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Effect of Processing on the Chemical and Microbiological Qualities of African Arowana (*Heterotis niloticus*), a Species of the *bonytongue* Fish

Olusegun A. Olaoye[1, *], Iniobong G. Lawrence[2], Yemi T. Ayanbukola[2]

[1]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria

[2]Department of Food Technology, Federal Polytechnic, Offa, Nigeria

Email address:

olaayosegun@yahoo.com (O. A. Olaoye), ytayanbukola@yahoo.com (Y. T. Ayanbukola)

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Abstract: In the present investigation, African arowana (*Heterotis niloticus*) fish samples were subjected to drying and smoking separately in order to evaluate the effect of low and elevated temperatures on the chemical and microbiological qualities of resulting product. The different temperatures used during drying included 50°C (SampDried50), 60°C (SampDried60), 80°C (SampDried80) and 100°C (SampDried100) and 120°C (SampDried120). Cold smoking (smoking at 45-50°C) and hot smoking (smoking at 75-80°C) were also used in producing smoked *Heterotis niloticus*. Analysis of the dried and smoked *Heterotis niloticus* samples indicated that the SampDried120 had the highest protein content of 37.98% while 4.12% was recorded for the SampSmoked75-80 sample as the highest ash content. Free fatty acid (FFA) was lowest (0.31 KOH/g lipid)) in the SampSmoked75-80 sample while 0.31 (mg MDA/kg) was recorded as Thiobarbituric acid (TBA) value for SampDried120. The SampDried120 sample recorded the highest potassium, calcium, phosphorus, magnesium and sodium contents (mg/100g), having respective values of 76.38, 43.04, 64.37, 21.20 and 134.24. Similar results were recorded for the essential amino acids of the *Heterotis niloticus* samples, with the SampDried120 sample having highest values. Evaluation of microbiological quality showed that *Pseudomonas*, coliforms and *Staphylococcus* were lower in the smoked samples than others. This investigation concluded that hot smoking and drying at elevated temperatures of 80, 100 and 120°C could extend shelf life of *Heterotis niloticus* as a result of reduction TBA and FFA values; furthermore, there were higher values of protein and ash than in other samples.

Keywords: *Heterotis niloticus*, Cold and Hot Smoking, Drying, Thiobarbituric Acid, Free Fatty Acids, Essential Amino Acids

1. Introduction

Heterotis niloticus is commonly known as African arowana or bony-tongue fish, and popularly referred to as Ecomog fish in Nigeria; it belongs to the family Ostoeglossidae [1]. It has a fast growth rate and an excellent meat quality, making it a good candidate for aquaculture. *Heterotis niloticus* is wide spread throughout Africa, where it is native to all the watersheds in Sahelo-Sudanese region, Senegal and Gambia as well as parts of Eastern Africa.

Generally, fish could be highly nutritious food particularly valued for its high quality protein compared to those of meat and egg [2]; it contains high quality protein, amino acids and absorbable dietary minerals [3]. Fish is currently being used as a good tool for food therapy and source of therapeutic substances for the treatment of coronary diseases, auto-immune diseases, anemia and protein energy malnutrition. However, fish is highly perishable because it provides favourable medium for the growth of microorganisms after death [4, 5].

Many processes including drying, canning and smoking are adopted in the preservation of fish; as these methods may efficiently help in the extension of shelf life. Dried fish is a major component of harvested fisheries in many countries of

the tropics, especially Nigeria. An average of around 30% of the world fish catch is consumed in the dried, salted, smoked form or combination of these processes [4]. Some of these preservation methods have various effects on the physical and nutritional quality of fish [5]. Among the methods used in the preservation of fish, drying and smoking rank highest with the primary objective of preventing spoilage and ensure availability. The effect of preservation by these processes includes the antioxidant and antimicrobial properties of phenolic compounds in smoke and removal of moisture by drying. The processes may bring about some modifications in the chemical, physical and sensory attributes of the processed fish [6]. In the traditional technique of smoking to preserve fish, the concentration of phenolic compounds in the products depends on the nature of the wood used in the smoking process [7]. The method of smoke generation and the smoking process may impart considerable influence on the sensory characteristics of smoked fish products.

