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Change in Lipid Quality of Tilapia Fish (*Oreochromis niloticus*) After Different Heat Treatments

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Abstract

Tilapia fish (*Oreochomis niloticus*) has been considered to be popular among the freshwater fishes, economically cheap and more abundant in Nigeria. For this reason, a study was conducted on the effect of traditional processing methods on fatty acid composition of *Oreochomis niloticus* using electric oven (control), sawdust, melon husk and rice bran as different heat treatments. Fatty acid composition was determined using standard analytical technique. The result showed that palmitic and oleic acids had the highest concentrations among saturated and unsaturated fatty acids in all the processed samples, respectively. It was also revealed that samples of *Oreochomis niloticus* recorded decrease in total saturated fatty acid (TSFA) with various heat treatments whereas the same heat treatments enhanced the components of total unsaturated fatty acids (TUFA) and total essential fatty acid (TEFA). It was found that levels of ratio of n–6 PUFA to n–3 PUFA and oleic to linoleic which are used as biomedical index are desirable in all the processed samples of *Oreochomis niloticus* oils. However, heat treatment using sawdust was proven to be of good economic potential.

Keywords: *Oreochomis niloticus*, agricultural wastes, fatty acids.

1. Introduction

Fish has been considered to contain high nutritive value due to the presence of essential mineral, amino acid and fatty acid compositions (Aremu and Ekunode, 2008). It has also been considered to be economically cheap and more abundant (Holland *et al.,* 1991). Among the fresh water fishes, tilapia (*Oreochromis niloticus*) has become popular. Tilapia fish is widely cultured in tropical and sub–tropical regions of the world and constitute the third largest group of farmed fish species especially in Nigeria. Fish is in increasing demand in Nigeria due to high population growth rate, increasing nutritional income cost of meat and other sources of animal protein (Adeyeye and Adamu, 2005; Aremu and Inajoh, 2007). The relatively high percent consumption of fish has been attributed to greater availability of this product at relatively cheaper prices (Aremu *et al.,* 2007).

Heating is one of the common methods in food processing. Heat is applied to foods or fishes in different ways; boiling, baking, roasting, frying and grilling to enhance their flavor and taste and also to increase shelf–life (Oluwaniyi and Dosumu, 2009; Silva *et al.,* 2009). During cooking of fish products, chemical and physical reactions take place that improve or impair their nutritional value. Cooking induces water loss in the fish, but in turn increases its lipid content in most cases, and only some fats are lost in the case of the lean fish species (Gall *et al.,* 1983). However, high temperature processing can potentially damage polyunsaturated fatty acid (PUFA), a generating secondary lipid oxidation product which leads to rancidity and other off flavours in food (Aubourg and Medina, 1997). Omega–3 PUFAs are very susceptible to oxidation which not only affects the sensory attributes of the foods but also contributes to many diseases in human (Shahidi and Miraliakkbari, 2005). Moreover, it has been reported that effect of processing on fish is dependent on the type of cooking method employed (Hearty *et al.,* 2007). FAO (1986) gave three main fish processing methods as drying, salting and smoking. Smoking is the removal of most of the moisture content from the fish and the deposition of preservative chemicals on the fish flesh. Nutritional values of fish regarding their fatty acid profiles have been studied on many commercially important fresh water or marine bony fish species (Aremu and Ekunode, 2008; Ho and Paul, 2009; Huynh and Kitta, 2009).

In view of the increasing demands of fish supply, the present research work was aimed at assessing the effect of processing on the fatty acid composition of tilapia fish (*Oreochromis niloticus*) by using electric oven (control), sawdust, melon husk and rice bran as different heat sources for smoking processes.

2. Materials and Methods

2.1 Sample collection

Fresh tilapia fish (*Oreochromis niloticus*) sample was purchased from a fisherman early in the morning at a popular market in Akwanga town of Nasarawa State, Nigeria. The fish numbering seven weighed about 2 kg was transported in a plastic container to chemistry laboratory of Nasarawa State University, Keffi, Nigeria.

