

## Assessment of Physicochemical Properties and Microbiological Profile of Smoked and Dried *Tilapia (Oreochromis niloticus* Linnaeus 1758), a Popular Fish Commonly Consumed in Western Nigeria

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### Abstract

Five fresh samples of *Tilapia* fish were used in this study; a sample was subjected to smoking while others were dried (Drd) separately at different temperatures of 45°C (Drd45°C), 65°C (Drd65°C), 80°C (Drd80°C) and 100°C (Drd100°C). The physicochemical and microbiological qualities of the resulting products were analysed. Results indicated that the Drd100°C and smoked samples had the highest protein and ash contents of 35.02% and 3.86% respectively. The lowest free fatty acid (0.37 KOH/g lipid) was recorded for the smoked sample while 0.36 mg MDA/kg was recorded as Thiobarbituric acid value for Drd100°C. The Drd100°C sample had the highest potassium, calcium, phosphorus, sodium and magnesium contents (mg/100g) of 75.48, 43.26, 64.38, 134.83 and 19.26 respectively. Essential amino acids of the fish samples were higher in the Drd100°C sample than others ( $P < 0.05$ ). Microbial analysis indicated that *Pseudomonas* and *Staphylococcus* had the lowest counts of 2.76 and 2.27 log CFU g<sup>-1</sup> respectively in the smoked sample. Unlike other bacteria, no detection of coliforms was recorded in DRd80°C, Drd100°C and smoked samples. From the results obtained, it was concluded that drying at temperatures of 80 and 100°C, and smoking could be adopted in processing of *Tilapia*, having good physicochemical and microbiological qualities during storage.

**Keywords:** Drying; Essential Amino Acids; Minerals; Smoking; *Tilapia*; Thiobarbituric Acid

### Introduction

Fish is a highly nutritious food and it is particularly valued for its high-quality protein compared to those of meat and egg [1]. It contains high quality protein, amino acids and absorbable dietary minerals [2]. 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 favorable medium for the growth of microorganisms after death [3,4]. It has become very important to ensure that fish once caught is fully and efficiently processed and utilized to avoid deterioration in quality which may ultimately result in wastage.

*Tilapia (Oreochromis niloticus)* are group of fish species native to Africa, however, they have been introduced in many other countries around the world. They are disease-resistant, reproduce easily, eat a wide variety of foods and tolerate poor water quality with low dissolved oxygen levels. Most will grow in brackish water and some will adapt to full strength sea water [5]. These characteristics make *Tilapia* well adapted to the environmental conditions of Africa and most developing countries.

In order to prolong the shelf life of fish, it is usually preserved by many processes such as drying, canning and smoking among others. Dried fish is a major component of harvested fisheries in many countries of the tropics, especially Nigeria. An average of about 30% of the world fish catch is consumed in the dried, salted, smoked forms or combination of these processes [3]. Some of these preservation methods have various effects on the

physical and nutritional quality of fish [4]. Among the traditional processes used for preservation of fish, drying and smoking rank highest with the primary objective of preventing spoilage thereby ensuring availability. The desirable effect of preservation by the two 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 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.

Drying and smoking methods of fish preservation vary between different countries and may also depend on the species of fish being processed as well as the specific quality 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 countries such as Nigeria, and traditional methods have been well adopted because of their relative cheapness which require 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].

The present study reports the assessment of physicochemical properties and microbiological profile of dried and smoked *Tilapia*, a popular fish in many countries, and commonly consumed in the Western part of Nigeria. The effect of drying of the fish at different temperatures on the associated thiobarbituric acid value, essential amino acids and minerals was also investigated.

## Materials and Methods

### Source of materials

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

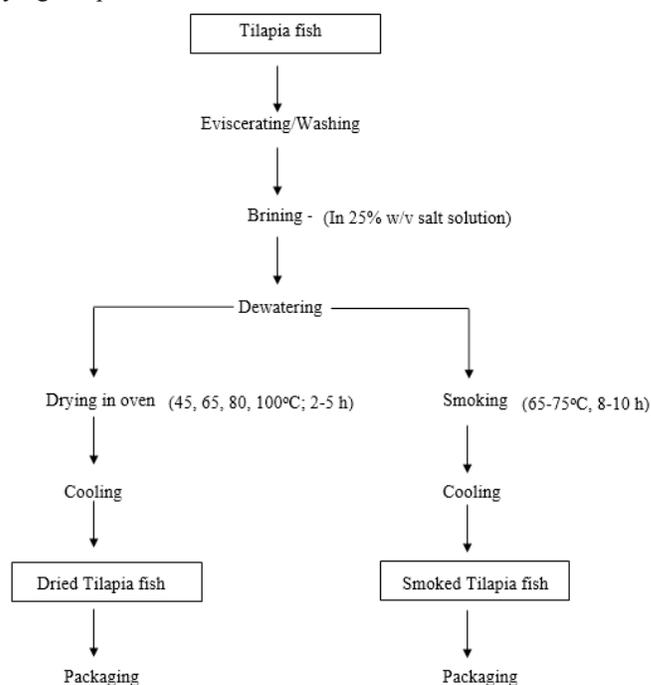
### Preliminary Treatment of the Fish Samples

