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Effect of Cooking Method on the Proximate, Amino Acid, and Fatty Acid Compositions of *Clarias gariepinus* and *Oreochromis niloticus*

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Abstract: The proximate, amino acid and fatty acid compositions of the fillet and oil of two commonly consumed fresh water fishes - *Clarias gariepinus* (Catfish) and *Oreochromis niloticus* (Tilapia) - were evaluated in this study. The samples were separately boiled, roasted (over hot charcoal) and fried using different types of oils (palm oil, groundnut oil, soybean oil and refined palm oil) and the effect of the processing methods on the nutritional composition was determined. The moisture content ranged from 76.27% for catfish to 79.97% for tilapia while the oil content ranged from 7.80% for tilapia and 11.00% for catfish. Ash content was in the range 8.03 – 9.16% and the protein content was 15.83 - 18.48%. The cooking methods resulted in a variation in the nutrient composition but no significant variation was observed in the amino acid composition except for the samples fried with palm oil which recorded significantly reduced essential amino acid contents. All the fish samples – both fresh and processed – have amino acid scores less than 100, with lysine, threonine and the sulfur-containing amino acids being among the limiting amino acids. Both fish samples contain more unsaturated than saturated fatty acids.

Keywords: Fish; proximate composition; fatty acid; amino acid.

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INTRODUCTION

Fishes are highly nutritious, tasty, and easily digested protein source for a large population in many developing countries. While marine fishes are generally cheaper when compared with fresh water fishes in Nigeria (1), fresh water fishes are increasingly becoming more abundant, constituting close to 70% of the total fish supply in Nigeria (2). Freshwater fishes are found in freshwater bodies, including streams, rivers, ponds and so on (3). They are available and abundant in riverine areas. About 41% of all known fish species are found in fresh water. In Nigeria and other developing nations of the world, fish is a very common and abundant animal protein source because it is cheaper than meat and the supply is relatively stable (4). About 60% of people in many developing countries are believed to depend on fish for more than 30% of their animal protein supplies (5).

Fishes generally contain very high moisture content, very little carbohydrate, and vitamins and minerals in trace quantities (1). Most fish species contain between 60 – 80% moisture, 15 – 26% protein and 2 – 13 % fat (6). The fat contents vary with species, age, size, and season. Fishes that are high in oil are known as fatty or oily fish and the dry matter may contain as much as 30% oil, while those that are low in oil are known as white fish. Fishes are generally rich in all essential amino acids, especially those that are in low quantity in cereals such as lysine. Fish protein can therefore serve as an amino acid supplement, improving the amino acid supply and the quality of protein in the diet (7).

The part of fish that is mostly consumed is the muscle (8) and it contributes both fatty acids and amino acids to diets. Ordinarily, consumption of animal protein usually results in a high consumption of saturated fats which is quite unhealthy for the heart; however, fish consumption does not have that problem because of its low content of fats generally and saturated fatty acids in particular. It affords the patient the opportunity to obtain good quality dietary protein without excessive fat consumption. Fish is therefore recommended for a good cardiac health.

Several varieties of fish species abound in the various water bodies in Nigeria and they serve both as food and as economic resource to the country. Prominent among these species are croakers, catfishes, tilapias, threadfins, soles and the clupeids and these account for close to 90% of Nigeria's fishes (9). This represents a major source of animal protein supply to Nigeria, which ordinarily has low protein consumption (10). In recent times, there has been an increase in fish farming in Nigeria, especially of African catfish (*Clarias gariepinus*) and the tilapia family because they grow very fast and also because of their ability to tolerate different environmental conditions and temperatures (11).

The two fish species chosen for this work were because of their abundance and good consumer acceptance. *Clarias gariepinus* is one of the most farmed fish in tropical and sub-tropical Africa and many Nigerians now farm the species either as a hobby or as a means of livelihood. *Oreochromis niloticus*, though not as farmed as *C. gariepinus,* is highly prolific and low in fat. In spite of the economic values and availability of these fishes, there is limited data on the nutritional composition of the samples and especially how processing may affect the nutritional quality. Previous report on marine water fishes (1), (4) have shown that processing does affect the nutritional and amino acid composition of marine water fishes, generally leading to a reduction in the nutritional values.

This work therefore aims to determine the proximate, fatty acid and amino acid composition of two freshwater fish species and to determine how the different methods of boiling, roasting and frying with different types of oil may affect these parameters.

MATERIALS AND METHODS

Collection and preparation of samples

Two freshwater fish species were used in this study - African sharp-tooth Catfish *(Clarias gariepinus)* and Tilapia (*Oreochromis niloticus)*. The samples were obtained fresh in October 2013 from different sources. African catfish (average weight: 0.9 kg, length: 340 mm) was obtained from a private fish farm (pond) in Tanke area, Ilorin, Kwara State, Nigeria while Tilapia (average weight: 0.5 kg, length: 190 mm) was obtained from Kainji Dam, Niger State, Nigeria. The fishes were obtained live.