2.2 Sample treatment

All the fish samples were thoroughly washed with tap and distilled water, divided into four equal portions and subjected to different heat treatments as smoking methods. The first portion was dried in an electric oven at about 60^{o}C for 24 h using it as control while the other three portions were smoked in a smoking kiln using sawdust, melon husk and rice bran at different times, respectively. The dried samples were blended separately into fine powder using Kenwood food blender. The powdered portion was put in a plastic container and kept in a refrigerator at about 4^{o}C prior to use.

2.3 Extraction of oils

Oven dried sample was extracted in Soxhlet apparatus with redistilled hexane of Analar grade (British Drug houses, London) for the recovery of undiluted oil. The crude oil extract was made to be free of water by filtering through the anhydrous sodium sulphate salt. The hexane was removed from the oil/hexane mixture by using rotary evaporator.

2.4 Fatty acid analysis

The oil extracted was converted to the methyl ester as using the method described by Akintayo and Bayer (2002). The fatty acid methyl esters were analyzed using a HP 6890 gas chromatograph powered with HP Chemstation Rev. A09.01 [1206] software fitted with a flame ionization detector and a computing integrator. Nitrogen was used as the carrier gas. The column initial temperature was 250^{o}C rising at 5^{o}C/min to a final temperature of 310^{o}C while the injection port and the dector were maintained at 310^{o}C and 350^{o}C, respectively. A polar (HP INNO Wax) capillary column (30 m x 0.5 mm x 0.25 m was used to separate the esters. The peaks were identified by comparison Sigma Chemical Co. (St. Louis, MO, USA).

2.5 Statistical evaluation

The statistical calculations included percentage value, grand mean, standard deviation and coefficient of variation percent (CV%).

3 Results and Discussion

The fatty acid composition of tilapia fish (*Oreochomis niloticus*) species after the application of different heat treatments is presented in Table 1. The most predominant fatty acid was palmitic acid (C16:0) which ranged from 23.08% in sample with rice bran heat treatment to 24.48% in sample fried with electric oven. These results are in agreement with the results obtained for *Oreochomis mossambicus* fish as reported by Dhanapal *et al.* (2012). The oleic acid (C18:1) had the highest concentration (31.77 – 32.37%) among the unsaturated fatty acids. Unusan (2007) has also observed that oleic acid was the most concentrated unsaturated fatty acid in rainbow trout (*Oncrohynchus mykiss*) species after cooking. α–Linolenic acid, an essential fatty acid ranged from 2.36% in sawdust smoked sample to 3.19% in electric oven heat treated sample. Despite the effect of processing the coefficient of variantion (CV%) levels were relatively close ranging from 0.96 in oleic acid to 34.78 in arachidic acid.

Table 2 displays the differences in the fatty acid composition between electric oven and sawdust smoked samples, between electric and melon husk smoked samples, and between electric oven and rice bran smoked samples. Lauric acid (C12:0) recorded decrease in sample smoked with sawdust by 1.9% while increase was observed in smoked samples using melon husk and rice bran by 1.6 and 29.3%, respectively. Myristic and arachidic acids (saturated fatty acids) showed an increase of 2.7% and 36.5%, respectively using rice bran heat

treatment whereas linoleic acid (unsaturated fatty acid) recorded increase in all the samples treated with sawdust, melon husk and rice bran smoking. But surprisingly, α–linolenic acid which is also an unsaturated fatty acid had decrease of 26.0, 25.7 and 7.2%, respectively for the three different heat treatments (Table 2). It has been reported that high temperature processing can potentially damage polyunsaturated fatty acid (PUFA) (Aubourg and Medina, 1997). Shahidi and Miraliakkbari (2005) also reported that n–3 polyunsaturated fatty acids are very susceptible to oxidation which not only affects the sensory attributes of the foods but also contribute to many diseases in human being. The percentage decrease in lignoceric acid (C24:0) accounted for 16.67% in samples smoked with all the heat treatments employed in this study. Margaric (C17:0) and stearic (18:0) acids also recorded decrease in all the samples with different heat treatments. The slight changes in fatty acids profile in samples with different smoking methods may be attributed to effect of thermal cracking on the fatty acids of *Oreochomis niloticus* species as reported by Domiszewski *et al.* (2011); Gall *et al.* (1983) and Finot (1997).