Upon conveyance of the fish 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 (about 20 min) in clean perforated containers and then salted by dipping into brine solution (25% w/v salt) for 30 min; they were then thoroughly drained in perforated container to remove majority of the resulting water as a result of effect of the brine.

### Drying Processing of Fish Samples

Four portions of the five eviscerated and salted fish samples were dried in a pre-heated electric oven (Gallenkamp, USA) at different temperatures of 45, 65, 80 and 100°C to produce four various dried fish samples, coded as Drd45°C, Drd65°C, Drd80°C and Drd100°C respectively. Samples were dried at different time intervals, varying from 2 to 5 h, depending on the drying temperature (Figure 1); longer time was required for relatively low drying temperatures.



**Figure 1:** Flow chart for production of dried and smoked *Tilapia* fish samples.

### Smoking Processing of Fish Samples

The fifth portion of the eviscerated and salted fish 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 mesh in the kiln and burning firewood was adjusted when necessary to maintain the required temperature of 65-75°C in the kiln chamber. Smoking took approximately 8-10 h to obtain well smoked fish product. Flow chart for the smoking process is shown in (Figure 1).

## Determination of Proximate Composition

Proximate analysis was carried out on the raw, dried and smoked *Tilapia* samples. The proximate parameters including moisture, ash, fat, and protein contents of the samples were determined using the methods of Association of Official Analytical Chemists [10]. Carbohydrate was determined by difference.

## Determination of Free Fatty Acids and Thiobarbituric Acid

Free Fatty Acid (FFA) was determined in the 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 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.

## Determination of total volatile nitrogen, Trimethyl Amine Oxide (TMAO), Trimethyl Amine (TMA)

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 [10] 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].

## Determination of Mineral Composition

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.

## Determination of Amino Acids

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 hydrolysed 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.

## Microbial Analysis

The counts of *Pseudomonas*, coliforms, staphylococci, Lactic Acid Bacteria (LAB) and Yeasts and Moulds (Y & M) were determined in the fish samples using the methods described by Olaoye and Dodd [17] (2010). 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).

## Statistical Analysis

The data obtained, which depended on processing methods, 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  $P < 0.05$ .

## Results and Discussion

The proximate composition of the different dried and smoked fish samples is shown in (Table 1). The raw fish had the highest moisture content of 69.93%; this was expected because drying and smoking normally involve removal of moisture from foods during drying and smoking processes [18]. The reduction in moisture content in the smoked and dried samples generally had

considerable effects on other proximate parameters in comparison with the raw samples; there was increase in values of crude protein, crude fat, crude fibre, ash and carbohydrate in the processed samples compared to their raw counterpart. This indicates possible effect of the smoking and drying processes on the products. Moisture was lower in the dried and smoked samples than those in the raw fish ( $P < 0.05$ ), and this could obviously be due to the heat involved during drying and smoking processes. The heat may have brought about evaporation of part of the moisture in the fish, thereby lowering the moisture contents in the dried and smoked fish samples. Crude protein was lower in the raw fish samples than others; the lowest and highest values of 22.71% and 35.02% were recorded for the raw fish sample and the one dried at 100°C (Drd100°C) respectively. Values of crude protein were higher than 30% in the dried and smoked samples, and no significant difference was observed between them ( $P > 0.05$ ); they were however significantly different from those of the raw sample ( $P < 0.05$ ). The higher content of crude protein observed in the dried and smoked fish samples than their raw counterpart could be attributed to removal of water during processing, which may have resulted in reduced moisture contents and hence concentration of other dry matter. The increase in the crude protein and decrease in the moisture contents of some smoked fish samples reported in research investigations by Oyero et al. [19] and Holma and Maalekuu [18] is supportive of the result obtained in the current study. In other related studies, Ogbonnaya [5] and Idah and Nwankwo [9] also observed increase in crude protein contents of *Tilapia* fish samples after smoking, thus further justifying the results of the present study.

