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Full Length Research Paper

Comparative study of proximate composition, amino and fatty acids of some economically important fish species in Lagos, Nigeria

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The proximate composition, amino and fatty acids of four economically important fish species from the lagoons and off Lagos coast around Lagos, Nigeria were determined over a period of two years. The mean proximate composition of the freshwater species were 19.64% protein, 1.15% lipid, 76.71% moisture and 1.23% ash for *Clarias gariepinus*; 19.55% protein, 0.96% lipid, 76.75% moisture and 1.11% ash for *Tilapia zillii*. The mean proximate composition of the marine water species were 19.80%, protein, 0.40% lipid, 72.63% moisture and 1.13% ash for *Pentanemus quinquarius* and 19.86% protein, 1.06% lipid, 75.40% moisture and 1.17% ash for *Pseudotolithus typus*. Nine essential amino acids namely lysine, leucine, valine, isoleucine, threonine, phenylalanine, methionine, tryptophan and histidine that are very important for human health were present in all the species examined. The highest total amino acids value of 179.74 mgg^{-1} was recorded in *P. typus*. The concentration of the total lipids, fatty acids, saturated, monounsaturated and polyunsaturated fatty acids levels were not the same within as well as between species. For the saturated fatty acids, palmitic acid had the highest proportion while oleic acid was the main monounsaturated fatty acid. Docosahexaenoic and eicosapentaenoic acids were the dominant polyunsaturated fatty acids in all the species. The results indicate that the fish species had high quality protein, essential amino acids and fatty acids. Overall, *C. gariepinus* appears to be the best diet for its relatively high nutrient components and the ratio of polyunsaturated: saturated fatty acid is followed by *P. typus*, *P. quinquarius* and *T. zillii*.

Key words: Proximate, freshwater, marine, fatty acids, amino acids, Nigeria.

INTRODUCTION

Fish has traditionally been a popular part of diets in many parts of the world including some West African countries where it constitutes the main source of animal protein among the coastal dwellers. The estimated fish demand in Nigeria is 1.80 million tonnes based on a population of 120 million people and a per capita consumption of 15 kg, which is the global average. Average total fish supply including those from distant water trawlers is, however, on the average about 900, 000 tonnes per annum making per capita consumption 7.5 kg/head/year (FDF, 2004). Typically, fish is lower in total fat and saturated fat than red meats (Lands, 1986) and it is also a source of omega-3 (n-3) polyunsaturated fatty acids (PUFA), which lower total serum cholesterol levels (Stansby, 1973). It is one of the cheapest sources of animal protein and accounts for about 40% of the total animal protein intake of the average Nigerian (Sadiku and Oladimeji, 1991).

Measurement of constituents of fish products is sometimes necessary to meet the requirements of food regulations or commercial specifications. For example, the fish content of fish cakes or the oil content of fishmeal may need to be known, in order to meet certain commercial or legal requirements (Murray and Burt, 1983).

In industrial processing of fish, knowledge of composition of fish is important in several ways: information on oil content of certain species and how the oil content varies with season or with location of capture is needed

to evaluate the possibility of its utilization in manufacture of oil. Moreover, information of the fatty acid content and amino acid profiles of fish is important in determining the suitability of fish oils for processing and the suitability of fishmeal as protein supplement in animal feeds. In addition, such information will be useful to dieticians who may need to prescribe diets for people who are health-conscious and those with certain medical conditions who may need to restrict their fat intake to polyunsaturated fatty acids (Ssali, 1988).

Stansby (1962) cited by Vlieg et al. (1983) reported that the relationship between the type of fat ingested and, arteriosclerosis coupled with the need for controls of obesity have made the knowledge of proximate composition of fish in high demand. Many heart specialists recommend that their patients use generous quantities of fish in their diets, both as a means of avoiding excessive consumption of saturated fatty acids and as a means of obtaining adequate protein in their diet without taking in excess fat.