Sample Treatment

Upon arrival at the laboratory, the fish samples were washed and cut into pieces. The head and viscera were removed and the pieces were thoroughly washed again with domestic water and then with distilled water. The pieces (about 90 g each) were separated into seven parts. One of the seven divisions was set apart as the control (raw), one was boiled and another roasted. The remaining four parts were separately deep-fried in four different cooking oils (palm oil, soybean oil, refined, decolorized palm oil and groundnut oil). Common procedures for preparation of fish for table consumption were followed. The boiling was done with domestic water for 10 minutes until the pieces were tender; the roasting was carried out with heat from hot charcoal for about 15 minutes and the deep – frying was done in a frying pan for 15 minutes. No ingredient or additive was added for the cooking. The bones were removed from the samples but the skin was not removed. The fish fillets were then mashed and the moisture content was determined immediately. The dried samples (after moisture content determination) were ground using mortar and pestle, wrapped in aluminum foil and then polyethylene bags before they were labelled and refrigerated (4).

Analytical Procedures

Standard methods of the Association of Official Analytical Chemists (AOAC) were adopted for the analyses of the samples (12). 2.0 g of each sample was heated to a constant weight in a crucible placed in an oven maintained at 105 °C to determine the moisture content. Crude fat was determined using a Soxhlet extractor and n-hexane as the extractant. Nitrogen content was determined by the Kjeldahl method, using 2.0 g of dried, defatted samples the crude protein was calculated as % total nitrogen x 6.25. Ash was determined by the incineration of 1.0 g of dried, defatted samples placed in a muffle furnace at 550°C for 5 hours.

The fatty acid profile of the oils extracted from the samples was determined by Gas Chromatography. The oil samples were re- extracted with redistilled n-hexane, filtered through anhydrous Na_2SO_4 and the solvent was removed using a rotary evaporator (12). The oil sample was then saponified for about 5 min at 95 °C with 0.5 M KOH in dry ethanol. The mixture was neutralized using 0.7 M HCl followed by the addition of 14 % BF_3 in methanol. The methylation process was completed by heating for 5 min at 90 °C. Identification and quantification of the fatty acids were done by injecting the esterified fat into the injection port of the gas chromatography equipment (HP 6890 powered with HP ChemStation Rev. A 09.01 [1206] Software) with nitrogen as the carrier gas.

Amino acid content determination was carried out by ion exchange chromatography (13), using the Technicon Sequential Multisample (TSM) Amino Acid Analyzer (Technicon Instruments Corporation, Dublin, Ireland). 2.0 g of sample was defatted using chloroform/methanol, hydrolyzed using 6 M HCl and the hydrolysate was injected into the TSM analyzer for separation and characterization. Tryptophan content was not determined.

The amino acid score for the essential amino acids was calculated using the formula (Eq. 1) (14):

$$Amino\ acid\ score = \frac{Amount\ of\ amino\ acid\ per\ sample\ protein\ [mg/g]}{Amount\ of\ amino\ acid\ per\ protein\ in\ reference\ protein\ [mg/g]} \quad \text{(Eq. 1)}$$

The total and percentage essential amino acids [TEAA and TEAA%], total acid amino acids [TAAA], sulfur-containing amino acids [TSAA] and aromatic amino acids [TArAA] were evaluated from the amino acid profile and the predicted protein efficiency ratio (P-PER) was determined using one of the equations of Alsmeyer and co-workers (15) adapted by Adeyeye (16) [*i.e.* P-PER = -0.468 + 0.454(Leu) – 0.105(Tyr)].

Statistical analysis

Results are expressed as mean ± standard deviation of triplicate trials. SPSS version 16.0 was used for the statistical analysis. One way analysis of variance (ANOVA) and Duncan's multiple range tests were carried out and statistical significance of differences were accepted at the 5% limit ($P \leq 0.05$).

RESULTS AND DISCUSSION

The results of the proximate composition of the two species are presented in Table 1. The moisture contents of catfish samples range from 76.27% in the fresh sample to 54.29% in the sample fried in soybean oil. For tilapia fish samples, moisture contents range from 79.97% in the fresh sample to 32.62% in the groundnut oil-fried sample. The moisture content of the two species are in the same range (76.27 – 79.97%) for the fresh samples but tilapia fish appeared to be more affected by processing, especially frying, resulting in a greater loss of the moisture content observed in tilapia than catfish. Catfish has a higher fat content (11%) than tilapia (7.8%). However, tilapia absorbs more fat during frying than catfish, resulting to a higher fat content observed in the fried samples of tilapia than catfish. The ash contents of both species reduce with processing while the protein content of both increase with processing except the protein content of *C. gariepinus* which decreased slightly but not significantly on boiling.

