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Nutritional Values of Smoked *Clarias Gariepinus* from Major Markets in Southwest, Nigeria

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Keywords: *smoked fish, markets, southwest, clarias gariepinus, nutritional values.*

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Peter Taiwo Olagbemide

Abstract - Smoked *Clarias gariepinus* from four major markets in the southwest, Nigeria were analyzed. The aim was to evaluate the nutritional values of the fish sold at the different markets. The results of the analyses showed that the nutritional values of the smoked fish are of good standard but nutritional and mineral compositions varied from market to market. The moisture content, protein, fat, fibre, ash and carbohydrate contents from the markets were in the range of 9.63 to 10.27%, 53.77 to 54.77%, 11.77 to 13.13%, 6.87 to 8.00%, 0.0 to 0.07% and 15.40 to 16.17% respectively. The range of the mineral compositions was 10.13 to 12.17mg/100g, 0.33 to 0.50mg/100g, 28.33 to 46.67mg/100g, 353.33 to 388.33mg/100g, 22.33 to 33.33mg/100g, and 271.67 to 305.00mg/100g for iron, zinc, magnesium, calcium, potassium and phosphorus respectively. Ascorbic acid, thiamine, niacin and riboflavin contents of the fish were in range of 0.17 to 0.27mg/100g, 0.05 to 0.07mg/100g, 0.24 to 0.28mg/100g, and 0.05 to 0.08mg/100g respectively. There were significant differences ($P < 0.05$) in the proximate, vitamin and mineral compositions between the paired samples from the markets. These variations could be explained as due to the different smoking devices employed, the duration and methods of storage and the effects of different fish handlers after smoking. It is therefore recommended that good smoking and storage methods should be adopted as well as maintenance of hygienic environment and practices by smoked fish handlers.

Keywords: smoked fish, markets, southwest, clarias gariepinus, nutritional values.

I. Introduction

Fish makes up about 60% of world protein supply and developing countries derive more than 30% of their annual protein from fish (FAO 1994). Teutscher (1990) and Saisithi (1994) reported that fish provides between 30% and 80% of the total animal protein intake of the coastal people of West Africa. In Nigeria fish constitute 40% of animal protein intake (Olatunde, 1998). Fish demand is increasing as a result of the increasing world population, higher living standards and the good overall image of fish among consumers (Cahu *et al*., 2004). In addition, the demand for fish is on the increase due to the health benefits of eating fish and due to increase in human population, the rinderpest disaster, and drought bane, which reduce the availability and affordability of red meat (Oshozekhai and Ngueku, 2014). Fish and fish products are highly nutritious with protein content of 15 to 20% and are particularly efficient in supplementing the cereal and tuber diets widely consumed in Africa (Fagbenro *et al*., 2005). Kreuzer and Heen (1962); Waterman (1976); Olomu (1995); Ojutiku *et al*. (2009) also highlighted that fish is rich in protein with amino acid composition very well suited to human dietary requirements comparing favorably with egg, milk and meat in the nutritional value of its protein. Fish also contains absorbable dietary minerals (Bruhiyan et al., 1993). In Nigeria, fish is eaten fresh and smoked and form a much cherished delicacy that cut across socio-economic, age, religions and educational barriers (Adebayo et al., 2008) and it is a rich source of protein commonly consumed due to the higher cost of meat and other sources of animal protein (Omolara and Omotayo, 2009). However, fish is highly perishable because it provides favourable medium for the growth of microorganisms after death (Aliya *et al*., 2012; Oparaku and Mgbenka, 2012). An estimate of 40% postharvest losses of total fish landings have been reported in Nigeria (Akande, 1996). Fish spoilage in Nigeria is influenced to a large extent by high ambient temperatures, considerable distances of landing ports to points of utilization and poor as well as inadequate infrastructure for postharvest processing and landing (Saliu, 2008). Thus, it is imperative to process and preserve some of the fish caught in the period of abundance, so as to ensure an all year round supply. This will invariably reduce postharvest losses, increase the shelf-life of fish, and guarantee a sustainable supply of fish during off season with concomitant increase in the profit of the fishermen (Eyo, 1997). Proper preservation starts the moment fish is harvested until reaches the consumer's table (Oluborode *et al*., 2010). A number of processing techniques is in operation in Nigeria. These include chilling, freezing, salting, canning, drying and smoking. However, smoking is the most popular method of fish processing (Eyo, 2000) and among the several methods of long term preservation of fish, smoking is perhaps the simplest method as it does not require sophisticated equipment or highly skilled workers (Olayemi *et al*., 2011). Smoked-dried fish is the most acceptable form of fish product in Nigeria (Stolyhiro and Sikorski, 2005; Yanar, 2007). Smoking is the oldest and most common method of fish preservation in many developing countries (Krasemann 2004; Kumolu-Johnson *et al*., 2010). It is a method of preservation effected by combination of drying and decomposition of naturally produced chemical resulting