In recent years, there has been heightened interest in the chemical composition of fish (Zenebe et al., 1998). Various authors have reported on the proximate chemical composition and seasonal variation of different fish species (Exler, 1987; Gooch et al., 1987; Chandrashekar and Deosthale, 1993), the amino and fatty acids profiles and their distribution (Dustan et al., 1988; Faheem et al., 1991; Sigurgisladottir and Palmadottir, 1993), as well as commercial feed trials and its effect on proximate composition (Arai, 1981; Bijen-Singh et al., 1990; Aursand et al., 1994; Badiani et al., 1996).

The proximate composition of temperate and sub-tropical fish is well documented in literature (Henderson and Tocher, 1987; Ahlgren et al., 1994, 1996), but regular updating of the tables is required because of changes in the nature and source of raw materials and manufacturing processes. In contrast, few data on a very few species are available on tropical fish, despite their diversity and economic importance (Olsen et al., 1990; Clement and Lovelli, 1994; Andrade et al., 1995).

The present knowledge of chemical composition of fish species from Nigerian waters is limited. There are scanty data on some important fish species in spite of their being in great demand. Water bodies in Nigeria are inhabited by a variety of fish species that serve as food and are of economic importance to the country. Some of the most important species accounting for about 90% of Nigeria's fishery include the croakers, catfishes, tilapias, threadfins, soles and the clupeids (FDF, 2004).

Four important fish species, namely two freshwater species, the, catfish, *Clarias gariepinus,* (Burchell) tilapia, *Tilapia zillii,* (Gervais) and two marine, threadfin, *Pentanemus quinquarius* (Linnaeus) and croaker, *Pseudotolithus typus* (Bleaker) were chosen for this work based on their economic importance and the fact that they are very abundant in Nigerian markets. They also serve an increasing role in the nation's nutrition as source of relatively cheap animal protein (FDF, 2004). This study was undertaken to determine the proximate composition, amino and fatty acids profiles of these four economic important fish species in Nigeria.

MATERIALS AND METHODS

Study area

The fishing grounds where the samples were collected comprised of the marine waters off Lagos Coast as well as the Lekki and Lagos Lagoons. These Lagoons are the major lagoons along the southwestern coast of Nigeria. Lekki Lagoon is located in Lagos State of Nigeria. It has a surface area of 247 km^2 with a maximum depth of 6.4 m; a greater part is shallow and less than 3.0 m deep. It lies between Longitude 3° 54" and 4° 13" E and latitude 6° 25" and 6° 35" N.

The Lagos Lagoon lies between longitudes 3° 20" and 3° 40" E and latitudes 6° 15" and 60° 40"N. It has an area of 208 km^2 and is the largest of the lagoon systems of the West African sub-region and has supported decades of small-scale fisheries. The Lagoon is shallow in depth and in most places, a little more than 1.5 m depth. Several rivers empty into the Lagoons while the lagoons empty into the Atlantic Ocean in the Gulf of Guinea via the Lagos harbour.

The fisherfolk live in villages and settlements located along the lagoon fronts. Some of them have their huts built on stilts or raised platforms jutting out of the shallow lagoons. The fishermen normally bring their catches from different hauls, already mixed together to the markets.

Collection and preservation of specimens

Specimens of catfish, *C. gariepinus* and tilapia, *T. zillii* were purchased at Epe fish market from fishermen as soon as they arrived from the fishing grounds. Live specimens of *C. gariepinus* were purchased but the other species were dead but still fresh when landed. The specimens of *T. zillii* were stored in an ice chest at 4°C. They were transported to the laboratory of Nigerian institute for oceanography and marine research (NIOMR), Victoria Island. *C. gariepinus* specimens were killed by clubbing on the head. Specimens of frozen threadfin, *P. quinquarius* and croaker, *P. typus* were bought at the NIOMR Fish Jetty on the day they were landed fresh at the dock. The samples were bought on monthly basis for a period of twenty-eight months. Fishing by the small sea vessels was done off Lagos coast. The specimens were packaged in separate labelled polythene bags and eventually stored in NIOMR cold room at about -22°C pending laboratory analysis.