The methods of drying and smoking for fish preservation vary between different countries, depending on the species being processed as well as the type of product desired [8]. Smoking as a method of preservation produces commonly acceptable products since it imparts desirable colour and flavour; smoked fish constitutes an important diet of many low income earners in the developing world, such as Nigeria and traditional methods have been well adopted because of their relative cheapness, requiring only simple equipment or facilities [9]. The extended shelf-life of smoked fish product is primarily due to the reduced water activity, and minimally to reduced moisture content. To ensure short time storage of dry fish that is safe from moulds and bacteria infestation, the moisture content must well below 30% [9].

This study evaluated the effect of processing by drying and smoking at low and elevated temperatures on the chemical and microbiological qualities of *Heterotis niloticus*, a species of the *bonytongue* fish.

2. Materials and Methods

2.1. Source of Materials

The African arowana (*Heterotis niloticus*) samples (Figure 1) and salt used in this study were purchased from Owode retail market in Offa, Kwara State, Nigeria. The fish were conveyed to the laboratory over ice crystals and were subjected to immediate processing to prevent or limit possible proliferation of spoilage microorganisms.

2.2. Preliminary Treatment of the Fish Samples

Upon conveyance of the *Heterotis niloticus* samples to the laboratory, they were thoroughly washed in clean water and then eviscerated to remove gills and intestinal materials, which may otherwise contaminate the final product. After evisceration, samples were washed again in clean water, allowed to drain briefly in perforated containers and then salted by dipping into brine solution (25% w/v salt) for 30 min; they were thoroughly drained in perforated container to remove majority of the resulting water due to osmosis as a result of effect of the brine..

2.3. Drying Processing of Heterotis niloticus

A portion of the eviscerated and salted *Heterotis niloticus* samples was divided into four sub-portions and dried in a pre-heated electric oven (Gallenkamp, USA) at different temperatures of 50, 60, 80, 100 and 120°C to produce four various dried fish samples, coded as SampDried50, SampDried60, SampDried80, SampDried100 and SampDried120 respectively. Samples were dried for different time intervals, varying from 2 to 5 h, depending on the drying temperature (Figure 2); longer time was used for relatively low drying temperatures.

2.4. Smoking Processing of Heterotis niloticus Samples

The other portion of the eviscerated and salted *Heterotis niloticus* samples was subjected to smoking using an improved traditional smoking kiln, with ignited firewood as source of smoke. The temperature of the generated smoke was monitored using a thermometer. The fish samples were placed on the wire gauze of uniform mesh sizes in the kiln and burning firewood was adjusted when necessary to maintain the required temperature of 40-45°C (cold smoking) and 75-80°C (hot smoking) in the kiln chamber. Smoking took approximately 10-15 h and 2-4 h to obtain well smoked fish products for cold and hot smoking respectively (Figure 2).

2.5. Determination of Proximate Components of the African Arowana (Heterotis niloticus) Samples

Proximate components of the *Heterotis niloticus* samples were determined using the methods of Association of Official Analytical Chemists [10]. The components were moisture, ash, fat, and protein; carbohydrate was determined by difference.

Figure 1. *Image of a typical African arowana (Heterotis niloticus).*

2.6. Determination of Free Fatty Acids and Thiobarbituric Acid in the Heterotis niloticus Samples

Free fatty acid (FFA) was determined in the *Heterotis niloticus* fish samples by comminuting 5 g of each sample and extracting the lipid followed by alkali titration. The

standard procedure of AOAC [10] was used in the determination of FFA.

Thiobarbituric acid (TBA) values were determined according to the method described by Brewer *et al*. [11]. Ten grams (10 g) of comminuted samples were blended with 15 ml of cold extracting solution containing 9% perchloric acid. The resulting slurries were transferred quantitatively to 100 ml capacity volumetric flasks and made up to 50 ml each with distilled water. The slurries were filtered through Whatman no. 2 filter paper. Fifty millilitres (50 ml) each of the filtrates was transferred to test tubes and 5 ml of 0.02N TBA reagent was added into each and mixed thoroughly. The tubes were kept in the dark for 17 h and the absorbance read at 530 nm with a spectrophotometer (Spectronic 20). TBA values were calculated from the standard solutions of tetraethoxypropane.