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from thermal breakdown of wood (Tobor, 2004). The smoke is produced by the process of incomplete combustion of wood in order to impart a characteristic flavour and colour to the fish. Smoke contributes to fish preservation and shelf life by drying, cooking, acting as an effective antioxidant, bacteriostatic and bactericidal agent as well as by depositing natural wood–smoke chemicals like tars, phenols and aldehydes; all of which provide a protective film on the surface of smoked fish and have powerful bactericidal action and prevent the growth of other microorganisms on the flesh of the fish (Gilbert and Knowles, 1995; Horner, 1997; Doe, 1998; Rorvik, 2000; Garrow and James, 2000; Daramola *et al*., 2007; Ahmed *et al*., 2010; Daramola *et al*., 2013). Several methods are available for fish smoking and different smoked products have been developed in various parts of the world in relation to the properties of the locally available raw materials and the general level of technology (Olley *et al.,* 1988).

African catfish (Clarias gariepinus) is one of the most important fish species currently being cultured both inside and outside its natural range of tropical and subtropical environments (Adewolu *et al*., 2008). Positive attributes such as resistance to diseases, high fecundity, and ease of larval production in captivity make it of commercial importance in aquaculture (Haylor, 1991). It is of great importance as it grows quickly, attains a large size, and is an edible fish with few spines in its flesh. It can withstand wide range of environmental conditions, including severe temperatures, as well as low oxygen. The importance of catfish itself cannot be overemphasized. According to Anoop et al., (2009), it provides food for the populace, it allows for improved protein nutrition because it has a high biological value in terms of high protein retention in the body, higher protein assimilation as compared to other protein sources, low cholesterol content and one of the safest sources of animal protein.

The aim of this study is to evaluate the nutritional value of the smoked *Clarias gariepinus* sold at the major markets in Southwest, Nigeria.

II. Materials and Methods

a) Sample collection

The fish samples used for this study were purchased from four major markets in Oyo and Ekiti States in Southwest, Nigeria. Two major markets (A and B) were selected in Ibadan, the capital of Oyo State and two major markets (C and D) in Ado-Ekiti, the capital of Ekiti State. These markets were selected because they are markets generally patronized by the populace. All samples were transported to the Department of Biological Sciences, Afe Babalola University for analyses.

b) Analysis of samples

The proximate analyses of the all the samples from the various markets (A, B, C and D) for moisture, ash and carbohydrate contents were determined as described by AOAC (2005). Crude protein, fibre and fat contents were determined using the methods described by Pearson (1976). Mineral contents of all the samples were determined by atomic absorption spectrometry, flame photometry and spectrophotometry according to the methods of AOAC (2003). The phytochemical analysis for the presence of saponins, tannins, alkaloids, and cyanogenic glycosides in the samples were carried out according to the methods described by Harborne (1973) and Trease and Evans (1983). The vitamins in the samples from the four markets were determined by the official methods of the Association of official Analytical chemists (AOAC, 1990). Each analysis was carried out in triplicate.

c) Statistical analysis

All assays were carried out in triplicate, and the means and standard error of means (SEM) were determined using SPSS version 20. Analysis of variance was performed to determine significant differences between the paired samples. Differences in paired samples performance for each nutrient and chemical composition were tested by the Student's t-test. <0.05 implies significance.