Biometric measurements

Fish samples were thawed in the open air in the laboratory and individual data for length, weight and sex were taken and recorded. The standard length was measured with the aid of a graduated fish measuring board. The weight was measured with a Satorious top loading electronic weighing balance, Satorious-Werke GMBH model (Type 1106/ Fabr. Nr. 2608053). The sex was determined by visual examination of the gonads.

Analytical methods

Each fish sample was gutted, cleaned, finely minced and then homogenized. Samples for the different chemical analyses were then taken from the homogenized material. Triplicate determinations were carried out on each sample.

Proximate composition analysis

The moisture content of the fish species was determined using the air oven drying method using a known weight of the fillet at 105°C until a constant weight was obtained (AOAC, 1994). Ash content was determined by incineration of the dried sample obtained from moisture determination in a muffle furnace at 525°C for 24 h. Crude protein content was calculated by converting the nitrogen content, determined by Kjeldahl's method (6.25 × N) (AOAC, 1994). The lipid extractions were performed by modification of the method of Bligh and Dyer as described by AOAC (1994).

Amino acid analysis

The preparation of the samples was adapted from the procedure described by Mason et al. (1980). Half gram sample was weighed into 100 cm^3 flat bottomed flask and 1 ml of Norleucine standard solution, 5 ml performic acid stand in ice bath in fridge for 16 h, 0.84 g sodium metabisulphite, 30 ml 6NHCl and anti bumping granules were then added. The mixture was hydrolysed for 24 h in polyethylene glycol bath set at 130°C. It was then allowed to cool and 30 mls of 4 M lithium hydroxide added. The pH was adjusted to 2.1 and the mixture made up to 100 ml final volume. 5 ml of the mixture was filtered through 2 µ filter paper and this was run through a Biochrom 20 amino acid analyser. The data was collected in the form of chromatograms. The analyser was ion exchange with several buffers at varying pH running through the column. Each sample took about 4 h to run through the system. The amino acid determination of the research was carried out at the Institute of Grassland and Environmental Research Laboratory, Aberystwyth, Wales, UK.

Fatty acid analysis

Fats were extracted from the sample and converted to free fatty acids by saponification. The fatty acids were converted to their methyl esters and into heptane. Internal standards were employed for estimation of actual fatty acids present in the fat. Identification/ quantification of fatty acids was achieved by gas chromatography, the former being resolved by elution times (AOAC, 1994). This analysis was carried out at Eclipse Scientific Group Laboratory, Chatteris-Cambridge, UK.

Statistical analysis

Statistical analyses used included correlation coefficient, student t-test and one-way analysis of variance (ANOVA). The statistical procedures were adopted from Zar (1998).

RESULTS

Proximate analysis

The mean monthly proximate compositions of the four commercially important fish species *C. gariepinus, T. zillii*, *P. quinquarius* and *P. typus* are shown in Table 1.

Amino acid composition

There were twenty- one different amino acids observed in *C. gariepinus* and *T. zillii*, and the total amino acid recorded was 168.84 mgg^{-1} for *C. gariepinus* and 170.26 mgg^{-1} for *T. zillii*. There were twenty different amino acids observed in *P. quinquarius* and *P. typus*, and the total amino acid recorded in *P. quinquarius* was 176.18 mgg^{-1}, while that of *P. typus* was 179.74 mgg-1. The various amino acids observed were grouped into three categories based on their concentration (Tables 2 to 4). The first category (Table 2) had high amino acids ranging from 10.00 to 32.00 mgg^{-1}. The most abundant amino acid in this group was glutamic acid; this was followed in decreasing order by aspartic acid, lysine, leucine, arginine and alanine. The second category (Table 3) had medium amount of amino acids ranging from 5.00 to 8.00 mgg^{-1}. In this category were valine, isoleucine, glycine, threonine, serine, phenylalanine, proline and methionine sulphone in decreasing order. The third category (Table 4) had low amino acids less than 4.99 mgg^{-1}. Among these were histidine, cystine, tyrosine, ornithine, g-aminobutyric acid and hydroxyproline. Each amino acid was not significantly different between the species except aspartic acid in *P. typus*.