Fish samples	Proximate parameters (%)											
	Moisture		Crude protein		Crude fat		Crude fibre		Ash		Carbohydrate	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Raw fish	69.93 <sup>a</sup>	15.48	22.71 <sup>b</sup>	1.27	3.04 <sup>c</sup>	0.18	0.93 <sup>a</sup>	0.08	1.23 <sup>b</sup>	0.05	2.16 <sup>b</sup>	0.02
Drd45°C	55.87 <sup>b</sup>	10.12	32.72 <sup>a</sup>	8.21	4.23 <sup>b</sup>	1.24	0.97 <sup>a</sup>	0.12	3.09 <sup>a</sup>	0.72	3.12 <sup>a</sup>	0.06
Drd65°C	53.88 <sup>b</sup>	6.59	33.98 <sup>a</sup>	3.28	4.91 <sup>a</sup>	0.82	0.97 <sup>a</sup>	0.14	3.12 <sup>a</sup>	0.27	3.14 <sup>a</sup>	0.29
Drd80°C	53.40 <sup>b</sup>	3.41	34.18 <sup>a</sup>	9.03	4.98 <sup>a</sup>	1.03	1.01 <sup>a</sup>	0.03	3.16 <sup>a</sup>	0.32	3.27 <sup>a</sup>	0.16
Drd100°C	51.82 <sup>b</sup>	9.27	35.02 <sup>a</sup>	1.72	5.12 <sup>a</sup>	0.48	1.02 <sup>a</sup>	0.07	3.23 <sup>a</sup>	0.37	3.79 <sup>a</sup>	0.34
Smoked fish	51.78 <sup>b</sup>	4.46	34.86 <sup>a</sup>	8.15	4.85 <sup>a</sup>	0.93	0.99 <sup>a</sup>	0.14	3.86 <sup>a</sup>	1.02	3.68 <sup>a</sup>	0.48

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ( $P < 0.05$ ). SD, standard deviation; Drd45°C, fish sample dried at 45°C; Drd65°C, fish sample dried at 65°C; Drd80°C, fish sample dried at 80°C; Drd100°C, fish sample dried at 100°C

**Table 1:** Proximate compositions of the dried and smoked *Tilapia* fish Samples.

Crude fat, fibre, ash and carbohydrate contents assumed similar trends to that of crude protein; higher values were recorded in the dried and smoked samples than in raw sample. Similar reasons given for the trend in crude protein could be applicable to those of other proximate parameters. Akintola et al. [20] reported increase in the contents of ash, fibre and lipid after subjecting a sea food (giant tiger shrimp, *Penaeus monodon*) to smoking and sun-drying processes; according to the authors, removal of water during these processes may be responsible for the increase recorded in the proximate parameters. This observation further corroborates the findings of the present report. Furthermore, in their report Idah and Nwankwo [9] noted similar increase in the proximate composition of *Tilapia* fish smoked at different temperatures. The increase recorded in the ash, fibre and protein contents of the dried and smoked fish samples over their raw counterparts in the current report could therefore be of nutritional advantage to consumers of *Tilapia*.

(Table 2) shows the chemical properties of the different fish samples, including 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; expressed as mg N g<sup>-1</sup>). The highest value of 0.82 was recorded as FFA in the raw sample followed by 0.71 in the Drd45°C sample. The lowest FFA value of 0.37 was obtained for the smoked fish sample. There was corresponding reduction in FFA of the fish samples with increase in processing temperature; this suggests that the Drd100°C and smoked samples having lower FFA values than others may have enhanced storage stability over other samples. This is because FFA usually occurs as a result of lipid degradation in food products (especially meat and fish) and has been noted to be associated with deteriorative changes in such products [19]. A similar trend was observed for TBA values of the fish samples; there was reduction in TBA with corresponding increase in processing temperature. The Drd100°C had the lowest value of 0.36 among the smoked and dried samples, while 0.43 was recorded as highest TBA value for the Drd45°C sample. Olaoye [21] reported that TBA results from lipid and degradation or oxidation which partly responsible for rancidity

development and off flavours in meat products. The fish samples with reduced values of TBA may therefore have an extended shelf life compared to others due to less possibility of rancid development.