The distribution of results in Table 1 into total saturated fatty acid (TSFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), essential fatty acid (EFA), oleic to linoleic ratio (O/L) is presented in Table 3. The TSFA ranged from 39.72% in sample smoked with sawdust to 42.17% in sample dried in electric oven with an average value of 40.72 ± 1.19 and CV% of 2.92. The average value of TSFA in this report is lower than 53.94% reported for tilapia fish (*Oreochomis mossambicus*) by Dhanapal *et al.* (2012). TUFA consists of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) which ranged from 57.82% in sample dried in electric oven to 60.28% in sample smoked with sawdust with mean value (59.28 ± 11.19%) and CV% (2.01). TUFA values are greater than TSFA values in all the processed samples. TMUFA which are palmitoleic (C16:1), oleic (C18:1) and erucic acids ranged from 40.06% in sample dried in electric oven to 40.19% in sample smoked with melon husk (Table 3). Monounsaturated fatty acids were the most predominant of the total unsaturated fatty acids present in all the samples. The TMUFA obtained in this study is significantly higher than the value obtained in rainbow trout (*Oreochomis niloticus*) after cooking as reported by Unusan (2007). TPUFA makes up linoleic (C18:2), linolenic (C18:3) and arachidonic (C20:4) acids. TPUFA ranged from 17.76% in sample dried in electric oven to 19.81% in sample smoked with sawdust and mean value of 18.87 ± 0.83%. The polyunsaturated fatty acids obtained in this study are also the essential fatty acids (EFA). The omega–3 PUFA (n–3 PUFA) detected were linolenic and arachidonic acids while the omega–6 PUFA (n–6 PUFA) was linoleic acid. n–3 PUFA ranged from 5.0% in sample smoked with sawdust to 5.77% in sample dried in electric oven which showed a mean value of 5.43 ± 0.43% and CV% (7.43) while n–6 PUFA had range values of 11.99 – 14.81%. The n–3 and n–6 fatty acids have critical roles in the membrane structure (Lynch and Thompson, 1984; Kinsella, 1990) and as precursors of eicosanoids. Since they compete for the same enzymes and have different biological roles, the balance between the n–3 and n–6 fatty acids in the diet can be of considerable importance (WHO/FAO, 1994). Linoleic and α–linolenic acids are the most important essential fatty acids required for growth, physiological functions and body maintenance (Salunkhe *et al.,* 1985; Audu *et al.,* 2011). In the present study, the two fatty acids were adequately present in all the samples of *Oreochomis niloticus* therefore the samples will participate well in these functions. The ratio of n–6 PUFA to n–3 PUFA which is used as a biomedical index is proven to be higher than the similar result reported for processed samples of tilapia fish (*Oreochomis mossambicus*) from India (Dhanapal *et al.,* 2012). This high value is an indication that *Oreochomis niloticus* species used in this study obtained in Nigeria is more nutritive. The oleic and linoleic (O/L) acids ratio has been associated with high stability and potentiality of the oil for deep frying fat (Branch *et al.,* 1990). The O/L levels ranged from 2.17 in sample smoked with sawdust to 2.70 in sample treated in electric oven. These values are higher than peanut oil (1.48) (Branch *et al.,* 1990) hence *Oreochomis niloticus* oils may be more stable compared with peanut oil and may also be useful as frying oil. The levels of CV% ranged from 0.01 in TFA to 16.53 in n–6/n–3 PUFA (Table 3).

The differences in the redistribution of fatty acids into saturation and unsaturation are shown in Table 4. TSFA recorded decrease in all the samples smoked with various heat treatments with range values of 2.68% in rice bran smoked sample to 5.81% in sawdust smoked one whereas different heat treatments enhanced the components of TUFA, TMUFA, TPUFA and TEFA. The O/L ratio decreased by 19.63, 13.33 and 9.63% with the application of sawdust, melon husk and rice bran heat treatments, respectively. CV% variously varied between 0.07 to 82.61.

4. Conclusion

The study has presented data on the concentrations of saturated and unsaturated fatty acids in tilapia fish (*Oreochomis niloticus*) subjected to different heat treatments using electric oven (control), sawdust, melon husk and rice bran. The results showed that processed tilapia fish oils contained high level of polyunsaturated fatty acids making it a healthy low–fat food. It was also revealed that various heat treatments enhanced the component of essential fatty acids.