Table 1. Proximate composition of fresh and processed *Clarias gariepinus* and *Oreochromis niloticus*

Proximate Quality	*C. gariepinus* (Fresh)	*C. gariepinus* (Boiled)	*C. gariepinus* (Roasted)	*C. gariepinus* (SOF)	*C. gariepinus* (GOF)	*C. gariepinus* (ReOF)	*C. gariepinus* (POF)
Moisture	76.27 ± 1.07^{a}	74.87 ± 0.15^{a}	63.11 ± 2.16^{b}	54.29 ± 1.89^{c}	60.94 ± 1.06^{b}	60.70 ± 0.91^{b}	62.05 ± 1.00^{b}
Fat (on Dry basis)	11.00 ± 1.21^{a}	14.21 ± 0.12^{a,b}	12.82 ± 0.34^{a,b}	26.52 ± 1.22^{c}	20.07 ± 2.81^{d}	16.53 ± 2.45^{b,d}	26.19 ± 4.23^{c}
Ash (on dry basis)	8.03 ± 0.88^{a}	6.50 ± 2.09^{a,c}	6.73 ± 0.59^{a,c}	4.67 ± 0.26^{b,c}	7.64 ± 2.57^{a,c}	2.39 ± 1.78^{b}	6.25 ± 1.78^{a,c}
Protein (on dry basis)	18.48 ± 0.91^{a}	18.18 ± 0.13^{a}	26.74 ± 1.64^{b,c}	28.23 ± 1.01^{c}	25.60 ± 1.16^{b,d}	28.39 ± 0.49^{c}	23.82 ± 1.96^{d}
	***O. niloticus* (Fresh)**	***O. niloticus* (Boiled)**	***O. niloticus* (Roasted)**	***O. niloticus* (SOF)**	***O. niloticus* (GOF)**	***O. niloticus* (ReOF)**	***O. niloticus* (POF)**
Moisture	79.97 ± 0.16^{a}	74.89 ± 0.81^{b}	66.03 ± 0.34^{c}	46.09 ± 0.41^{d}	32.62 ± 0.61^{f}	48.55 ± 0.21^{e}	33.77 ± 0.83^{g}
Fat (on Dry basis)	7.80 ± 0.39^{a}	13.08 ± 0.63^{b}	13.59 ± 0.48^{b}	36.08 ± 1.29^{c,d}	32.54 ± 4.43^{c}	32.46 ± 0.54^{c}	37.80 ± 1.23^{d}
Ash (on dry basis)	9.16 ± 0.62^{a}	6.69 ± 1.49^{b,d}	8.67 ± 0.85^{a,c}	5.86 ± 0.81^{b,d}	7.42 ± 0.57^{c,d}	5.13 ± 0.36^{b}	5.78 ± 0.29^{b}
Protein (on dry basis)	15.83 ± 0.08^{a}	18.49 ± 0.50^{b}	24.62 ± 0.37^{c}	26.32 ± 0.36^{c,d}	38.24 ± 2.63^{e}	28.41 ± 0.34^{d}	36.05 ± 1.03^{e}

a, b,..Values are means ± standard deviations of triplicate determinations; Values in the same row sharing the same letters are not significantly different ($p<0.05$ level); POF= Fish sample fried in palm oil; SOF= Fish sample fried in soybean oil; ReOF= Fish sample fried in refined palm oil; GOF = Fish sample fried in groundnut oil.

The moisture contents obtained for the two fish species were in the ranges previously reported by other workers (5), (17), (18), *etc*. The moisture contents generally reduced with processing with the reduction being more pronounced and significant in the fried samples than in the other processed samples. On the other hand, the fat content increased as a result of processing with the increase being more pronounced in the fried samples. The fat content results showed that *C. gariepinus* is a medium fat fish while *O. niloticus* is a low fat fish species. Several factors affect the fat content of fish samples including species, geographical region, age, and diet (19). *C. gariepinus* used in this study were farmed and thus fed with artificial and controlled diets, whereas the *O. niloticus* was free and thus were feeding on naturally available diets; this could significantly impact on the proximate compositions, hence the observed variations. Though *O. niloticus* had less fat than *C. gariepinus* originally, the fried samples of *O. niloticus* have higher fat contents than the fried *C. gariepinus*. Candela *et al.* (20) had earlier reported that the frying process affect different fish species in different ways and that this should be taken into account in determining the total fat consumed in a fish meal. This could therefore account for the different behaviors of the fishes to frying. The ash contents of both species reduced with processing, though the reduction did not follow any particular order and the reduction was attributed to the possible loss of some water soluble and heat-labile minerals during processing. The protein contents of the samples increased after processing and this is quite noteworthy because fishes are generally consumed as a protein source in food and it is therefore very important that processing or preparation methods should not have a negative impact on either the protein content or quality. The processing techniques involved here did not result in a reduction in the protein contents. While only a slight difference was observed in the protein content of the fresh and boiled samples, other treatments resulted in large differences in the protein contents.

Tables 2 - 4 present the amino acid composition and amino acid scores of the two species with tilapia having a slightly better amino acid profile than catfish. Although a greater loss of total amino acids was observed following the processing of catfish than tilapia, there is an increase in the total and percentage of essential amino acids following the processing of catfish. The amino acids lost in catfish as a result of processing were mainly the acid amino acids. Of all the processing techniques investigated, frying with palm oil appeared to have the worst effect on the amino acid contents of the fish samples, resulting in the loss of essential amino acids for the two species.