III. Results

The proximate analyses of the samples from the different markets are shown in Table 1 while Table 2 shows the paired samples test of the proximate analyses of the samples from the markets. The values of the proximate analyses in the samples varied from market to market. The moisture content, protein, fat, fibre, ash and carbohydrate contents from the markets were in the range of 9.63 to 10.27%, 53.77 to 54.77%, 11.77 to 13.13%, 6.87 to 8.00%, 0.0 to 0.07% and 15.40 to 16.17% respectively. Samples from Market A and Market D recorded higher values of moisture contents than samples from Markets B and C. Table 2 shows that there were significant differences in the moisture content values between the samples from Market A and Markets B, C and between samples from Market D and Markets B, C. There was no significant difference in moisture values between samples from Market A and D and between samples from Market B and C. The protein content values of the samples from the markets were high but showed variation in the markets. There was a significant difference in the protein values of the samples between Market A and Market B and between Market B and Market C. The fat content showed significant difference only between samples from Market C and Market D. There was no significant different in the crude fibre and carbohydrates values of the samples from the markets.

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Table 1 : Proximate Analyses of *Clarias gariepinus* from the four markets

Parameters	Market A	Market B	Market C	Market D
Moisture content (%)	10.13±0.09	9.63±0.09	9.67±0.09	10.27±0.09
Protein (%)	54.53±0.09	53.77±0.07	54.77±0.09	54.17±0.09
Ether extracts (fat) %	12.17±0.09	12.33±0.09	13.13±0.09	11.77±0.07
Ash (%)	7.63±0.09	8.00±0.07	6.87±0.09	7.53±0.09
Crude fibre (%)	0.07±0.03	0.00	0.00	0.03±0.03
Carbohydrate (by difference) %	15.43±0.09	16.17±0.12	15.40±0.17	16.03±0.15

Values are means ±SEM (Standard error of means) of triplicate samples.

Table 2 : Paired samples test of proximate analyses of *Clarias gariepinus* from the markets

Parameters	Paired samples	Diff.Mean	Sig. (2-Tailed)
Moisture content (%)	Market A-Market B	0.50±0.12	0.049
	Market A-Market C	0.47±0.09	0.034
	Market A-Market D	-0.13±0.03	0.057
	Market B-Market C	-0.03±0.17	0.860
	Market B-Market D	-0.63±0.09	0.019
	Market C-Market D	-0.60±0.12	0.035
Protein (%)	Market A-Market B	0.77±0.12	0.024
	Market A-Market C	-0.23±0.09	0.118
	Market A-Market D	0.37±0.09	0.053
	Market B-Market C	1.00±0.05	0.030
	Market B-Market D	-0.40±0.15	0.120
	Market C-Market D	0.60±0.15	0.590
Ether extract (fat) %	Market A-Market B	-0.17±0.09	0.200
	Market A-Market C	-0.97±0.09	0.080
	Market A-Market D	0.40±0.17	0.148
	Market B-Market C	-0.80±0.15	0.350
	Market B-Market D	0.57±0.13	0.051
	Market C-Market D	1.37±0.17	0.015
Ash content (%)	Market A-Market B	-0.37±0.13	0.111
	Market A-Market C	0.77±0.18	0.049
	Market A-Market D	0.10±0.15	0.580
	Market B-Market C	1.13±0.07	0.003
	Market B-Market D	0.47±0.03	0.005
	Market C-Market D	-0.67±0.09	0.017
Crude fibre (%)	Market A-Market B	0.07±0.03	0.184
	Market A-Market C	0.07±0.03	0.184
	Market A-Market D	0.03±0.03	0.423
	Market B-Market C	.....	.....
	Market B-Market D	-0.03±0.03	0.423
	Market C-Market D	-0.03±0.03	0.423
Carbohydrate (by difference) %	Market A-Market B	-0.73±0.07	0.008
	Market A-Market C	0.03±0.17	0.860
	Market A-Market D	-0.60±0.23	0.122
	Market B-Market C	0.77±0.23	0.081
	Market B-Market D	0.13±0.24	0.635
	Market C-Market D	-0.63±0.28	0.156

Significant difference ($P < 0.05$)

Table 3 shows the values of mineral compositions of the samples from the markets while Table 4 shows the paired samples test of the mineral compositions of the samples from the markets.