Fish samples	Chemical properties									
	FFA (KOH/g lipid)		TBA (mg MDA/kg)		TMAO (mg/100g)		TMA (mg/100g)		TVN (mg N g <sup>-1</sup> )	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Raw fish	0.82 <sup>a</sup>	0.02	0.31 <sup>b</sup>	0.01	69.02 <sup>a</sup>	10.02	0.56 <sup>c</sup>	0.02	5.10 <sup>d</sup>	0.81
Drd45°C	0.71 <sup>b</sup>	0.06	0.43 <sup>a</sup>	0.15	57.23 <sup>b</sup>	2.36	0.84 <sup>b</sup>	0.15	9.72 <sup>a</sup>	1.27
Drd65°C	0.63 <sup>b</sup>	0.11	0.41 <sup>a</sup>	0.07	51.93 <sup>b</sup>	5.18	0.97 <sup>b</sup>	0.19	8.36 <sup>a</sup>	0.55
Drd80°C	0.55 <sup>b</sup>	0.16	0.37 <sup>a</sup>	0.11	53.05 <sup>b</sup>	8.23	0.91 <sup>b</sup>	0.2	7.35 <sup>b</sup>	0.38
Drd100°C	0.41 <sup>c</sup>	0.03	0.36 <sup>a</sup>	0.09	50.27 <sup>b</sup>	8.44	1.05 <sup>a</sup>	0.08	6.72 <sup>c</sup>	0.92
Smoked fish	0.37 <sup>c</sup>	0.07	0.40 <sup>a</sup>	0.1	43.61 <sup>c</sup>	2.19	1.27 <sup>a</sup>	0.24	6.97 <sup>c</sup>	1.06

Values are means of three replicated samples; Means with different superscripts across columns are significantly different (P < 0.05). FFA, Free Fatty Acids; PV: Peroxide Value; TBA: Thiobarbituric Acid; TMAO: Tri-Methyl Amine Oxide; TMA: tri-Methyl Amine; TVN: Total Volatile Nitrogen; MDA: Malonaldehyde; SD: Standard Deviation; Drd45°C, fish sample dried at 45°C; Drd65°C, fish sample dried at 65°C; Drd80°C, fish sample dried at 80°C; Drd100°C, fish sample dried at 100°C

**Table 2:** Chemical properties of the dried and smoked *Tilapia* fish samples.

The trimethyl amine (TMA; mg/100g) was lowest (0.56) in the raw fish sample and highest (1.27) in the smoked counterpart. TMA was generally lower in dried samples than their smoked counterparts, and significant difference was recorded between them (P < 0.05). TMA has been reported as a product of microbial degradation of Trimethyl Amine Oxide (TMAO), a naturally present molecule in fresh fish [22]. TMA is usually a pungent volatile amine which has been reported to be associated with spoilage in fish [23]. According to Ghaly et al. [23], very low TMA is usually associated with fresh fish, while higher values are found in processed ones due to activity of microbial action especially on TMAO. In the present study, the aforementioned reason could be responsible for the lower values of TMA recorded in the raw fish sample than the dried and smoked samples, where microbial activities may have taken place during processing. The higher TMAO recorded in the raw fish sample is supportive of the findings of Ali et al. [22] during a study carried out on generation of some amine compounds from two types of fish, Galda (*Macrobrachium rosenbergii*) and Bagda (*Penaeus monodon*). The trend of the Total Volatile Amine (TVN) is similar to that of TMA; TVN and TMA are both amine products derived from microbial degradation of TMAO and are also indicative of spoilage in most processed fish products.

The result of the different minerals analysed in the fish samples are presented in (Table 3); the minerals included Potassium (K), Calcium (Ca), Phosphorus (P), Sodium (Na) And Magnesium (Mg). Result showed that increase was recorded in the contents (mg/100g) of the different minerals in the dried and smoked fish samples compared to the raw sample. There was corresponding increase in the mineral contents with increase in the drying temperatures of the samples, and the lower values were observed in the raw sample. This may be attributed to removal of water from the fish samples during the processes of drying and smoking, which could result in concentration of the mineral contents on weight per moisture basis. The result is supported by a study carried out by Oyero et al. [19] who noted increase in most of the minerals analysed in smoked *Tilapia* fish compared to the un-smoked raw sample. Besides the extension of shelf life and relatively shelf stability that drying and smoking processes may confer on the dried and smoked fish samples in the present study, increase in mineral contents recorded in the samples over the raw counterpart may be of nutritional significance to consumers of the fish product.