Fatty acid composition of the fish species

The percentage composition of the different fatty acids of the four fish species is shown in Table 5. There were twenty-seven fatty acids in *C. gariepinus*, twenty-two in *T. zillii*, twenty-nine in *P. quinquarius* and thirty in *P. typus*. The dominant individual fatty acids were palmitic acid (C16:0), stearic acid (C18:0) and oleic acid (C18:1). Of the saturated fatty acids (SFA) palmitic acid (C16:0) had the highest proportion, while oleic acid (C18:1) was the main monounsaturated fatty acid (MUFA) and docosahexaenoic acid (DHA) the dominant polyunsaturated fatty acid (PUFA).

The mean saturated, monounsaturated and polyunsaturated fatty acid of the lipid extracted from the four commercially important fish species is as shown in Figure 1. In each species, SFA was the highest, followed by MUFA and the least was PUFA.

DISCUSSION

Protein content was slightly higher in the muscle of *P. typus* than in the other three species. Although, slight variations were observed for the dry and rainy seasons, protein levels were not statistically different ($P>0.05$) indicating that protein levels were the same in the species. The results of the range of protein content were within the range of variations reported by Zelibe (1989). However, the four species had their highest protein concentrations at different months indicating that they had different life cycles, that is, different spawning periods, which may affect the feeding regime of the

Table 1. Average monthly proximate composition of the four commercially important fish species.