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Table 3 : Mineral compositions of *Clarias gariepinus* from the four markets

Parameters (mg/100g)	Market A	Market B	Market C	Market D
Iron (Fe^{++})	11.33±0.09	10.13±0.09	12.17±0.09	11.57±0.09
Zinc (Zn^{++})	0.43±0,03	0.40±0.06	0.50±0.06	0.33±0.03
Magnesium (Mg^{++})	46.67±1.67	36.67±1.67	28.33±1.67	40.00±2.89
Calcium (Ca^{++})	353.33±6.01	373.33±7.26	358.33±4.41	388.33±1.67
Potassium (K^{+})	33.33±1.67	30.00±2.89	25.00±2.89	22.33±1.45
Phosphorus (PO_4^{---})	280.01±2.89	288.33±4.41	271.67±4.41	305.00±2.89
Ca/P	1.26±0.02	1.30±0.01	1.32±0.04	1.27±0.02
Ca/Mg	7.60±0.36	10.22±0.47	12.75±0.84	9.81±0.67
Ca/K	10.65±0.53	12.71±1.36	14.67±1.76	17.54±1.19

Values are means ±SEM (Standard error of means) of triplicate samples.

Table 4 : Paired samples test of the mineral composition of *Clarias gariepinus* from the markets

Parameters	Paired samples	Diff. Mean	Sig. (2-Tailed)
Iron	Market A-Market B	1.20±0.15	0.016
	Market A-Market C	-0.83±0.18	0.042
	Market A-Market D	-0.23±0.17	0.300
	Market B-Market C	2.03±0.09	0.002
	Market B-Market D	1.43±0.03	0.001
	Market C-Market D	0.60±0.06	0.09
Zinc	Market A-Market B	0.03±0.07	0.667
	Market A-Market C	-0.07±0.03	0.184
	Market A-Market D	----------	--------
	Market B-Market C	-0.10±0.01	0.423
	Market B-Market D	0.07±0.07	0.423
	Market C-Market D	0.17±0.03	0.038
Magnesium	Market A-Market B	10.00±2.89	0.074
	Market A-Market C	18.33±1.67	0.008
	Market A-Market D	6.67±4.41	0.270
	Market B-Market C	8.33±3.33	0.130
	Market B-Market D	-3.33±1.67	0.184
	Market C-Market D	11.67±4.41	0.118
Calcium	Market A-Market B	20.00±2.89	0.020
	Market A-Market C	5.00±2.89	0.225
	Market A-Market D	35.00±5.00	0.020
	Market B-Market C	15.00±2.89	0.035
	Market B-Market D	15.00±5.77	0.122
	Market C-Market D	30.00±2.89	0.009
Potassium	Market A-Market B	3.33±1.69	0.184
	Market A-Market C	8.33±4.41	0.199
	Market A-Market D	11.00±2.08	0.034
	Market B-Market C	5.00±5.00	0.423
	Market B-Market D	7.67±2.33	0.081
	Market C-Market D	2.67±2.67	0.423
Phosphorus	Market A-Market B	8.33±4.41	0.199
	Market A-Market C	8.33±6.00	0.300
	Market A-Market D	25.00±5.00	0.038
	Market B-Market C	16.67±8.82	0.199
	Market B-Market D	16.67±7.26	0.149
	Market C-Market D	33.33±1.67	0.02
Ca/P	Market A-Market B	-0.04±0.01	0.093
	Market A-Market C	-0.06±0.02	0.122
	Market A-Market D	-0.01±0.00	0.057

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	Market B-Market C	-0.02±0.03	0.551
	Market B-Market D	0.02±0.01	0.222
	Market C-Market D	0.05±0.02	0.148
Ca/Mg	Market A-Market B	-2.63±0.53	0.039
	Market A-Market C	-5.15±0.76	0.021
	Market A-Market D	-2.21±0.97	0.150
	Market B-Market C	-2.52±1.25	0.181
	Market B-Market D	0.42±0.58	0.550
	Market C-Market D	2.94±1.48	0.186
Ca/K	Market A-Market B	-2.05±0.85	0.138
	Market A-Market C	-4.01±2.09	0.195
	Market A-Market D	-6.89±1.10	0.025
	Market B-Market C	-1.96±2.52	0.517
	Market B-Market D	-4.84±1.15	0.052
	Market C-Market D	-2.88±1.43	0.181