Table 2. Amino Acid Composition of Fresh and Processed *Clarias gariepinus* (g/100 g protein)

Amino Acid	***C. gariepinus* (Fresh)**	***C. gariepinus* (Boiled)**	***C. gariepinus* (Roasted)**	***C. gariepinus* (SOF)**	***C. gariepinus* (GOF)**	***C. gariepinus* (ReOF)**	***C. gariepinus* (POF)**
Lysine (Lys)[a]	5.00	5.40	5.00	5.27	4.92	5.62	4.92
Histidine (His)[b]	2.21	2.33	2.24	2.24	2.21	2.46	1.89
Arginine (Arg)	5.26	5.61	5.26	5.52	4.92	5.78	4.66
Aspartic acid (Asp)	23.26	10.92	10.02	10.61	9.87	11.26	21.21
Threonine (Thr)[a]	3.26	3.20	3.01	3.09	2.95	3.28	2.65
Serine (Ser)	4.26	3.53	3.47	3.5	3.07	3.66	3.96
Glutamic acid (Glu)	15.98	13.18	12.80	12.88	12.12	13.33	15.3
Proline (Pro)	4.69	3.46	3.05	3.15	3.15	3.56	4.27
Glycine (Gly)	4.18	5.52	4.95	5.19	4.32	5.60	3.51
Alanine (Ala)	5.05	4.82	4.22	4.48	4.03	5.05	4.72
Cystine (Cys)[a]	1.19	0.99	0.86	0.86	0.80	0.99	1.72
Valine (Val)[a]	3.82	3.65	3.27	3.42	3.01	3.50	3.86
Methionine (Met)[a]	0.68	2.29	2.19	2.24	2.08	2.40	0.86
Isoleucine (Ile)[a]	3.17	3.39	3.04	3.2	2.92	3.39	3.01
Leucine (Leu)[a]	5.95	6.85	6.50	6.66	6.23	6.94	5.21
Tyrosine (Tyr)[a]	3.02	3.33	3.02	3.18	3.02	3.65	2.70
Phenylalanine (Phe)[a]	4.05	4.44	4.39	4.40	4.47	4.47	3.37
Total Amino acids	**95.03**	**82.91**	**77.29**	**79.89**	**74.09**	**84.94**	**87.82**
% Difference		-12.12	-17.74	-15.14	-20.94	-10.09	-7.21

Total Essential amino acids [EAA]	28.14 (29.61%)	31.55 (38.05%)	29.64 (38.35%)	30.52 (38.20%)	28.79 (38.86%)	32.06 (37.74%)	25.77 (29.34%)
Total Acid amino acids [AAA]	39.24 (41.29%)	24.10 (29.07%)	22.82 (29.53%)	23.49 (29.40%)	21.99 (29.68%)	24.59 (28.95%)	36.51 (41.57%)
Sulfur amino acids [SAA]	1.87 (1.97%)	3.28 (3.96%)	3.05 (3.95%)	3.10 (3.88%)	2.88 (3.89%)	3.39 (3.99%)	2.58 (2.94%)
Aromatic amino acids [ArAA]	9.28 (9.77%)	10.10 (12.18%)	9.65 (12.49%)	9.82 (12.29%)	9.70 (13.09%)	10.58 (12.46%)	7.96 (9.06%)

[a] Essential amino acids according to FAO/WHO (1975); [b] Indispensable amino acid in human adult according to FAO/WHO/UNU (1985); ND = Not determined; POF= Fish sample fried in palm oil; SOF= Fish sample fried in soybean oil; ReOF= Fish sample fried in refined oil; GOF = Fish sample fried in groundnut oil. Values in parenthesis are % of TAA

Table 3. Amino Acid Composition of Fresh and Processed *Oreochromis niloticus* (g/100 g protein)

	***O. niloticus* (Fresh)**	***O. niloticus* (Boiled)**	***O. niloticus* (Roasted)**	***O. niloticus* (SOF)**	***O. niloticus* (GOF**	***O. niloticus* (ReOF)**	***O. niloticus* (POF)**
Lysine (Lys)[a]	5.21	4.38	3.92	3.40	4.02	3.62	5.02
Histidine (His)[b]	2.21	2.30	2.37	2.02	2.24	2.02	2.24
Arginine (Arg)	5.35	5.26	5.61	5.26	5.01	4.92	5.35
Aspartic acid (Asp)	10.08	10.11	10.55	9.02	11.26	10.05	23.6
Threonine (Thr)[a]	3.01	3.45	3.29	3.01	3.15	3.01	3.15
Serine (Ser)	3.42	3.61	2.96	2.52	3.01	2.55	4.15
Glutamic acid (Glu)	12.72	13.63	12.20	11.59	12.72	11.29	16.35
Proline (Pro)	3.26	3.87	3.66	3.26	3.97	3.15	4.78
Glycine (Gly)	4.90	4.01	3.65	3.55	3.94	3.41	4.20
Alanine (Ala)	5.51	4.21	3.99	3.68	4.41	3.87	5.24
Cystine (Cys)[a]	0.93	1.39	1.26	1.19	1.32	1.13	1.26
Valine (Val)[a]	3.18	4.20	3.71	3.42	4.00	3.42	3.91
Methionine (Met)[a]	2.19	1.51	1.41	1.35	1.64	1.30	0.70
Isoleucine (Ile)[a]	3.20	3.68	3.11	3.01	3.55	3.01	3.42
Leucine (Leu)[a]	6.53	7.21	6.94	6.55	7.02	6.09	6.03
Tyrosine (Tyr)[a]	3.17	3.33	3.02	2.70	3.18	3.33	3.02
Phenylalanine (Phe)[a]	4.22	4.81	4.55	4.22	4.81	4.02	3.96
Total Amino acids	**79.09**	**80.96**	**76.2**	**69.75**	**79.25**	**70.19**	**96.38**
% Difference		1.87	-2.89	-9.34	0.16	-8.90	17.29
Total Essential amino acids [EAA]	29.75 (37.62%)	31.54 (38.96%)	29.30 (38.45%)	26.98 (38.68 %)	30.43 (38.40 %)	26.49 (37.74%)	28.43 (29.50%)
Total Acid amino acids [AAA]	22.8 (28.83%)	23.74 (29.32%)	22.75 (29.86%)	20.61 (29.55 %)	23.98 (30.26 %)	21.34 (30.40%)	39.95 (41.45%)
Total Sulfur amino acids [SAA]	3.12 (3.94%)	2.90 (3.58%)	2.67 (3.50%)	2.54 (3.64%)	2.96 (3.74%)	2.43 (3.46%)	1.96 (2.03%)
Total Aromatic amino acids [ArAA]	9.60 (12.14%)	10.44 (12.90%)	9.94 (13.04%)	8.94 (12.82 %)	10.23 (12.91 %)	9.37 (13.35%)	9.22 (9.57%)