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Table 1: Fatty acids composition (%) of Tilapia fish (*Oreochromis niloticus*) after different heat treatments

Fatty acids	Heat Treatments				Mean	SD	CV%
	Electric oven I	Sawdust II	Melon husk III	Rice bran IV			
Lauric acid (C12:0)	3.11	3.05	3.16	4.02	3.34	0.46	13.76
Myristic acid (C14:0)	5.24	3.78	4.79	5.38	4.80	0.68	14.16
Palmitic acid (C16:0)	24.48	23.45	23.16	23.08	23.54	0.62	2.63
Palmitoleic acid (C16:1)	4.55	4.98	4.40	4.44	4.59	0.26	5.58
Margaric acid (C17:0)	0.61	0.50	0.45	0.49	0.51	0.06	11.76
Stearic acid (C18:0)	8.11	8.03	7.90	7.28	7.83	0.37	4.73
Oleic acid (C18:1)	32.37	32.18	32.52	31.77	32.21	0.31	0.96
Linoleic acid (C18:2)	11.99	14.81	13.91	13.04	13.44	1.23	9.15
Linolenic acid (C18:3)	3.19	2.36	2.37	2.96	2.72	0.47	17.40
Arachidic acid (C20:0)	0.39	0.62	0.29	0.54	0.46	0.16	34.78
Arachidonic acid (C20:4)	2.58	2.64	2.88	2.73	2.71	0.13	4.80
Behenic acid (C22:0)	0.17	0.24	0.13	0.20	0.19	0.05	26.32
Erucic acid (C22:1)	3.14	3.31	3.99	4.01	3.61	0.52	14.31
Lignoceric acid (C24:0)	0.06	0.05	0.05	0.05	0.05	0.003	6.67

SD = Standard deviation; **CV% =** Percentage of coefficient variation

Table 2: Difference in fatty acid composition (%) of tilapia fish (*Oreochromis niloticus*) after different heat treatments

Fatty acids	Heat Treatments			Mean	SD	CV%
	I—II	I—III	I—IV			
Lauric acid (C12:0)	0.06(1.9%)	-0.05(-1.6%)	-0.91(-29.3%)	0.34	0.57	167.6
Myristic acid (C14:0)	1.46(27.9%)	0.45(8.6%)	-0.14(-2.7%)	0.68	0.78	114.7
Palmitic acid (C16:0)	1.03(4.2%)	1.32(5.4%)	1.4(5.7%)	1.25	0.22	17.6
Palmitoleic acid (C16:1)	-0.43(-9.5%)	0.15(3.3%)	0.11(2.4%)	0.23	0.20	86.9
Margaric acid (C17:0)	0.11(18.0%)	0.16(26.2%)	0.12(19.7%)	0.13	0.03	23.1
Stearic acid (C18:0)	0.08(0.9%)	0.21(2.6%)	0.83(10.2%)	0.37	0.46	124.3
Oleic acid (C18:1)	0.19(0.6%)	0.15(0.5%)	0.6(1.9%)	0.31	0.29	93.5
Linoleic acid (C18:2)	-2.82(-23.5%)	-1.92(-16.0%)	-1.05(-8.8%)	1.93	0.89	46.1
Linolenic acid (C18:3)	0.83(26.0%)	0.82(25.7%)	0.23(7.2%)	0.63	0.40	63.5
Arachidic acid (C20:0)	-0.23(-58.9%)	0.1(25.6%)	-0.15(-36.5%)	0.16	0.07	43.75
Arachidonic acid (C20:4)	-0.06(2.3%)	0.3(-11.6%)	-0.15(-5.8%)	0.17	0.13	76.47
Behenic acid (C22:0)	-0.07(-41.2%)	0.04(23.5%)	-0.03(-17.7%)	0.05	0.03	60
Erucic acid (C22:1)	-0.17(-5.4%)	0.85(-27.1%)	- 0.87(-27.7%)	0.63	0.46	73.02
Lignoceric acid (C24:0)	0.01(16.7%)	0.01(16.7%)	0.01(16.7%)	0.01	0.00	0.00