2.7. Determination of Total Volatile Nitrogen, Trimethyl Amine Oxide (TMAO), Trimethyl Amine (TMA) in the Heterotis niloticus Samples

Total volatile nitrogen (TVN) was determined by steam distillation during 10 min of 10 g of minced flesh with 2 g MgO and 30 ml of distilled water. Distillate was titrated with 10 mM hydrochloric acid and TVN obtained by AOAC (2005) procedures.

For the determination of trimethyl amine oxide (TMAO) and trimethyl amine (TMA), extracts of the fish samples were prepared by macerating 20 g of samples with 60 ml of an aqueous solution of 5% (w/v) trichloroacetic acid (TCA) for 2 min using Ultra Turrax macerator (IKA-Werke GmbH & Co., Germany). The extracts were allowed to stand for 15 min at 4°C, stirred and filtered through a Whatman #2 filter paper to obtain clear extracts. The clear extracts were made up to 100 ml with 5% TCA solution and kept frozen for analysis.

TMA was measured by the spectrophotometric method described by Tozawa *et al*. [12], and TMAO by reduction with titanium (III) chloride [13].

2.8. Determination of Mineral Components in the Heterotis niloticus Samples

The methods of Saura-Calixto *et al*. [14] and Bonire *et al*. [15] were used for the determination of mineral contents in the fish samples. Potassium and sodium were determined by digesting the ash of the samples with perchloric acid and nitric acid, and then taking the readings on Jenway digital flame photometer (spectronic20). Phosphorus was determined by vanado- molybdate colorimetric method. Calcium and magnesium were determined spectrophotometrically by using Buck 200 atomic absorption spectrophotometer (Buck Scientific, Norwalk) and compared with absorption of standards of the minerals.

2.9. Determination of Amino Acids in the Heterotis niloticus Samples

The slightly modified method of Wang and Cavins [16] was adopted for determination of amino acids in the fish samples. Defatted fish samples were dried and hydrolyzed for 24 h by refluxing in 6N hydrochloric acid (HCL); they were evaporated to dryness, and then dissolved in citrate buffer (pH 2.2). A portion of the hydrolysate with norleucine as internal standard was analysed for amino acids with a Trace GC Ultra gas chromatograph (Thermo Electron Corporation) system which automatically computed the resulting data. Known concentrations of amino acid standards were used to obtain standard curves from which those of samples were extrapolated.

2.10. Determination of Microbial Counts in the Heterotis niloticus Samples

The counts of *Pseudomonas*, coliforms, staphylococci, lactic acid bacteria (LAB) and yeasts and moulds (Y & M) were determined in the *Heterotis niloticus* fish samples using the methods described by Olaoye and Dodd [17]. Kings medium (Oxoid, UK), MacConkey agar (Oxoid, UK), Mannitol salt agar (SigmaAldrich, UK), deMan Rogossa Sharpe (MRS; Oxoid, UK) and Plate count agar (PCA; SigmaAldrich) were used in the enumeration of the respective organisms. Y & M were incubated at 25°C for 72 h and others at 30°C for 24 h. Results were expressed in logarithm of colony forming unit per gram of sample (log CFU/g), except Y & M (log count/g).

2.11. Statistical Analysis

The data obtained, which depended on processing methods (drying and smoking), were analysed using the means of three replicates of each sample. Means were separated and analysed using the *t*-test in data analysis functionality of Microsoft Excel 2010 SP2 (version 14.0.7015.1000) to establish differences. Significant differences among samples were determined at $P < 0.05$.

