ISSN 1682-296X (Print)
ISSN 1682-2978 (Online)

Bio Technology

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS

Biotechnology

ISSN 1682-296X
DOI: 10.3923/biotech.2022.59.64

Research Article

Fatty Acids and Amino Acids Content of *Heterotis niloticus* (Cuvier, 1829) and *Protopterus annectens* (Owen, 1883) from Lake Alau, Northeast Nigeria

Olanrewaju, Adewale Nurudeen

Federal College of Freshwater Fisheries Technology, Baga, P.M.B 1060, Maiduguri, Nigeria

Abstract

Background and Objective: The amino and fatty acids composition of edible fishes occupies a unique position in nutrition but information on major nutritive compositions of most freshwater fishes is scanty. Thus, this study was carried out to determine the fatty and amino acids compositions of *Heterotis niloticus* and *Protopterus annectens* from Lake Alau. **Materials and Methods:** Ten live samples (weight: 500.00-2800.00 g) of each species were analyzed for fatty and amino acids using standard procedures. Data were analyzed using descriptive and chi-square statistics. **Results:** Total acid value (105.19±117.62 g 100 g^{-1}) was higher ($p<0.05$) in *P. annectens*, than *H. niloticus* (71.55±52.96 g 100 g^{-1}). Oleic acid (183.00±71.00 mg g^{-1}) and palmitic acid (18.00±1.50 mg g^{-1}) were higher in *H. niloticus* than those of *P. annectens*, but no significant variations were observed ($p>0.05$). However, the lauric acid content of *H. niloticus* was slightly higher than that of the *P. annectens* ($p>0.05$). Eighteen amino acids with varying levels were profiled from the two fish species. Methionine (1.39±0.09 g 100 g^{-1}), lysine (4.73±0.35 g 100 g^{-1}), threonine (1.77±0.08 g 100 g^{-1}), isoleucine (4.03±0.04 g 100 g^{-1}) and leucine (8.85±0.06 g 100 g^{-1}) were significantly higher ($p<0.05$) in *H. niloticus* than in *P. annectens*. However, *P. annectens* showed markedly high valine (3.98±0.14 g 100 g^{-1}), arginine (4.52±0.32 g 100 g^{-1}) and proline (3.78±0.59 g 100 g^{-1}) than values obtained in *H. niloticus*. **Conclusion:** The study revealed that *H. niloticus* and *P. annectens* were a good sources of monosaturated omega-9 fatty acids with rich essential and non-essential amino acids.

Key words: *Heterotis niloticus*, *Protopterus annectens*, nutritive composition, Omega-9, Lake Alau

Citation: Olanrewaju, A.N., 2022. Fatty acids and amino acids content of *Heterotis niloticus* (Cuvier, 1829) and *Protopterus annectens* (Owen, 1883) from Lake Alau, Northeast Nigeria. Biotechnology, 21: 59-64.

Corresponding Author: Olanrewaju, Adewale Nurudeen, Federal College of Freshwater Fisheries Technology, Baga, P.M.B 1060, Maiduguri, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fish is one of the valuable and safe foods highly recommended for man's healthy living. It greatly complements the food supply made available largely by land-based agriculture as it provides a crucial source of animal protein, fatty acids, minerals and essential micronutrients[1]. The proteins in fish are easily digestible and rich in essential amino acids which advance the healthy development of infants, growing children and expectant mothers[2]. This justifies the ever-increasing preference for fish food consumption among rural and urban dwellers especially those in riverine and coastal areas. Nutrient composition of fish, however, varies from one species to another and also within the same species due to season, geographical regions, age, maturity stage and food availability[3]. Similarly, fresh and marine water fish species do not have the same composition and even within the same environment, the chemical composition varies[4]. These variations in composition constitute the basis for the classification of fish into fat or lean fish.