[a] Essential amino acids according to FAO/WHO (1975); [b] Indispensable amino acid in human adult according to FAO/WHO/UNU (1985); ND = Not determined; POF= Fish sample fried in palm oil; SOF= Fish sample fried in soybean oil; ReOF= Fish sample fried in refined oil; GOF = Fish sample fried in groundnut oil. Values in parenthesis are % of TAA

Table 4. Amino Acid Score of Fresh and Processed *Clarias gariepinus* and *Oreochromis niloticus*

	Ile	Leu	Lys	Met + Cys	Phe + Try	Thr	Try	Val	His
Standard	2.8	6.6	5.8	2.5	6.3	3.4	1.1	3.5	1.9
***C. gariepinus* (Fresh)**	113	90	86	**75**	112	96	ND	109	116
***C. gariepinus* (Boiled)**	121	104	**93**	131	123	94	ND	104	123
***C. gariepinus* (Roasted)**	109	98	**86**	122	118	89	ND	93	118
***C. gariepinus* (SOF)**	114	101	91	124	120	**91**	ND	98	118
***C. gariepinus* (GOF**	104	94	**85**	115	119	87	ND	86	116
***C. gariepinus* (ReOF)**	121	105	97	136	129	**96**	ND	100	129
***C. gariepinus* (POF)**	108	79	85	103	96	**78**	ND	110	99
***O. niloticus* (Fresh)**	114	99	90	125	117	**89**	ND	91	116
***O. niloticus* (Boiled)**	131	109	**76**	116	129	101	ND	120	121
***O. niloticus* (Roasted)**	111	105	**68**	107	120	97	ND	106	125
***O. niloticus* (SOF)**	108	99	**59**	102	110	89	ND	98	106
***O. niloticus* (GOF)**	127	106	**69**	118	127	93	ND	114	118
***O. niloticus* (ReOF)**	108	92	**62**	97	117	89	ND	98	106
***O. niloticus* (POF)**	122	91	87	**78**	111	93	ND	112	118

ND = Not determined

Although the amino acid analysis did not reveal an increase in the amino acid contents as one may have expected from the protein contents, there was an observed increase in both the quantity and percentage of the total essential amino acids except for the sample fried with crude palm oil which recorded a reduction in the total essential amino acids for both *C. gariepinus* and *O. niloticus*. For *C. gariepinus*, there was also observed an increase in the sulfur-containing amino acids and aromatic amino acids and a reduction in the acid amino acids while for *O. niloticus,* the acid amino acids increased slightly while both the sulfur-containing amino acids and the aromatic amino acids recorded only slight variations. Frying with crude palm oil appeared to have the worst effect on the quality of amino acids for both fish species. Although it resulted in an increase in total amino acids for *O. niloticus* and only a slight decrease for *C. gariepinus*, the number of limiting amino acids increased as a result of the loss of the essential amino acids.

Previous workers have reported varying effects of processing on the protein and amino acid contents of fish samples. While some reported no significant effect on protein and amino acid contents following boiling and frying (21), others reported that heat processing resulted in reduction in protein value by destroying the constituent amino acids or making them unavailable (22). This may imply that the length of time of heat treatment also contributed to the change in amino acid contents of the fish samples. Our previous work on marine water fishes (4) had reported that boiling and roasting had no significant effect on the amino acid composition of the four fish samples investigated while frying resulted in a significant reduction in essential, sulfur-containing and aromatic amino acids. Samples fried with palm oil also reported the lowest values of essential amino acids and they were also the only samples with limiting amino acids. These results therefore suggest that processing has different types of effects on different fish types but frying has the worst kind of effect as far as protein quality is concerned. One can also deduce that increase in protein content does not necessarily imply an increase in the quality of the protein. The results also show that both *C. gariepinus* and *O. niloticus* are not sources of complete proteins. They have several essential amino acids with scores less than 100 including lysine, threonine, methionine, cysteine, leucine, and valine whereas the marine water fishes have no limiting amino acids except when fried (4). Amino acid scoring provides a way to predict how efficiently a protein will meet a person's amino acid needs. This concept assumes that tissue protein synthesis is limited unless all required amino acids are available at the same time and in appropriate amounts at the site of tissue protein synthesis.