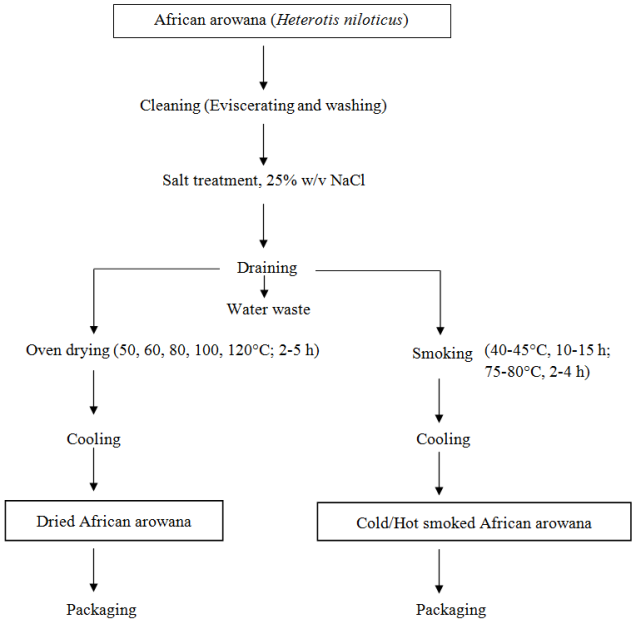

Figure 2. *Flow chart for processing of African arowana (Heterotis niloticus) at low and elevated temperature.*

3. Results and Discussion

In the present finding, samples of African arowana (*Heterotis niloticus*) fish were processed by drying and smoking methods at varying low and elevated temperatures to evaluate their effects on the fish products. The proximate components of the different dried and smoked fish samples are presented in Table 1. There was lower moisture in the dried and smoked samples than in unprocessed fish and significant difference was recorded between them ($p<0.05$). The lower moisture in the processed *Heterotis niloticus* samples could be attributed to the heat application during the drying and smoking processes, which may have caused evaporation of the some of the moisture in the fish, thereby lowering the moisture contents in the samples. Crude protein (%) was lower in the unprocessed sample compared to their processed counterparts; the lowest and highest values of 20.33 and 37.98 were recorded for the unprocessed sample and that dried at 120°C (SampDried120) respectively. Crude protein was not significantly different ($p>0.05$) among the dried and smoked samples, however there was significant difference ($p<0.05$) between them and the unprocessed sample. The seemingly higher crude protein recorded in the processed fish samples than their unprocessed counterpart may be as a result of removal of water during the drying and smoking processes which may have resulted in reduced moisture contents, causing concentration of other dry matter. In a research investigation reported by Oyero *et al.* [18] and Holma and Maalekuu [19], it was noted that increase in crude protein and decrease in the moisture contents of some fish samples occurred after smoking. The result of the present study also corroborates those of similar studies [9,20] where increase in crude protein contents of smoked fish samples was observed.

The trends of crude fat, fibre, ash and carbohydrate contents were similar to that of crude protein where higher values were recorded in the processed samples than in unprocessed counterpart. In a study, Akintola *et al.* [21] reported increase in the contents of ash, fibre and lipid after subjecting giant tiger shrimp to smoking and sun-drying processes. The authors reported attributed the increase to removal of water during the processes, which may further corroborate the findings of the present study. Moreover, Idah and Nwankwo [9] noted similar increase in the proximate composition of fish smoked at different temperatures. The increase recorded in the ash, fibre and protein contents of the dried and smoked fish samples over their unprocessed counterpart in could therefore be of nutritional advantage to consumers of African arowana (*Heterotis niloticus*).