A fish is considered "lean" when its flesh contains less than 2% fat, while fat fish possess high-quality lipids (about 28%). Skåre *et al.*[5] reports that fatty fish contain more fat in their tissues and have a larger variety of fatty acids than lean fish, while lean fish contain more iodine and less energy than fatty fish. Fish have been linked to many health benefits, including a lower risk of heart disease, improved mental ability, protection from cancer, alcohol-related dementia and rheumatoid arthritis[6].

In Nigeria, fish from the artisanal fishery constitute the major chain of supply, especially in the inland waters where over 316 fish species have been so far catalogued[7]. The West African Lungfish (*Protopterus annectens*) and African Bony tongue (*Heterotis niloticus*) are widely distributed in Nigeria inland waters and grow large to the relish of riparian communities. These scaly species have good quality flesh enhanced by their high muscle to bone ratio and their bones and cartilage pose less danger of choking consumers. Extensive study has been conducted on fatty and amino acids profiling of many Nigeria inland fish species[8-11] but scanty reports exist on *Heterotis niloticus* and *Protopterus annectens*. The present study was therefore carried out to analyze the fatty and amino acid composition of *H. niloticus* and *P. annectens* captured from Lake Alau, Nigeria.

MATERIALS AND METHODS

Study area: Lake Alau, the second largest lake in Borno State, Nigeria is located between latitude 11°39'84"-11°40'02"N and longitude 13°39'92"-13°40"12"E. It was created by damming river Ngadda about 22 km from Maiduguri, along Bama road. It is about 354 m above sea level with a total surface area of 56 km^2. The annual inflow into Lake Alau was calculated to be 329,000 cubic meters of water[12]. The Lake was built in the late 1980s primarily for the provision of potable water but has since sustains a thriving artisanal fisheries industry.

Sample collection and preparation: Ten live samples each of *Heterotis niloticus* and *Protopterus annectens* (weight: 500.00-2800.00 g) were collected from fishermen landing at Lake Alau. The sampling was done during morning hours and the randomly captured samples were selected and morphometrically identified. Specimens collected were sorted and immediately transported to the Biochemistry Laboratory, Yobe State University, Nigeria in ice boxes for analyses. Thereafter, the fish samples were separated, reduced to fillet and oven-dried in the laboratory. The dried fillets were then ground in an agate pestle and mortar to obtain muscle powder which was later used for fatty and amino acids.

Fatty acids analyses: The total lipids were extracted from the powder following[13] the (1959) method and fatty acid composition were determined as their methyl esters by gas chromatography (GC) technique[14] and identified by comparing their retention time with those of several commercial standard mixtures (Supelco, USA). The concentration of individual fatty acid was calculated using Heneicosanoic acid (C21:0) as an internal standard. Each sample was analyzed 3 times and its averages were calculated (Means$\pm$ Standard Deviation (SD)) as both weight percentage (fatty acid profile) and concentration (g/100 g dry tissues).

Amino acids composition analyses: Well extracted oven-dried powdered samples of the muscle were used for estimating the amino acids in High-Performance Liquid Chromatography (HPLC) (Merck-Hitachi L-7400) using Baker and Han[15] method. The results were expressed as percentages of total amino acids in each species.

Statistical analysis: Data generated were analyzed descriptively using SPSS 20.0 Statistical Software (SPSS Inc., Chicago, IL, USA). Student's t-tests were used to compare parameters between the two species. All the statistical analyses were considered at the significance level of 5% ($p<0.05$).

RESULTS

The body weights and lengths of *Protopterus annectens* and *Heterotis niloticus* samples used are as shown in Table 1. The average body weight of *P. annectens* and *H. niloticus* were 850.00±635.09 and 1200.00±1070.83 g, respectively while the standard length was 44.00±9.42 cm in *P. annectens* and 38.75±12.87 cm in *H. niloticus*. However, the variations in fish body weight and size were not statistically significant (p>0.05) between the two species.