I = Electric oven; **II** = Sawdust; **III** = Melon husk; **IV** = Rice bran; **SD** = Standard deviation; **CV%** = Percentage of coefficient variation

Table 3: Distribution of fatty acids of tilapia fish (*Oreochromis niloticus*) samples according to saturation and unsaturation

Fatty acid %	Heat Treatment				Mean	SD	CV%
	Electric oven I	Sawdust II	Melon husk III	Rice husk IV			
TFA	99.99	100	100	99.99	99.99	0.01	0.01
TSFA	42.17	39.72	39.93	41.04	40.72	1.19	2.91
TUFA	57.82	60.28	60.07	58.96	59.28	1.19	2.01
TMUFA	40.06	40.47	40.91	40.22	40.42	0.37	0.91
TPUFA	17.76	19.81	19.16	18.73	18.87	0.83	4.38
TEFA	17.76	19.81	19.16	18.73	18.87	0.83	4.38
Σn-3 PUFA	5.77	5.0	5.25	5.69	5.43	0.40	7.43
Σn-6 PUFA	11.99	14.81	13.91	13.04	13.44	1.23	9.15
Σn-6/Σn-3 PUFA	2.08	2.96	2.65	2.29	2.50	0.41	16.53
O/L ratio	2.70	2.17	2.34	2.44	2.41	0.21	8.71

TFA = Total fatty acids; **TSFA =** Total saturated fatty acids; **TUFA =** Total unsaturated fatty acids; **TMUFA =** Total monounsaturated fatty acid; **TPUFA =** Total polyunsaturated fatty acids; **TEFA =** Total essential fatty acid; **Σn-3 PUFA =** Total omega-3 PUFA;
Σn-6 PUFA = Total omega-6 PUFA; **Σn-6/Σn-3 PUFA =** Ratio of omega-6 to omega-3;
O/L = Ratio of oleic acid to linoleic acid; **SD** = Standard deviation; **CV% =** Percentage of coefficient variation

Table 4: Difference in fatty acid composition (%) of (*Oreochromis niloticus*) between heat treatments

Fatty acids	Heat Treatments			Mean	SD	CV%
	I—II	I—III	I—IV			
TFA	-0.01(-0.01%)	-0.01(-0.01%)	0.0(0.0%)	0.01	0.00	0.07
TSFA	2.45(5.81%)	2.24(5.3%)	1.31(2.7%)	1.94	0.81	41.75
TUFA	-2.46(-4.25%)	-2.25(-3.9%)	-1.14(-1.9%)	1.95	0.81	4.54
TMUFA	-0.41(-0.01%)	-0.85(-2.12%)	-0.16(-0.39%)	0.47	0.38	80.85
TPUFA	-2.05(-11.54%)	-1.4(-7.88%)	-0.97(-5.46%)	1.47	0.58	39.46
TEFA	-2.05(-11.54%)	-1.4(-7.88%)	-0.97(-5.46%)	1.47	0.58	39.46
Σn-3 PUFA	0.77(13.34%)	0.52(9.01%)	0.08(1.39%)	0.46	0.38	82.61
Σn-6 PUFA	-2.82(-23.52%)	-1.92(-16.01%)	-1.05(-8.76%)	1.93	0.89	46.11
n-6/n-3 PUFA	-0.88(-42.31%)	-0.57(-27.40%)	-0.21(--10.09%)	0.55	0.35	63.64
O/L ratio	0.53(19.63%)	0.36(13.33%)	0.26(9.63%)	0.38	0.15	39.47

I = Electric oven; **II** = Sawdust; **III** = Melon husk; **IV** = Rice bran; **TFA** = Total fatty acids; **TSFA** = Total saturated fatty acids; **TUFA** = Total unsaturated fatty acids; **TMUFA** = Total monounsaturated fatty acid; **TPUFA** = Total polyunsaturated fatty acids; **TEFA** = Total essential fatty acid; **Σn-3 PUFA** = Total omega-3 PUFA; **Σn-6 PUFA** = Total omega-6 PUFA; **Σn-6/Σn-3 PUFA** = Ratio of omega-6 to omega-3; **O/L** = Ratio of oleic acid to linoleic acid;
SD = Standard deviation; **CV%** = Percentage of coefficient variation