Presented in Table 2 are the chemical indices of the *Heterotis niloticus* fish samples. The chemical indices analysed were free fatty acid (FFA; KOH/g lipid), thiobarbituric acid (TBA; mg MDA/kg), trimethyl amine oxide (TMAO; mg/100g), trimethyl amine (TMA; mg/100g) and total volatile nitrogen (TVN; mg/100g). The highest value of 0.79 was recorded for FFA in the unprocessed sample followed by 0.70, obtained for the SampDried50 sample. The lowest FFA value (0.31) was obtained for the hot smoked sample (SampSmoked75-80). Corresponding reduction in FFA of the samples was recorded with increase in processing temperature, indicating that the SampDried120 and SampSmoked75-80 samples having lower FFA values than others may have better storage stability. The occurrence of FFA has been attributed to lipid degradation in food products (especially meat and fish), which has been noted to associate with deteriorative changes in such products [18]. Trend similar to that of FFA was observed for TBA values of the *Heterotis niloticus* samples; reduction was noted in the TBA values with corresponding increase in processing temperature. Among the processed samples, SampDried120 sample had the lowest value (0.31) while 0.47 was recorded as highest TBA value for SampDried50. In a study, Olaoye [22] reported that TBA results from lipid and degradation or oxidation which is partly responsible for rancidity development and off flavours in meat products.

Table 1. *Proximate components of the African arowana (Heterotis niloticus) samples.*

	Proximate components (%)											
	Moisture		**Crude protein**		**Crude fat**		**Crude fibre**		**Ash**		**Carbohydrate**	
Samples	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**
Unprocessed	68.13^{a}	10.54	20.33^{b}	2.11	2.98^{c}	0.13	0.98^{a}	0.03	1.26^{b}	0.12	1.92^{b}	0.11
SampDried50	54.53^{b}	9.97	30.34^{a}	5.44	4.44^{b}	1.03	0.99^{a}	0.23	3.34^{a}	0.65	2.98^{a}	0.23
SampDried60	54.02^{b}	7.03	32.37^{a}	3.34	4.97^{a}	0.73	1.01^{a}	0.21	3.42^{a}	0.74	2.99^{a}	0.14
SampDried80	51.95^{b}	6.56	33.84^{a}	9.03	5.02^{a}	0.93	1.22^{a}	0.34	3.56^{a}	0.25	3.21^{a}	0.24
SampDried100	50.93^{b}	10.20	37.67^{a}	7.34	5.34^{a}	1.22	1.34^{a}	0.11	3.61^{a}	0.55	3.60^{a}	0.15
SampDried120	45.47^{c}	10.73	37.98^{a}	2.10	5.43^{a}	0.93	1.43^{a}	0.08	3.75^{a}	1.02	3.86^{a}	1.28
SampSmoked45-50	50.36^{b}	10.35	35.34^{a}	3.26	5.02^{a}	1.27	1.08^{a}	0.23	3.98^{a}	1.10	3.74^{a}	0.21
SampSmoked75-80	47.48^{c}	9.03	37.24^{a}	2.13	5.46^{a}	0.05	1.13^{a}	0.06	4.12^{a}	0.84	3.96^{a}	0.66

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ($P < 0.05$).
SD, standard deviation; SampDried50, African arowana dried at 50°C; SampDried60, African arowana dried at 60°C; SampDried80, African arowana dried at 80°C; SampDried100, African arowana dried at 100°C; SampDried120, African arowana dried at 120°C; SampSmoked45-50, African arowana smoked at 45-50°C; SampSmoked75-80, African arowana smoked at 65-75°C.

Table 2. *Chemical indices of the African arowana (Heterotis niloticus) samples.*

	Chemical indices									
	FFA (KOH/g lipid)		TBA (mg MDA/kg)		TMAO (mg/100g)		TMA (mg/100g)		TVN (mg/100g)	
Samples	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**	**Value**	**SD(±)**
Unprocessed	0.79^{a}	0.11	0.29^{b}	0.06	70.13^{a}	11.12	0.54^{c}	0.15	5.27^{d}	0.72
SampDried50	0.70^{b}	0.13	0.47^{a}	0.07	56.97^{b}	11.09	0.76^{b}	0.33	9.88^{a}	1.84
SampDried60	0.65^{b}	0.24	0.42^{a}	0.12	52.37^{b}	8.47	0.91^{b}	0.22	8.54^{a}	0.28
SampDried80	0.57^{b}	0.07	0.38^{a}	0.08	51.26^{b}	7.56	0.98^{b}	0.19	7.56^{b}	0.27
SampDried100	0.45^{c}	0.11	0.35^{a}	0.14	50.65^{b}	4.58	1.12^{a}	0.10	6.98^{c}	1.03
SampDried120	0.41^{c}	0.09	0.31^{b}	0.03	49.83^{b}	11.20	1.18^{a}	0.07	6.74^{c}	0.92
SampSmoked45-50	0.39^{c}	0.10	0.39^{a}	0.10	42.89^{c}	9.23	1.30^{a}	0.11	6.99^{c}	1.55
SampSmoked75-80	0.31^{d}	0.05	0.34^{a}	0.06	41.20^{c}	7.52	1.38^{a}	0.08	6.75^{c}	1.23