The total acid value (TAV) of muscle tissue of *P. annectens* was comparatively higher (105.19±117.62 mg g^{-1}) than 71.55±52.96 mg g^{-1} of *H. niloticus* in Table 2. Also, a total of three fatty acids i.e., lauric acid (C12:0), palmitic acid (C16:0) and oleic acid (C18:1) were analyzed for the fish samples. These fatty acids were found oscillating between 6.00 mg and 282 mg in the two species. Oleic acid (183.00±71.00 mg g^{-1}) and palmitic acid (18.00±1.50 mg g^{-1}) were higher in *H. niloticus* than those of *P. annectens*, but no significant variations were observed (p>0.05). However, the lauric acid content of *H. niloticus* was slightly higher than that of the *P. annectens* (p>0.05).

The muscle tissue of *P. annectens* and *H. niloticus* has nine essential amino acids (EAA) in varying amounts in Table 3. The dominance of the identified EAA is in the order of Leu>Val>Phe>Trp>His>Met>Lys>Ile>Thr in West African Lungfish and Leu>Met>Lys>Ile>Trp>Phe>Val>His>Thr in African Bony tongue. Valine (3.98±0.14 g) and threonine (2.59±0.30 g) quantity were significantly higher in *P. annectens*, whereas, methionine (4.73±0.35 g), isoleucine (4.03±0.04 g), leucine (8.85±0.06 g) and lysine (4.73±0.35 g) were markedly superior in *H. niloticus*. Similarly, phenylalanine (3.95±0.25 g) and histidine (3.70±0.23 g) levels were higher in *H. niloticus* but with no significant variation (p>0.05) between species. The tryptophan content (3.91±0.54 g) of the African Bony tongue muscle was slightly higher than those of the West African Lungfish, but no significant differences were observed (p>0.05).

Table 1: Biometry measurement of the investigated fish species

	Protopterus annectens		*Heterotis niloticus*		
Parameters	Range	Mean	Range	Mean	Significance value
Weight (g)	500.00-1800.00	850.00±635.09	600.00-2800.00	1200.00±1070.83	0.594
SL (cm)	38.00-58.00	44.00±9.42	25.00-55.00	38.75±12.87	0.535
TL (cm)	44.00-69.00	51.50±11.79	28.00-62.00	43.50±14.82	0.431

SL: Standard length, SL: Total length, *p<0.005

Table 2: Total acid value and fatty acid composition (mg 100 g^{-1}) of the muscle of *Protopterus annectens* and *Heterotis niloticus* captured from Lake Alau

	Protopterus annectens		*Heterotis niloticus*		
Parameters	Range	Mean	Range	Mean	Significance value
TAV	28.05-280.50	105.19±117.62	20.67-130.90	71.55±52.96	0.621
Lauric acid	6.00-20.00	14.00±2.00	6.00-18.00	13.00±1.10	0.902
Palmitic acid	8.00-25.00	16.00±8.00	8.00-28.00	18.00±1.50	0.902
Oleic acid	85.00-282.00	176.00±84.00	85.00-254.00	183.00±71.00	0.902

TAV: Total acid value, *p<0.005

Table 3: Essential amino-acids (EAA) profile of *Protopterus annectens* and *Heterotis niloticus* from Lake Alau, Maiduguri (g 100 g^{-1})

	Protopterus annectens		*Heterotis niloticus*		
Parameters	Range	Mean	Range	Mean	FAO/WHO Pattern
Methionine (Met)	3.00-3.63	3.25±0.24	4.16-4.96	4.73±0.35*	2.00
Valine (Val)	3.85-4.18	3.98±0.14*	3.55-3.82	3.68±0.10	5.00
Tryptophan (Trp)	3.25-4.12	3.72±0.33	3.25-4.66	3.91±0.54	1.00
Phenylalanine (Phe)	3.75-4.35	3.95±0.25	3.75-3.88	3.83±0.54	3.05
Iso-Leucine (Ile)	2.00-4.05	2.97±0.77	3.98-4.08	4.03±0.04*	4.00
Leucine (Leu)	7.24-8.14	7.66±0.40	8.77-8.93	8.85±0.06*	7.00
Histidine (His)	3.45-3.95	3.70±0.23	2.70-3.86	3.07±0.49	2.50
Lysine (Lys)	3.00-4.12	3.25±0.24	4.16-4.96	4.73±0.35*	5.40
Threonine (Thr)	2.25-2.97	2.59±0.30*	1.65-1.85	1.77±0.08	4.00