The results of the fatty acid analysis of both fish species, presented in Tables 5 and 6, show that both species contain more unsaturated fatty acids than saturated, and that palmitic acid is the main saturated fatty acid in both species. Oleic acid is the major unsaturated fatty acid in both species with linoleic acid, linolenic acid and palmitoleic acid also being present in varying amounts.

Table 5: Fatty Acid Composition of Fresh and Processed *Clarias gariepinus*

Fatty acid	***C. gariepinus*** **(Fresh)**	***C. gariepinus*** **(Boiled)**	***C. gariepinus*** **(Roasted)**	***C. gariepinus*** **(SOF)**	***C. gariepinus*** **(GOF**	***C. gariepinus*** **(ReOF)**	***C. gariepinus*** **(POF)**
Caprylic acid (C8:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capric acid (C10:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lauric acid (C12:0)	2.81	2.51	0.00	2.51	0.00	0.00	3.49
Myristic acid (C14:0)	4.77	5.10	0.31	5.07	0.36	0.32	4.71
Palmitic acid (C16:0)	22.40	18.97	26.99	23.76	23.40	26.03	23.16
Palmitoleic acid (C16:1)	3.96	5.23	10.42	5.20	11.99	10.87	2.82
Margaric acid (C17:0)	1.22	1.61	1.89	1.60	2.18	1.97	0.51
Stearic acid (C18:0)	5.56	7.34	5.74	7.30	6.61	5.99	10.21
Oleic acid (C18:1)	29.94	28.26	30.95	27.37	28.34	29.73	30.08
Linoleic acid (C18:2)	14.94	16.89	6.42	13.16	7.23	7.05	16.72
α-Linolenic acid (C18:3)	5.34	7.05	11.05	7.02	12.72	11.53	4.49
Arachidic acid (C20:0)	1.32	1.74	0.00	1.73	0.00	0.00	0.56
Arachidonic acid (C20:4)	1.45	1.91	2.25	1.90	2.59	2.34	0.61
Behenic acid (C22:0)	0.54	0.71	0.83	0.71	0.96	0.87	0.23
Erucic acid (C22:1)	5.76	2.67	3.15	2.66	3.62	3.28	2.42
Lignoceric acid (C24:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL FATTY ACIDS	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
TOTAL SATURATED FATTY ACIDS	38.61	37.98	35.77	42.69	33.51	35.19	42.86
TOTAL UNSATURATED FAs	61.39	62.02	64.23	57.31	66.49	64.81	57.14

Values are % of eluted methyl esters; ND = Not detected

Table 6. Fatty Acid Composition of Fresh and Processed *Oreochromis niloticus*

Fatty acid	***O. niloticus* (Fresh)**	***O. niloticus* (Boiled)**	***O. niloticus* (Roasted)**	***O. niloticus* (SOF)**	***O. niloticus* (GOF**	***O. niloticus* (ReOF)**	***O. niloticus* (POF)**
Caprylic acid (C8:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capric acid (C10:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lauric acid (C12:0)	0.00	2.62	0.00	3.82	2.66	0.00	2.41
Myristic acid (C14:0)	0.30	4.44	0.31	6.21	4.50	0.31	4.86
Palmitic acid (C16:0)	27.97	25.39	30.71	24.16	23.81	26.71	24.32
Palmitoleic acid (C16:1)	10.18	3.68	10.46	5.54	3.74	10.31	4.98
Margaric acid (C17:0)	1.85	1.13	1.90	1.01	1.15	1.87	1.53
Stearic acid (C18:0)	5.61	5.17	5.77	4.59	5.24	5.69	6.99
Oleic acid (C18:1)	30.84	33.85	26.63	27.24	31.37	31.02	27.56
Linoleic acid (C18:2)	6.35	10.33	6.87	15.54	13.94	6.99	13.91
α-Linolenic acid (C18:3)	10.80	4.96	11.10	4.41	5.04	10.94	6.72
Arachidic acid (C20:0)	0.00	1.23	0.00	1.09	1.25	0.00	1.66
Arachidonic acid (C20:4)	2.20	1.34	2.26	1.19	1.36	2.22	1.82
Behenic acid (C22:0)	0.82	0.50	0.84	0.44	0.51	0.83	0.68
Erucic acid (C22:1)	3.08	5.35	3.16	4.76	5.43	3.11	2.55
Lignoceric acid (C24:0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL FATTY ACIDS	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
TOTAL SATURATED FATTY ACIDS	36.56	40.47	39.53	41.32	39.12	35.40	42.46
TOTAL UNSATURATED Fas	63.44	59.53	60.47	58.68	60.88	64.60	57.54