Fish samples	Minerals (mg/100g)									
	Potassium (K)		Calcium (Ca)		Phosphorus (P)		Sodium (Na)		Magnesium (Mg)	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Raw fish	67.78 <sup>b</sup>	2.36	35.22 <sup>c</sup>	3.28	56.26 <sup>b</sup>	10.26	122.15 <sup>c</sup>	10.27	14.20 <sup>b</sup>	1.29

Drd45°C	69.44 <sup>ab</sup>	12.27	37.35 <sup>b</sup>	7.72	57.32 <sup>b</sup>	3.37	124.46 <sup>bc</sup>	21.25	14.72 <sup>b</sup>	2.81
Drd65°C	70.52 <sup>a</sup>	17.49	38.99 <sup>ab</sup>	3.73	59.88 <sup>a</sup>	10.28	127.25 <sup>b</sup>	13.25	15.28 <sup>b</sup>	0.92
Drd80°C	72.12 <sup>a</sup>	9.83	41.27 <sup>a</sup>	0.97	61.26 <sup>a</sup>	11.27	130.34 <sup>a</sup>	13.93	16.15 <sup>b</sup>	2.38
Drd100°C	75.48 <sup>a</sup>	10.72	43.26 <sup>a</sup>	10.24	64.38 <sup>a</sup>	9.83	134.83 <sup>a</sup>	9.96	19.26 <sup>a</sup>	4.32
Smoked fish	72.16 <sup>a</sup>	8.26	37.86 <sup>a</sup>	5.46	57.74 <sup>b</sup>	7.55	125.40 <sup>b</sup>	7.23	15.01 <sup>b</sup>	3.05

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ( $P < 0.05$ ). SD: Standard Deviation; Drd45°C, fish sample dried at 45°C; Drd65°C, fish sample dried at 65°C; Drd80°C, fish sample dried at 80°C; Drd100°C, fish sample dried at 100°C

**Table 3:** Mineral composition of the dried and smoked *Tilapia* fish samples.

(Table 4) presents the result of the essential amino acids analysed in the fish samples, which included leucine, lysine, methionine, threonine, histidine, isoleucine, valine and phenylalanine. Result indicated that almost all the amino acids have higher values in the dried and smoked fish products than in raw sample. This may be due to reduction in their moisture contents as a result of the drying and smoking processes, thereby increasing the dry matters and hence the protein contents which compose of the amino acids. The result of the amino acids recorded in this study was supported by finding of Akintola et al. [20] who noted similar observation in a smoked and dried seafood, giant tiger shrimp (*Penaeus monodon*).

Fish samples	Amino acids (g/100g protein)															
	Leucine		Lysine		Methionine		Threonine		Histidine		Isoleucine		Valine		Phenylalanine	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Raw fish	8.84 <sup>c</sup>	0.26	4.03 <sup>c</sup>	0.03	2.04 <sup>d</sup>	0.02	5.83 <sup>d</sup>	1.02	6.01 <sup>d</sup>	1.28	6.64 <sup>d</sup>	0.92	7.48 <sup>c</sup>	1.2	5.04 <sup>c</sup>	0.08
Drd 45°C	9.99 <sup>b</sup>	1.27	4.63 <sup>d</sup>	0.66	2.83 <sup>d</sup>	0.15	6.97 <sup>c</sup>	2.11	7.73 <sup>c</sup>	2.16	7.99 <sup>c</sup>	0.55	8.73 <sup>b</sup>	0.83	5.64 <sup>c</sup>	0.35
Drd 65°C	11.02 <sup>b</sup>	2.35	5.82 <sup>b</sup>	1.02	3.75 <sup>c</sup>	0.64	8.02 <sup>b</sup>	0.93	8.84 <sup>b</sup>	1.75	8.53 <sup>c</sup>	0.73	9.45 <sup>b</sup>	0.99	6.83 <sup>b</sup>	0.77
Drd 80°C	13.34 <sup>a</sup>	0.78	6.99 <sup>b</sup>	0.53	5.02 <sup>b</sup>	1.03	8.93 <sup>b</sup>	0.55	9.99 <sup>b</sup>	0.83	10.03 <sup>b</sup>	2.06	10.27 <sup>a</sup>	0.27	7.34 <sup>a</sup>	1.04
Drd 100°C	15.26 <sup>a</sup>	3.2	9.35 <sup>a</sup>	2.17	7.35 <sup>a</sup>	2.17	10.99 <sup>a</sup>	0.68	11.23 <sup>a</sup>	2.97	11.98 <sup>a</sup>	3.38	11.86 <sup>a</sup>	2.3	8.02 <sup>a</sup>	2.1
Smoked fish	10.24 <sup>b</sup>	0.93	5.45 <sup>b</sup>	0.82	3.26 <sup>c</sup>	0.85	6.75 <sup>c</sup>	1.42	7.86 <sup>c</sup>	0.35	8.02 <sup>c</sup>	1.29	8.93 <sup>b</sup>	1.28	5.73 <sup>c</sup>	0.93