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ($P < 0.05$).
MDA, malonaldehyde; SD, standard deviation; SampDried50, African arowana dried at 50°C; SampDried60, African arowana dried at 60°C; SampDried80, African arowana dried at 80°C; SampDried100, African arowana dried at 100°C; SampDried120, African arowana dried at 120°C; SampSmoked45-50, African arowana smoked at 45-50°C; SampSmoked75-80, African arowana smoked at 75-80°C.

The samples with reduced TBA values may therefore have an extended shelf, life, as there is less possibility of rancid development.

The TMA was lowest (0.54 mg/100g) in the unprocessed sample and highest (1.38) in the hot smoked counterpart (SampSmoked75-80). TMA was observed to be lower in the dried samples compared to their smoked counterparts, and significant difference ($p<0.05$) was recorded between them. TMA has been noted to be a product of microbial degradation of trimethyl amine oxide (TMAO), a naturally present molecule in fresh fish [23]. TMA is a pungent volatile amine and its association with spoilage in fish has been reported by Ghaly *et al.* [24] who noted that very low TMA is normally associated with fresh fish, while higher values are found in processed ones due to activity of microbial action. In the present finding, this stated reason could be responsible for the lower values of TMA recorded in unprocessed sample than their processed counterparts, where microbial activities may have taken place during or post processing. The higher TMAO recorded in the unprocessed sample is supportive of the report of Ali *et al.* [23] who carried out on generation of amine compounds in two types of fish, Galda (*Macrobrachium rosenbergii*) and Bagda (*Penaeus monodon*). The result of the total volatile amine (TVN) is similar to that of TMA; it should be noted that TVN and TMA are amine products derived from microbial degradation of TMAO, and both are also indicative of spoilage in most processed fish products.

From the result of the mineral analysis of the *Heterotis niloticus* samples (Table 3), there was increase in the contents (mg/100g) of the different minerals in the processed samples over the unprocessed one. A corresponding increase in the mineral contents occurred with increase in the drying temperatures of the samples, while lowest value was observed in the unprocessed sample. The observation may be due probably to removal of water from the *Heterotis niloticus* samples during the processes of drying and smoking, which may result in concentration of mineral contents. The observation is supported by a study reported by Oyero *et al.* [18] where increase in most of the mineral analysed in smoked fish was noted in comparison to the unsmoked sample. In addition to extension of shelf life (shelf stability) that drying and smoking processes may impart on the dried and smoked fish samples, the increase in mineral contents of the samples over the unprocessed one may be of nutritional advantage.

The essential amino acids in the *Heterotis niloticus* samples indicated that they were present in higher concentrations in dried and smoked samples compared to unprocessed sample (Table 4). The observation could be due to reduction in their moisture contents as a result of the drying and smoking processes, which have been noted to result in increase of the dry matters, including protein composing of amino acids. The result of this study was supportive of the finding of Akintola *et al.* [21].

The microbial quality of the African arowana (*Heterotis niloticus*) samples (Table 5) showed that *Pseudomonas* had lowest count (2.35 log CFU/g), recorded for the hot smoked sample (i.e SampSmoked75-80) while the highest count of 3.54 was obtained for the SampDried50 sample. There was no significant difference ($p>0.05$) between the dried and unprocessed samples in the counts of *Pseudomonas*. The SampDried50 sample also recorded highest counts of 2.84 and 3.99 for coliforms and *Staphylococcus* respectively. No detection was recorded for coliforms in the smoked samples and samples dried at 80^{o}C and above. Counts of lactic acid bacteria (LAB) were between 2.87 and 4.94 log CFU/g, where the SampDried50 sample had the highest count. Yeast and moulds was highest (3.62 log count/g) for the unproccessed sample while the lowest (2.65) was obtained for the hot smoked sample. According to the report of Akintola *et al*. [21], the reduced counts of *Pseudomonas* and coliforms recorded in the processed samples in the present study, may be attributed to reduced water activity and antimicrobial properties of phenolic compounds known to be associated with drying and smoking respectively.