Values are % of eluted methyl esters; ND = Not detected

Fish lipids are very desirable because of their rich content of long-chain omega-3 polyunsaturated fatty acids (LC ω-3 PUFA), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA can be synthesized from α-linoleic acid (ALA) thus; ALA and linoleic acid (LA) are the two truly essential fatty acids. Though the percentage quantities of DHA and EPA were not determined, the results of the fatty acid composition revealed that both fish samples contain the two essential fatty acids in sizeable quantities. These two acids account for 20.28% of the fatty acids in fresh *C. gariepinus* (with ALA accounting for 5.34%) and 17.15% in fresh *O. niloticus* (with 10.80% ALA). Though these values vary in the processed samples, the range remains fairly constant. Apart from the two essential fatty acids, the two fish samples contain rich supply of other fatty acids. Both samples are very rich in oleic acid and palmitic acid. Generally, the fish samples contain more unsaturated fatty acids (61.39 – 63.44%) than the saturated fatty acids (36.56 – 38.61%). PUFAs regulate prostaglandin synthesis and accelerate wound healing (23), (24) and the ω-3 and ω-6 PUFAs have been reported to contribute positively to the treatment of cardiovascular diseases and cancers (25). Increasing the consumption of fish and fish products, which are rich in polyunsaturated fatty acids, is therefore desirable for human health (26), (27). The contents of PUFAs in different fish species and even among freshwater and marine fish may vary (28) and the results obtained here have indicated that there was indeed a variation in the composition of PUFA in the two fish species.

CONCLUSION

This study has shown that *C. gariepinus* had medium oil content while *O. niloticus* was low in oil contents. The two species have also been shown to be low in some essential amino acids and the methods of table preparation may further reduce the amino acid composition. Frying did exert a significant effect on the amino acid composition of the samples but when palm oil was used in the frying process, there was observed a significant reduction in protein quality in terms of loss of the amino acids, especially the essential amino acids; thus frying with palm oil is not a nutritionally beneficial method of table preparation of fresh water fish.

REFERENCES

1. Oluwaniyi OO, Dosumu OO. Preliminary Studies on the effect of processing methods on the quality of three commonly consumed marine fishes in Nigeria. Biokemistri 2009; 21(1):1-7. URL: http://www.bioline.org.br/request?bk09001.

2. Federal Office of Statistics. Nigerian Fish Production by Sectors. Lagos 1990. Nigerian Government Printers. Nigeria. 40.

3. www.ucmp.berkeley.edu/exhibits/biomes/freshwater.php.

4. Oluwaniyi OO, Dosumu OO, Awolola GV. Effect of local processing methods (boiling, frying and roasting) on the amino acid composition of four marine fishes commonly consumed in Nigeria. *Food Chemistry 2010;* 123: 1000–1006. DOI: 10.1016/j.foodchem.2010.05.051.

5. Osibona AO, Kusemiju K, Akande GR. Fatty acid composition and amino acid profile of two freshwater species, African catfish (*Clarias gariepinus*) and Tilapia (*Tilapia zillii*). *Afri. Jour. Food Agr. Nutr. Dev. (AJFAND)* 1990; 9(1): 608 – 621. URL: http://www.ajfand.net/Volume9/No1/Adesola2965.pdf.

6. Pearson D, Cox HE. The Chemical Analysis of Foods (7th edition) Churchill Livingstone. 1976. 575 p. ISBN: 0443014116, 9780443014116.

7. United Nations Food & Agriculture Organization, Nutritional elements of fish. FAO, Rome. 2005.

8. Ackman RG. Seafood lipids and fatty acids. *Food Reviews International*. 1990; 6 (4): 617-646. DOI: 10.1080/87559129009540896.

9. Federal Department of Fisheries, Abuja Nigeria. 3rd Edition. Publisher Fisheries Statistics of Nigeria. 2004; 45.

10. Afolabi AO, Arawomo OA, Oke OL. Quality changes of Nigerian traditionally processed fresh water fish species I. Nutritive and organoleptic changes. *J. Food Techno*. 1984; 19: 333-340. DOI: 10.1111/j.1365-2621.1984.tb00356.x.

11. Hecht J, Oellermann L, Verheust L. Perpectives on clariid catfish culture in Africa. *Aquat. Living Resour*. 1996; 9: 197-206 (Hors Serie). URL: www.alr-journal.org/articles/alr/pdf/1996/05/alr96hs16.pdf.

12. Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC), Vols. I and II, Association of Analytical Chemists, Arlington. 1994.

13. FAO/WHO Protein quality evaluation. Report of joint FAO/WHO expert consultation. FAO food and nutrition paper 51. 1991. Italy: Rome.

14. FAO/WHO Energy and protein requirements. Technical report series no. 522. 1973. Geneva, Switzerland: WHO.

15. Alsmeyer RH, Cunningham AE, Hapich ML. (1974). Equations predict PER from amino acid analysis. Food Technology 1974; 28: 34–38. URL: http://agris.fao.org/agris-search/search.do?recordID=US201303166075.