Values are means of three replicated samples; Means with different superscripts across columns are significantly different ( $P < 0.05$ ). SD: Standard Deviation; Drd45°C, fish sample dried at 45°C; Drd65°C, fish sample dried at 65°C; Drd80°C, fish sample dried at 80°C; Drd100°C, fish sample dried at 100°C

**Table 4:** Some essential amino acids in the dried and smoked *Tilapia* fish samples.

The microbial analysis showed that *Pseudomonas* had lowest value of 2.76 log CFU/g in the smoked sample while the highest counts of 3.47 was recorded for the Drd45°C sample (Table 5). No significant difference was recorded between the dried and raw samples in the counts of *Pseudomonas* ( $P > 0.05$ ); however, count in the smoked sample was significantly different from those of others ( $P < 0.05$ ). The Drd45°C also recorded highest counts (log CFU/g) of 2.53 and 4.36 for coliforms and *Staphylococcus* respectively. There was no detection of coliforms in the Drd80°C, Drd100°C and smoked samples. Lactic acid bacteria count of the fish samples were in the range of 3.06 and 4.86 log CFU/g, with the Drd45°C sample having the highest count while the lowest was recorded for the smoked sample. Count (log counts/g) of Yeast and Moulds (Y & M) was highest (3.62) for the Drd65°C sample; the Drd100°C counterpart had

the lowest count of 2.97. The lower counts of *Pseudomonas* and coliforms recorded in the smoked sample than others could be as a result of reduced water activity of the fish and antimicrobial properties of phenolic compounds known to be associated with smoking [20].

Fish samples	Microorganisms									
	Pseudomonas (log CFU/g)		Coliforms (log CFU/g)		Staphylococcus (log CFU/g)		LAB (log CFU/g)		Yeasts/moulds (log count/g)	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Raw fish	3.14 <sup>a</sup>	0.12	2.35 <sup>a</sup>	0.04	3.02 <sup>b</sup>	0.05	4.37 <sup>a</sup>	1.22	3.28 <sup>a</sup>	0.09
Drd45°C	3.53 <sup>a</sup>	0.35	2.53 <sup>a</sup>	0.17	4.36 <sup>a</sup>	0.44	4.86 <sup>a</sup>	0.05	3.45 <sup>a</sup>	0.26
Drd65°C	3.47 <sup>a</sup>	0.09	2.02 <sup>a</sup>	0.52	3.87 <sup>a</sup>	1.29	4.74 <sup>a</sup>	0.17	3.62 <sup>a</sup>	0.77
Drd80°C	3.26 <sup>a</sup>	1.02	ND	-	3.36 <sup>a</sup>	0.64	3.98 <sup>ab</sup>	0.43	3.53 <sup>a</sup>	1.02
Drd100°C	3.02 <sup>a</sup>	0.87	ND	-	2.84 <sup>b</sup>	0.27	3.34 <sup>b</sup>	0.18	2.97 <sup>b</sup>	0.46
Smoked fish	2.76 <sup>b</sup>	0.55	ND	-	2.27 <sup>b</sup>	0.09	3.06 <sup>c</sup>	0.72	3.27 <sup>a</sup>	0.84

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; Drd45°C, fish sample dried at 45°C; Drd65°C, fish sample dried at 65°C; Drd80°C, fish sample dried at 80°C; Drd100°C, fish sample dried at 100°C.

**Table 5:** Microbial counts of the dried and smoked *Tilapia* fish samples.

## Conclusions

This research investigation concluded that drying of the *Tilapia* fish at 80 and 100°C may be better options than at lower temperatures. This is due to the enhancement recorded in protein and mineral contents, as well as reduced contents of FFA, TBA, TMA and TVN. Also, drying and smoking resulted in reduction in the counts of *Pseudomonas* and coliforms in the fish products. The two processes of drying (especially at 80 and 100°C) and smoking are therefore suggested to be adopted in the production of traditional *Tilapia* products, as this may enhance shelf life and storage stability. The findings of this study may also be beneficial to small scale entrepreneurs who may engage in processing of fish by drying and smoking for sale to consumers.

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