Period	Average proximate composition (%)															
	Protein				Lipid				Moisture				Ash			
	C. gariepinus	*T. zillii*	*P. quinquarius*	*P. typus*	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*
Sep-07	19.54	18.39	18.02	19.12	1.30	1.06	0.58	1.57	69.32	77.71	72.83	73.75	1.22	1.12	1.01	1.36
Oct.	18.88	17.75	18.32	20.55	1.31	0.46	0.66	1.78	65.64	76.44	75.85	74.08	1.00	1.38	1.34	1.11
Nov.	20.00	17.94	20.24	19.65	1.11	0.97	0.91	1.75	74.08	78.03	74.93	77.98	1.91	1.18	1.34	1.11
Dec.	19.08	18.31	20.40	19.14	1.44	0.93	0.66	1.88	78.50	77.94	75.67	75.43	2.92	1.11	1.28	1.55
Jan-08	20.25	19.46	18.13	18.93	1.84	1.37	0.97	1.12	74.81	77.19	74.22	77.89	1.26	1.14	1.18	1.75
Feb.	18.34	20.84	20.36	20.07	1.40	0.45	0.53	0.88	76.87	80.15	74.78	75.71	1.13	1.10	1.17	1.13
Mar.	20.32	20.57	20.14	20.61	1.21	0.45	0.21	0.37	80.17	81.00	77.19	77.67	1.23	1.13	1.29	1.25
Apr.	20.42	19.49	21.36	21.59	0.90	0.28	0.37	0.43	79.43	80.47	71.23	74.93	1.23	1.40	1.14	1.31
May	20.07	19.97	18.93	20.27	0.95	0.90	0.20	0.41	77.33	79.16	78.59	79.03	1.10	1.13	1.23	0.98
Jun.	19.09	19.42	18.62	18.14	1.24	1.00	0.43	0.55	75.86	77.79	75.84	70.24	1.33	0.97	1.22	0.77
Jul.	20.75	19.37	20.76	19.25	1.80	0.81	0.34	0.68	74.04	78.61	74.39	74.48	1.17	0.98	1.10	1.28
Aug.	19.48	20.32	20.00	20.95	0.98	0.82	0.39	1.05	73.46	72.14	70.54	76.36	1.12	1.20	1.06	1.18
Sep.	19.31	20.02	19.71	18.90	1.02	1.09	0.34	1.35	77.35	71.77	71.15	77.56	1.10	1.06	1.06	1.09
Oct.	18.97	20.06	19.61	18.73	1.02	1.06	0.32	1.64	79.63	74.19	71.04	76.98	1.07	1.05	1.10	1.14
Nov.	19.17	19.91	20.00	20.23	1.00	1.10	0.36	1.78	77.19	72.30	71.44	76.00	1.02	1.06	1.09	1.05
Dec.	19.22	19.31	20.60	20.25	1.03	1.00	0.29	1.92	77.75	73.32	71.14	71.12	1.04	1.02	1.06	1.21
Jan-09	18.91	19.73	20.31	20.04	1.01	1.07	0.30	1.35	78.58	73.76	71.64	73.81	1.03	1.02	1.05	1.11
Feb.	18.95	20.25	20.80	20.83	0.98	1.19	0.30	1.04	78.65	77.24	71.78	74.22	1.06	1.25	1.13	1.13
Mar.	18.50	19.62	20.34	19.26	1.07	1.14	0.31	0.51	76.92	73.69	70.47	75.48	1.30	1.08	1.09	1.12
Apr.	18.66	19.64	20.63	20.70	1.01	1.21	0.36	0.66	77.38	77.54	70.76	76.32	1.16	1.04	1.05	1.11
May.	19.73	20.26	20.93	20.75	1.28	1.29	0.32	0.73	78.67	76.00	70.48	73.92	1.10	1.20	1.07	1.05
Jun.	19.68	20.27	20.65	17.98	1.13	1.29	0.28	0.99	79.05	77.77	70.50	73.80	1.10	0.97	1.06	1.15
Jul.	20.34	21.03	19.18	20.68	0.71	1.37	0.24	1.03	79.78	74.66	70.52	76.06	1.13	1.05	1.03	1.04
Aug.	18.80	19.97	19.28	20.70	1.03	1.16	0.32	0.93	78.48	76.88	71.02	74.05	1.17	1.08	1.10	1.18
Sep.	19.06	18.34	20.20	20.95	1.03	0.78	0.35	1.32	77.73	80.09	71.66	73.75	1.09	1.14	1.13	1.15
Oct.	19.99	19.01	19.04	18.38	1.14	0.90	0.33	1.22	77.42	79.57	71.60	73.04	1.18	1.04	1.01	1.09
Nov.	18.96	18.29	19.08	18.72	1.17	0.89	0.30	1.03	76.94	77.93	70.60	79.38	1.18	1.15	1.09	1.13
Dec.	19.45	20.12	18.76	19.64	1.15	0.91	0.29	1.99	76.75	75.71	71.73	77.98	1.14	1.10	1.04	1.08
Mean	19.43± 0.63	19.56± 0.87	19.80± 0.91	19.82± 0.97	1.15± 0.24	0.96± 0.28	0.40± 0.19	1.06± 0.50	76.71± 3.16	76.75± 2.64	72.63± 2.35	75.39± 2.22	1.23± 0.37	1.11± 0.11	1.13± 0.09	1.16± 0.18

Table 2. Concentration of major amino acids in the four commercial fish species (mgg^{-1}).

Major amino acid	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*
Glutamic acid	28.45	29.03	30.77	31.58
Aspartic acid	18.14	17.85	19.21	31.58
Lysine	17.00	16.57	17.60	18.20
Leucine	15.22	15.17	16.05	16.45
Arginine	10.89	10.94	11.36	11.32
Alanine	10.30	10.82	10.95	11.32

Table 3. Concentration of medium amino acids in the four commercial fish species (mgg^{-1}).