16. Adeyeye EI. Amino acid composition of three species of Nigerian fish: Clarias anguillaris, Oreochromis niloticus and Cynoglossus senegalensis. Food Chemistry 2009; 113(1), 43–46. DOI: 10.1016/j.foodchem.2008.07.007.

17. Elagba Mohamed HA, Rabie A, Mohammed MH. Proximate composition, amino acid and mineral contents of five commercial Nile fishes in Sudan. *Afri. Jour. Food Sci.* 2010; 4(10): 650 – 654. URL: http://www.academicjournals.org/article/article1380732813_Elagba%20et%20al.pdf.

18. Ogbonnaya C, Ibrahim MS. Effects of drying methods on proximate compositions of catfish (*Clarias gariepinus*) *World Jour. of Agr. Sci.* 2009; 5(1): 114 – 116. URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.415.5187&rep=rep1&type=pdf.

19. Piggott GM, Tucker BW. Seafood: Effects of technology on nutrition.CRC Press New York, USA. 1990. 384 p. ISBN: 0824779223, 9780824779221.

20. Candela M, Astiasaran I, Bello J. Deep-fat frying modifies high fat fish lipid fraction. J. Agric. Food Chem. 1998; 46: 2793 – 2796. URL: http://pubs.acs.org/doi/abs/10.1021/jf9709616.

21. Ismail A, Hainida E, Ikram K. Effects of cooking practices (boiling and frying) on the protein and amino acids contents of four selected fishes. *Nutrition and Food Science* 2004; 34(2): 54–59. DOI: 10.1108/00346650410529005.

22. Burger IH, Walters CL. The effect of processing on the nutritive value of flesh foods. Symposium on the effect of processing on the nutritive value of food held on 10th November 1972. *Proceedings of Nutrition Society* 1973; 32: 1–8. DOI: 10.1079/PNS19730002.

23. Bowman WC, Rand MJ. Textbook of pharmacology (2nd. Ed.) Wiley - Blackwell Oxford. 1991. 1928 p. ISBN: 0632099909, 978-0632099900.

24. Gibson RA. Australian fish – an excellent source of both arachidonic acid and 3 polyunsaturated fatty acids. *Lipids* 1983; 18:743-752. URL: http://link.springer.com/article/10.1007/BF02534631.

25. Connor WE. The beneficial effects of omega-3 fatty acids: cardiovascular diseases and neurodevelopment. *Current Opinion in Lipidology* 1997; 8: 1-3. URL: http://www.ncbi.nlm.nih.gov/pubmed/9127702.

26. Burr ML. Fish and cardiovascular system. *Progress in Food and Nutrition Science* 1989; 13: 291-316. URL: http://www.ncbi.nlm.nih.gov/pubmed/2699044.

27. Sargent JR. Fish oils and human diet. *British Journal of Nutrition* 1997; 78 (Suppl. 1): S5-S13 DOI: 10.1079/BJN19970131.

28. Abd Rahnan S, Teh SH, Osman H, Daud NM. Fatty acid composition of some Malaysian fresh water fish. *Food Chemistry* 1995; 54: 45-49. DOI: 10.1016/0308-8146(95)92660-C.

Türkçe Öz ve Anahtar Kelimeler

Clarias gariepinus ve Oreochromis niloticus Türlerindeki Yakın Sonuçlar, Amino Asit ve Yağ Asidi Bileşenleri Üzerinde Pişirme Yönteminin Etkisi

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Öz: Bu çalışmada, yakın analiz, amino asit ve yağ asidi bileşenleri fileto ve yağ kısmında incelendi ve yaygın tüketilen iki balık türü olan *Clarias gariepinus* (yayın balığı) ve *Oreochromis niloticus* (tatlısu çipurası) üzerinde çalışıldı. Örnekler ayrı ayrı pişirildi, sıcak kömür ateşinde kızartıldı ve farklı yağlar kullanılarak (hurma yağı, yerfıstığı yağı, soya fasülyesi yağı ve rafine edilmiş hurma yağı) kızartıldı. Besin bileşimi üzerine işleme tekniklerinin etkisi belirlendi. Nem içeriği yayın balığında %76,27 ve tatlısu çipurasında %79,97 olarak bulundu, yağ içeriği ise yayın balığı için %11,00 ve tatlısu çipurası için ise %7,80 olarak tespit edildi. Kül içeriği %8,03 – 9,16 aralığında bulunurken protein içeriği ise %15,83 – 18,48 olarak tespit edildi. Pişirme yöntemleri besin içeriğinde bir değişmeye neden olmakla birlikte, örnekler hurma yağı ile kızartılmadığı müddetçe amino asitlerde belirgin bir değişme olmamaktadır, hurma yağı esansiyel amino asit içeriklerinde ciddi bir azalmaya neden olmaktadır. Bütün balık örnekleri hem taze, hem de işlenmiş olarak amino asit skoru bakımından 100'Den düşüktür, sınırlayıcı amino asitler lizin, treonin ve kükürtlü amino asitlerdir. Her iki balık türü, doymuş yağ asitlerine nazaran daha fazla doymamış yağ asidi içermektedir.

Anahtar kelimeler: Balık; yakın bileşim; yağ asidi; amino asit.

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