Table 3. *Mineral analysis of the African arowana (Heterotis niloticus) samples.*

	Minerals (mg/100g)									
	Potassium (K)		Calcium (Ca)		Phosphorus (P)		Magnesium (Mg)		Sodium (Na)	
Samples	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)
Unprocessed	68.02^{b}	4.49	34.98^{c}	5.47	55.75^{b}	7.55	14.14^{b}	2.33	123.20^{c}	8.56
SampDried50	69.76^{b}	9.36	36.04^{b}	10.21	58.04^{b}	11.28	14.94^{b}	3.24	125.13^{bc}	7.48
SampDried60	70.66^{a}	12.36	37.83^{b}	4.38	59.97^{a}	5.63	15.75^{b}	1.28	128.05^{b}	11.29
SampDried80	72.45^{a}	10.21	39.45^{a}	11.23	60.97^{a}	7.49	16.88^{b}	8.34	131.23^{a}	8.45
SampDried100	75.53^{a}	11.26	42.83^{a}	9.47	63.46^{a}	10.26	20.13^{a}	3.27	133.57^{a}	13.23
SampDried120	76.38^{a}	15.48	43.04^{a}	5.48	64.37^{a}	6.42	21.20^{a}	2.39	134.24^{a}	16.70
SampSmoked45-50	72.23^{a}	7,45	38.03^{a}	8.23	58.13^{b}	5.47	15.43^{b}	2.37	124.75^{b}	10.25
SampSmoked75-80	72.84^{a}	6.40	39.27^{a}	10.22	59.47^{b}	11.21	16.18^{b}	3.28	125.96^{b}	6.57

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ($P < 0.05$).
SD, standard deviation; SampDried50, African arowana dried at 50°C; SampDried60, African arowana dried at 60°C; SampDried80, African arowana dried at 80°C; SampDried100, African arowana dried at 100°C; SampDried120, African arowana dried at 120°C; SampSmoked45-50, African arowana smoked at 45-50°C; SampSmoked75-80, African arowana smoked at 75-80°C.

Table 4. *Essential amino acids of the African arowana (Heterotis niloticus) samples.*

	Amino acids (g/100g protein)															
	Leucine		Lysine		Methionine		Threonine		Histidine		Isoleucine		Valine		Phenylalanine	
Samples	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)
Raw fish	9.23^{c}	1.12	4.43^{e}	0.54	2.25^{d}	0.54	6.02^{d}	1.23	6.43^{d}	0.83	6.95^{d}	1.03	7.84^{c}	1.73	5.45^{c}	1.23
SampDried50	10.13^{c}	2.14	4.94^{d}	1.02	2.96^{cd}	0.34	7.02^{c}	1.68	7.97^{c}	0.53	8.25^{c}	1.28	8.37^{b}	1.08	5.75^{c}	0.74
SampDried60	10.99^{b}	1.29	6.01^{b}	0.93	3.98^{c}	0.23	8.36^{b}	2.36	9.07^{b}	2.09	8.99^{c}	2.36	9.88^{b}	1.83	7.01^{b}	1.26
SampDried80	12.83^{a}	4.34	7.24^{b}	1.24	5.64^{b}	1.74	9.12^{b}	1.27	10.18^{b}	2.27	9.84^{b}	1.24	10.54^{a}	1.09	7.45^{a}	0.96
SampDried100	14.73^{a}	0.95	9.16^{a}	1.28	7.74^{a}	1.28	11.28^{a}	1.79	10.96^{a}	1.28	10.99^{a}	1.27	11.34^{a}	1.24	8.26^{a}	0.95
SampDried120	15.24^{a}	4.34	9.74^{a}	2.10	8.19^{a}	1.85	11.92^{a}	2.71	11.27^{a}	0.92	11.47^{c}	0.38	12.09^{a}	3.27	9.12^{a}	1.27
SampSmoked 45-50	10.63^{c}	1.27	5.76^{b}	1.24	3.57^{c}	0.33	6.92^{c}	0.34	7.76^{c}	1.08	8.74^{c}	2.03	9.03^{b}	0.47	5.88^{c}	0.73
SampSmoked 75-80	11.98^{b}	2.38	6.10^{b}	1.29	4.10^{c}	0.27	7.75^{c}	1.17	8.62^{c}	1.27	9.17^{c}	0.38	9.75^{b}	1.29	6.79^{c}	1.20