Medium amino acid	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*
Valine	8.53	8.28	8.50	8.98
Isoleucine	8.35	8.05	8.48	8.59
Glycine	8.10	8.31	7.20	7.61
Threonine	7.68	7.67	7.99	8.43
Serine	7.16	7.15	7.64	8.21
Phenylalanine	6.69	6.49	7.42	7.06
Proline	6.09	6.32	5.69	6.18
Methionine sulphone	5.06	5.07	5.60	5.80

Table 4. Concentration of minor amino acids in the four commercial fish species (mgg^{-1}).

Minor amino acid	*C. gariepinus*	*T. zillii*	*P. quinquarius*	*P. typus*
Histidine	4.37	3.97	3.71	3.91
Cystine	1.85	1.84	1.99	2.12
Tyrosine	1.85	2.35	1.25	1.18
Ornithine	1.03	0.43	0.34	0.52
Taurine	0.85	2.41	3.20	1.65
g-aminobutyric acid	0.81	1.05	1.25	0.45
Hydroxyproline	0.45	0.48	*ND	*ND

*ND-Not detected.

species, thus affecting the protein content of the species.

The fish species examined belonged to high protein, low oil category, because the protein contents were between 15 to 20% and oil 0.20 to 2.00% (Stansby, 1982). The fish species may therefore be an ideal source of animal protein for use in controlling diets. The high tissue protein content of the fish species in this study may be related to the high protein contents of their common diets as they fed mostly on fish items, crustaceans, molluscs, algae and diatoms (Osibona, 2005).

The variation in lipid content among the studied species especially in *P. quinquarius*, which was significant, may be due to the fact that this species does not store lipid in the muscle, which is the portion examined in this study. Zenebe et al. (1998) also reported variation in the lipid values of *C. gariepinus* and *T. zillii*. The results on lipid content fall within the range of variation detected in fillets of six fishes from the Rio de la Plata (Mendez et al., 1996). Lipid content in *T. zillii* obtained in this study was lower than the value reported by Zelibe (1989) in *T. zillii* collected from Oba Reservoir, Ibadan, Nigeria. The variation in the results may be due to the fact that the *T. zillii* from Oba Reservoir were confined and were fed formulated diet that may be rich in high lipid, while species examined in this study were obtained from the wild and may not have had access to diet high in lipid.

The results of the lipid analyses of the croaker, *P. typus* in this study, was however relatively lower than that of Atlantic croakers reported by Gallagher et al. (1991). The difference might probably be due to available diet in the different regions (Ahlgren et al., 1994, 1996), or environmental factors, such as temperature, pH and

Table 5. Fatty acid composition (%) of four important commercially fish species.