Significant difference (P<0.05)

The values of the mineral composition in the samples varied from market to market. The range was 10.13 to 12.17mg/100g, 0.33 to 0.50mg/100g, 28.33 to 46.67mg/100g, 353.33 to 388.33mg/100g, 22.33 to 33.33mg/100g, and 271.67 to 305.00mg/100g for iron, zinc, magnesium, calcium, potassium and phosphorus respectively. There was a significant difference in iron content of the samples between Market A and Markets B, C and between Market B and Markets C, D. There was a significant difference in the values of zinc in the samples between Market C and Market D. Magnesium in the samples showed significant difference between Market A and Market C. There was a significant difference in the values of calcium in the samples between Market A and Markets B, D; between Market B and Market C and between Market C and Market D. Potassium showed significant difference in the samples between Market A and Market D while Phosphorus showed significant difference in the samples between Market A and D and between Market C and Market D.

Table 5 shows phytochemical and vitamin compositions of the samples from the markets while Table 6 shows the paired samples test of the phytochemical and vitamin compositions of the samples from the markets. The phytate, saponin, ascorbic acid, thiamine, niacin and riboflavin contents were in the range of 21.67 to 28.33mg/100g, 0.00 to 0.17mg/100g, 0.17 to 0.27mg/100g, 0.05 to 0.07mg/100g, 0.24 to 0.28mg/100g, and 0.05 to 0.08mg/100g respectively. Thiamine and phytates showed no significant difference in their values in the samples between the markets while ascorbic acid and riboflavin showed significant difference in their values in the samples only between Market C and Market D. Niacin showed significant difference in its values in the sample between Market A and Market B and between Market B and Market C while saponin showed significant difference in its value in the samples between A and Market C and between Market C and Market D.

Table 5 : Phytochemical and vitamin compositions of *Clarias gariepinus* from the markets

Parameters	Market A	Market B	Market C	Market D
Pyhtates	28.33±1.67	21.67±1.67	25.00±2.89	28.33±1.67
Saponins	0.17±0.03	0.17±0.09	0.00±0.00	0.17±0.03
Ascorbic acid	0.27±0.03	0.20±0.06	0.17±0.06	0.33±0.06
TThiamine	0.06±0.00	0.06±0.03	0.07±0.01	0.05±0.01
Niacin	0.24±0.01	0.27±0.01	0.23±0.01	0.28±0.01
Riboflavin	0.07±0.00	0.06±0.00	0.05±0.01	0.08±0.00

Values are means ±SEM (Standard error of means) of triplicate samples.

Table 6 : Paired samples test of the phytochemical and vitamin of *Clarias gariepinus* from the markets

Parameters	Paired samples	Diff. Mean	Sig. (2-Tailed)
Phytates	Market A-Market B	6.67±1.67	0.057
	Market A-Market C	3.33±1.67	0.184
	Market A-Market D	0.00±2.89	1.000
	Market B-Market C	-3.33±3.33	0.423
	Market B-Market D	-6.67±3.33	0.184