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ($P < 0.05$).
SD, standard deviation; SampDried50, African arowana dried at 50°C; SampDried60, African arowana dried at 60°C; SampDried80, African arowana dried at 80°C; SampDried100, African arowana dried at 100°C; SampDried120, African arowana dried at 120°C; SampSmoked45-50, African arowana smoked at 45-50°C; SampSmoked75-80, African arowana smoked at 75-80°C.

Table 5. *Microbial quality of the African arowana (Heterotis niloticus) samples.*

	Microorganisms											
	Pseudomonas (log CFU/g)		Coliforms (log CFU/g)		Staphylococcus (log CFU/g)		LAB (log CFU/g)		Yeasts/moulds (log CFU/g)		Total Bacteria (log CFU/g)	
Samples	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)	Value	SD(±)
Unprocessed	3.25^{a}	0.05	2.73^{a}	0.36	3.24^{b}	0.34	4.65^{a}	0.37	3.83^{a}	0.45	5.48^{a}	018
SampDried50	3.54^{a}	0.74	2.84^{a}	0.34	3.99^{a}	0.35	4.94^{a}	0.14	3.51^{a}	1.04	5.24^{a}	1/02
SampDried60	3.41^{a}	0.36	2.13^{a}	0.37	3.79^{a}	0.45	4.70^{a}	0.34	3.47^{a}	0.44	5.03^{b}	0.09
SampDried80	3.35^{a}	0.48	ND	-	3.35^{a}	1.02	3.76^{ab}	0.29	3.31^{a}	0.25	4.74^{b}	1.28
SampDried100	3.10^{a}	0.56	ND	-	2.73^{b}	0.46	3.29^{b}	0.73	2.83^{b}	0.15	4.56^{b}	0.37
SampDried120	2.77^{a}	0.06	ND	-	2.20^{b}	0.13	2.93^{c}	1.03	2.35^{b}	0.22	2.34^{d}	0.47
SampSmoked45-50	2.79^{b}	0.33	ND	-	2.31^{b}	0.24	3.12^{c}	0.66	3.14^{a}	0.53	3.98^{c}	1.27
SampSmoked75-80	2.35^{b}	0.73	ND	-	2.17^{b}	0.15	2.87^{c}	0.37	2.65^{a}	0.26	2.56^{c}	0.92

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ($P < 0.05$).
CFU, colony forming unit; SD, standard deviation; SampDried50, African arowana dried at 50°C; SampDried60, African arowana dried at 60°C; SampDried80, African arowana dried at 80°C; SampDried100, African arowana dried at 100°C; SampDried120, African arowana dried at 120°C; SampSmoked45-50, African arowana smoked at 45-50°C; SampSmoked75-80, African arowana smoked at 75-80°C.

4. Conclusion

From the results obtained in this study, it was concluded that hot smoking and drying at elevated temperatures resulted in enhanced quantitative increase in the proximate components of *Heterotis niloticus* fish samples. Furthermore, hot smoking and drying at elevated temperatures of 80, 100 and 120°C could extend shelf life of *Heterotis niloticus* as a result of reduction TBA and FFA values. The reduced moisture contents obtained in the dried fish samples could

contribute positively to their shelf stability.

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