Fatty acids	No. of carbon atoms	Type of fatty acid	Percentage composition			
			C. gariepinus	*T. zillii*	P. *quinquarius*	P. *typus*
Palmitic acid	C16:0	SFA	22.0	32.2	31.0	31.9
Oleic acid	C18:1	MUFA	26.0	16.2	15.5	13.0
Stearic acid	C18:0	SFA	8.1	9.5	13.7	10.0
Palmitoleic acid	C16:1	MUFA	3.6	13.2	7.2	9.4
Docosahexaenoic acid	C22:4	PUFA	3.0	3.5	5.9	8.2
Myristic acid	C14:0	SFA	4.2	5.2	5.5	2.7
Linoleic acid	C18:2	PUFA	12.3	1.4	0.6	2.8
Heptadecanoic acid	C17:1	SFA	0.7	3.0	2.4	2.4
Clupanodonic acid	C22:5	PUFA	1.0	3.7	1.5	1.0
Docosatetraenoic acid	C22:4	PUFA	0.6	1.3	2.2	2.2
Gadoleic acid	C20:1	MUFA	2.5	0.6	1.0	1.1
Eicosapentaenoic acid	C20:5	PUFA	1.0	0.7	1.0	2.4
Arachidonic acid (omega 6)	C20:4	PUFA	0.6	0.6	1.0	1.8
Pentadecanoic acid	C15:0	SFA	0.3	1.4	1.3	1.1
Lauric acid	C12:0	SFA	3.1	0.1	0.2	0.3
Linolenic acid (omega 3)	C18:3	PUFA	1.0	0.9	0.4	0.5
Octadecatetraenoic acid	C18:4	PUFA	1.6	ND	0.3	0.3
Behenic acid	C22:0	SFA	0.1	0.8	0.5	0.8
Cetoleic acid	C22:1	PUFA	1.3	ND	1.1	0.7
Linolenic acid (omega 6)	C18:3	PUFA	0.6	ND	0.5	0.4
Heptadecenoic acid	C17:1	MUFA	0.2	0.2	0.7	0.3
Myristoleic acid	C14:1	MUFA	0.2	0.5	0.4	0.2
Arachidic acid	C20:0	SFA	0.2	0.2	0.6	0.6
Eicosatrienoic acid (omega 6)	C20:3	PUFA	0.6	ND	0.2	0.3
Eicosadienoic acid	C20:2	PUFA	0.6	ND	0.2	0.2
Arachidonic acid (omega 3)	C20:0	SFA	0.3	0.3	0.1	0.2
Lingnoceric acid	C24:0	SFA	ND	ND	0.3	0.3
Eicosatrienoic acid (omega 3)	C20:3	PUFA	0.1	ND	0.2	0.2
Capric acid	C8:0	SFA	ND	0.1	0.1	0.1
Caprylic acid	C10:0	SFA	ND	ND	ND	0.1

salinity (De Torrengo and Brenner, 1976; Farkas, 1984; Henderson and Tocher, 1987). In this study, the highest lipid contents in the croaker, *P. typus* were recorded in the dry season months of October to December. These months corresponded with high results obtained for Atlantic croaker by Warlen (1982). The low lipid values in March may be as a result of spawning depletion. The increase in concentration of lipid from June may be indicative of summer feeding and storage of fat for spawning. This agreed with trends reported by Goosh et al. (1987) for 40 south eastern US finfish species.

Lipid content, in particular has been observed to vary between individual of the same species (Ssali, 1988). These variations were attributed to such factors as the geographical area in which the fish were caught, age, sex and size. The specimens used in this study were purchased from commercial catch; the different species might have been caught from different fishing areas.

The dominance of glutamic acid as a major amino acid reported in this study is similar to previous reports on amino acids composition of coho salmon (Arai, 1981); cherry salmon (Ogata et al., 1983) and channel catfish (Wilson and Poe, 1985).

The same amino acids were present in the four fish species analysed and the fact that there was no significant difference in their concentration may be because it was only the tissues that were analysed in this study. Studies have shown that concentrations of the amino acids depend on the nature of the tissues analysed (Sadiku and Oladimeji, 1989).

Nine essential amino acids namely, lysine, leucine, valine, isoleucine, threonine, phenylalanine, methionine, tryptophan and histidine that are very important for human body were present in the four species examined, therefore these species would be very good source of these amino acids in our diet. The concentration of these