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	Market C-Market D	3.33±3.33	0.423
Saponins	Market A-Market B	0.00±0.12	1.000
	Market A-Market C	0.17±0.03	0.038
	Market A-Market D	0.00±0.06	1.000
	Market B-Market C	0.17±0.09	0.199
	Market B-Market D	0.00±0.06	1.000
	Market C-Market D	-0.17±0.03	0.038
Ascorbic acid	Market A-Market B	0.07±0.07	0.423
	Market A-Market C	----------	-------
	Market A-Market D	-0.07±0.03	0.184
	Market B-Market C	0.03±0.07	0.667
	Market B-Market D	-0.13±0.09	0.270
	Market C-Market D	-0.02±0.03	0.038
Thiamine	Market A-Market B	-0.00±0.00	0.423
	Market A-Market C	0.01±0.01	0.529
	Market A-Market D	0.01±0.00	0.184
	Market B-Market C	-0.00±0.01	0.667
	Market B-Market D	----------	-------
	Market C-Market D	0.01±0.01	0.184
Niacin	Market A-Market B	-0.03±0.01	0.035
	Market A-Market C	0.01±0.01	0.383
	Market A-Market D	-0.04±0.02	0.120
	Market B-Market C	0.04±0.01	0.023
	Market B-Market D	-0.01±0.02	0.580
	Market C-Market D	-0.05±0.01	0.067
Riboflavin	Market A-Market B	----------	-------
	Market A-Market C	0.02±0.01	0.199
	Market A-Market D	-0.02±0.00	0.038
	Market B-Market C	0.01±0.01	0.529
	Market B-Market D	-0.03±0.00	0.015
	Market C-Market D	-0.03±0.06	0.038

Significant difference (P<0.05)

IV. Discussion

The moisture content can be used as a pointer to the rate at which deterioration occurs in fish samples resulting in the early decomposition. The moisture content recorded in the samples in the Markets A-D is within the range (9-13%) recorded by Plahar *et* al. (1996) and is considered to be low enough to present little deterioration problems if storage conditions are properly controlled. The low moisture content is to reduce to minimum the conditions in the fish that allow for spoilage organisms and chemical activities. Kaneko (1976) reported that a lot of proteolytic, lipolytic deterioration and microbial proliferation are encouraged at moisture levels of 15% and above. The results of the proximate compositions in this study were slightly different from those of Adebowale *et al.* (2008) who reported the range of moisture, protein, fat and ash content of Nigerian smoked catfish to be 7.16-10.71, 33.66-66.04, 1.58-6.09 and 9.21-12.16%, respectively. The low crude fibre value recorded in the samples from the markets is due to the fact that the energy content in smoked *Clarias gariepinus* is high because crude fiber is considered as indigestible. The crude fibre content indicates the amount of cell walls in the feed. The fat levels in the samples from the four markets were below the range (15-33%) reported by Plahar *et al*. (1991) to cause rancidity problems in storage. In this study, the crude protein formed the largest quantity of the dry matter in all the fish samples. This is in-line with the report that protein forms the largest quantity of dry matter in fish (Pannevis, 1993) and thus, smoked *Clarias gariepinus* is a good source of pure protein and would be more than enough to prevent malnutrition in children and adult who feed solely on this fish as a main source of protein. It also clear from the results of this study that smoked *Clarias gariepinus* is a good source of macro and micro mineral elements in spite of the processing effects of smoking and may contribute to health, growth and development of human beings. The ratios of the mineral compositions further point out the nutritional values of the fish as reported by Watts (2010) that determining nutritional interrelationships is much more important than knowing mineral level alone. Mineral ratios are often more important in determining nutritional deficiencies and excess; it is predictive of future metabolic dysfunctions or hidden metabolic dysfunction. The high Ca/P ratio observed in all the samples from the markets is of nutritional benefit, particularly for children and the aged who need higher intakes of calcium and phosphorus for bone formation and maintenance. Food is considered 'good' if the ratio is above one and 'poor' if the ratio is less than 0.5 while Ca/P ratio above two helps to increase the absorption of calcium in the small

