeria . *British Journal of Applied Science & Technology,* 11(1): 1-13.

Riemersma, RA. (2002). Analysis and possible significance of oxidised lipids in food. European *Journal of Lipid Science and Technology*, 104:419-42

Saad, H.A. and Alim, D.I. (2015). Amino Acids Profile of Some Economically Important Marine and Freshwater Fish from Sudan. *International Journal of Advanced Research*, 3(2): 838-844.

Sainani, K. and Kapute, F. (2017). Effect of cooking method on proximate and mineral composition of lake Malawi tilapia (*Oreochromis karongae*). *Afr. J. Food Agric. Nutr. Dev*. 17(4): 12589-12599.

Samuel, O.F, Folake, P., Olatunj, K.M, Onyebuchi, N.E, Bayode, O.G. and Oluwaseun, A.C. (2010). Effect on brinning on the microbial quality and safety of smoked catfish. *Nature and Science*, 8(4):59.69.

Vadivel, V. and Janardhanan, K. (2005). Nutritional and antinutritional characteristics of seven south Indian wild legumes. *Plant Foods Hum. Nutr.* 60: 69–75.