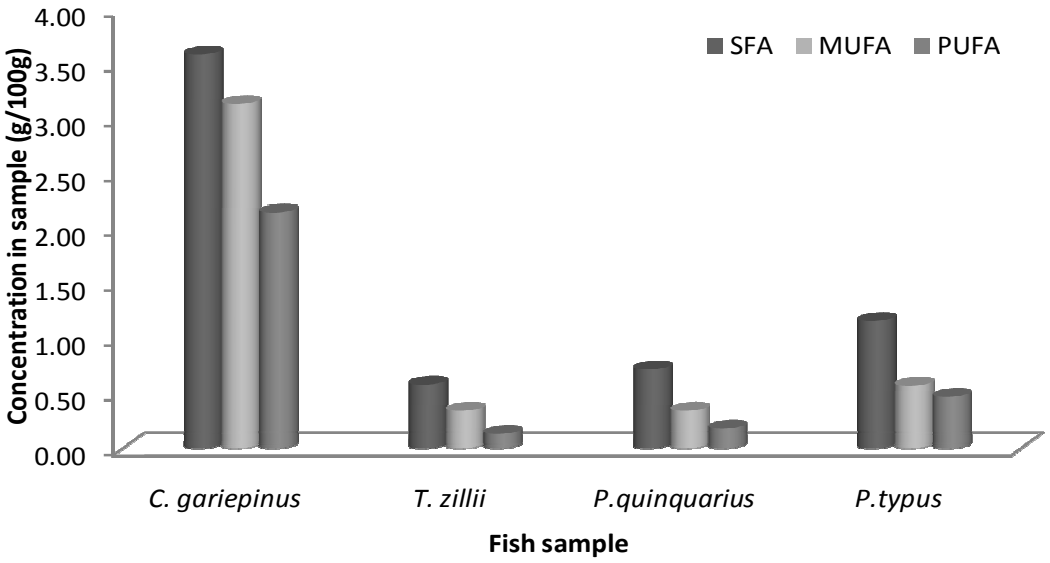

Figure 1. Total concentration of saturated, monounsaturated and polyunsaturated fatty acids of four commercially important fish species.

The amino acids were not significantly different between the species and thus, eating any of these species would provide virtually the same type of amino acids in the diet.

Hydroxyproline, a non-essential amino acid was absent in the marine species, (*P. typus* and *P. quinquarius*) but present in the freshwater species (*C. gariepinus* and *T. zillii*). This amino acid was found to be more in the collagen than in the muscle (Nelson and Cox 2005). This may be that freshwater species have more collagen than the marine species.

The significantly higher values of saturated, mono-unsaturated and polyunsaturated fatty acids in *C. gariepinus* compared to the other three fish species indicated that this species may probably be very good for human diet and it may be related to the high lipid contents of its food. Zenebe et al. (1998) reported high tissue lipid and fatty acid contents of the same species.

The most abundant fatty acids in the four fish species were the same; palmitic and stearic acids for saturated fatty acids, palmitoleic and oleic acids for mono-unsaturated fatty acid, linoleic and docosahexaenoic acids for polyunsaturated fatty acid. Similar studies on tropical (Clement and Lovell, 1994) and temperate freshwater fishes (Ahlgren et al., 1994) showed the dominance of these fatty acids in their tissues.

The most abundant fatty acids in the four fish species were the same; palmitic and stearic acids for saturated fatty acids, palmitoleic and oleic acids for mono-unsaturated fatty acid, linoleic and docosahexaenoic acids for polyunsaturated fatty acid. Similar studies performed on tropical (Clement and Lovell, 1994) and temperate (Ahlgren et al., 1994) freshwater fishes showed the dominance of these fatty acids in the tissue of fish.

The fatty acids composition of the fish used for this study was in agreement with the data available on the fatty acid composition of the fish species reported by Ackman (1980). Several authors have concluded that fatty acid profiles in fish reflect the diets of the animals (Gatlin and Stickney, 1982; Linko et al., 1985; Ogata and Murai, 1989; Watanabe et al., 1989; Turner et al., 1990). In addition to diet composition, the spawning activity of these fish could drain their fat reserves, thereby contributing to the variability of the fatty acids and low tissue lipids.

The principal acids in the polyunsaturated group were linoleic acid (C18:2), and docosahexaenoic acid (C22:6, DHA). The results of DHA obtained in this study are similar to that reported in the marine fish by Gopakumar and Nair (1972, 1978).

The result obtained in this study has provided scientific information and detailed knowledge of the proximate composition of these four important commercial fish species. The results showed that the fish species had high quality protein, essential amino acids and fatty acids. Overall, *C. gariepinus* appears to be best as diet for humans due to its relatively high nutrient components and the ratio of polyunsaturated: saturated fatty acid followed by *P. typus*, *P. quinquarius*, and *T. zillii*.

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