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intestine (Niemann *etal*., 1992). Ca/K ratio is usually called thyroid ratio because calcium and potassium play a vital role in regulating thyroid activity and the ratio in this study is around the range (8-16) needed to maintain the regulation of thyroid activity in good balance (ARL, 2012). Ca/Mg ratio in the fish from the markets is within the range that enhances mental and emotional stability whereas ratio beyond 16 or less than 2 is associated with mental and emotional disturbances (ARL, 2012). The relatively small amount of zinc content recorded in smoked fish from all the markets is not surprising since zinc is a trace mineral and is needed only in small amounts by our bodies but has many important functions. It is needed for the body's defensive (immune) system to properly work; plays a role in cell division, cell growth, wound healing and the breakdown of carbohydrates and is also needed for the senses of smell and taste. The presence of riboflavin, niacin, thiamine and ascorbic acid in all the samples from the markets is a pointer to the nutritional value of smoked *Clarias gariepinus*. Riboflavin is important for body growth and the production of red blood cells; niacin helps maintain healthy skin and nerves and ensures that the digestive and nervous systems function properly; thiamine helps the body cells to change carbohydrates into energy and ascorbic acid helps the body to make collagen, an important protein used to make skin, cartilage, tendons, ligaments, and blood vessels and is also needed for healing wounds, and for repairing and maintaining bones and teeth. The high value of phytates recorded in all the samples from the markets indicates that fishes are likely sources of phytates to their environments. This is because ruminant animals (e.g., cattle, sheep, goats, buffalo) possess phytase producing flora for digesting phytates while non-ruminant animals (e.g., pigs, chickens, dogs, cats, fish) don't have phytase producing flora and as a consequence of low digestibility of phytates by fish, most of the phytates end up being excreted and make their way into their immediate environments. The relative small quantity of saponins in all the samples from the markets is likely to be due to their toxicity to cold-blooded animals at certain concentration. Francis *et al* (2002) reported that saponins are toxic to fish.

However, there were variations in values of the proximate analyses and the chemical compositions of *Clarias* gariepinus from the markets sampled and these variations are likely to affect the wholeness, safety and shelf life of the products. Variations in proximate and chemical compositions of smoked fish are said to be caused by different factors, such as fish species, smoking methods, smoking time and salt concentration (Adegunwa *et al*., 2013). Huda *et al* (2010) reported that nutrient content of fish is influenced by several factors including smoking method and time and the nutrient composition of locally available foods. According to Swastawati (2004) differences in smoked fish flesh composition are due to different fish species and smoking methods and Dvorak and Vognsrova (1997) reported that difference in smoke quality can make the end-products to differ with respect to nutritional esthetic quality. This is because, according to Kostrya and Pikielna (2006), different smoke sources produce different complex smoke compounds that could consist of mixture of various volatile and non volatile compounds, such as phenol, syringol and guaiacol and its derivatives that affect the quality of the smoked fish. In this study, the variations observed in proximate and chemical compositions of the samples from the different markets may be due to smoking methods and time and not because of difference in species. This is because traditional fish smoking devices are poorly constructed; the technology employed by local fishermen in smoking is not standardized and lack mechanisms for the control of smoke and heat production so that most parameters remain uncontrolled. Hence, essential drying parameters such as duration, air humidity and temperature which affect the efficiency of smoking and the quality of the final products (Olopade *et al*., 2013) are not precisely determined and mastered. In addition, the variations in the nutritional value of *Clarias gariepinus* from different markets may also be due to the storage methods and the durations of storage after smoking. Smoking decreases the water activity in fish tissue (Sveinsdottir, 1998) and if the smoked fish is not properly stored afterward, the efforts involved in smoking may not yield the expected preservative effect. Jallow (1995) reported that fish with 10-15% moisture content has a shelf life of 3-9 months when stored properly. Thus the concentrations of chemicals in smoked fish are contingent on the storage time and temperature. It is therefore necessary to consider the recommendations of Daramola *et al*. (2007) that "intermittent sun-drying or mild smoking can be carried out on smoked fish to extend its shelf life; moisture content less than 10% should be maintained in stored smoked fish to reduce the growth of bacteria and moulds and preservatives such as pirimiphos-methyl (actelic) can be applied to preserve smoked fish." Thus, this study advocates the need for the adoption of good processing practices and storage methods of smoked fish. In addition, the people that are involved in the processing and selling of smoked fish should maintain hygienic environment and practices so as to ensure that safety standards are maintained in smoked fish and market worthiness of the products is preserved.

V. Conclusion

The nutritional and chemical compositions of smoked *Clarias gariepinus* showed variations from market to market; the results however indicate that smoking method is an important preservation method which could preserve the nutritive values of fishes and

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possibly reduce post-harvest losses. However, good smoking method should be adopted and hygienic and proper storage devices put in place.

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