*p<0.005

Table 4: Non-essential amino-acids (NEAA) profile of *Protopterus annectens* and *Heterotis niloticus* from Lake Alau, Maiduguri (g 100 g^{-1})

	Protopterus annectens		*Heterotis niloticus*		
Parameters	Range	Mean	Range	Mean	FAO/WHO Pattern
Alanine (Ala)	1.70-3.17	1.92±0.51	1.72-3.15	2.38±0.41	6.10
Aspartic Acid (Asp)	6.34-8.52	7.64±0.88	7.34-7.88	7.72±0.23	7.70
Proline (Pro)	3.15-4.66	3.78±0.59*	2.84-3.35	3.03±0.22	10.70
Glutamic Acid (Glu)	11.10-13.46	12.54±0.97	11.10-11.74	11.55±0.27	14.70
Serine (Ser)	3.45-3.89	3.74±0.18	3.40-4.31	3.91±0.36	7.70
Tyrosine (Tyr)	4.61-5.82	3.72±0.33	3.25-4.66	3.91±0.54	3.05
Cystine (Cys)	2.00-2.99	2.50±0.46	2.15-2.52	2.35±0.15	3.00
Arginine (Arg)	4.23-4.97	4.52±0.32	3.31-4.05	3.72±0.29*	5.20
Glycine (Gly)	3.04-3.42	3.25±0.18*	3.04-3.26	3.14±0.08	2.20

*p<0.005

The non-essential amino acids (NEAA) compositions of the West African Lungfish and African Bony tongue samples are shown in Table 4. The quantity of NEAA identified follow the order as Glu>Asp>Arg>Pro>Ser>Tyr>Gly>Cys>Ala in West African Lungfish and Glu>Asp>Ser>Tyr>Arg>Gly>Pro>Ala>Cys in African Bony tongue. Significantly higher ($p<0.05$) contents of proline (3.78±0.59 g) and glycine (3.25±0.18 g) were found in *P. annectens*. However, *H. niloticus* showed considerably high arginine content (3.72±0.29 g) as compared to *P. annectens*. Also, alanine (2.38±0.41 g), aspartic acid (7.72±0.23 g), serine (3.91±0.36 g) and tyrosine (3.91±0.54 g) were higher in *H. niloticus* but with no significant variation ($p>0.05$) between species.

DISCUSSION

Knowledge of the biochemical composition of fish food is important to evaluate the quality and palatability of the fillet nutrients. It is, therefore, crucial to making available the complete nutritional value of various fish species in Nigeria inland water for the benefit of consumers. The flesh obtained from the experimental fishes was characterized by a varied content of fatty acids with no statistically significant differences noted between species. The total acid value (TAV) was slightly higher in *Protopterus annectens* than *Heterotis niloticus* in the current study. This result conflicts with the previous studies on *P. annectens* from other regions[16]. Oleic acid (C18:1), a monosaturated omega-9 fatty acid is the most abundant fatty acid in *P. annectens* and *H. niloticus* in the current study. This is consistent with the work of Osibona *et al.*[8], who reported that C18:1was the dominant fatty acid in *Clarias gariepinus* and *Tilapia zilli* from Makoko and Epe Landing sites in Lagos, Nigeria. When compared with muscle oleic acid contents in *P. annectens* (0.82±029 g 100 g^{-1}) and *H. niloticus* (21.42±0.14 g 100 g^{-1}) reported by the previous study[16,17] the content of fatty acid in the current study were lower. Also, the oleic level in this study was comparatively low to the values reported in four freshwater fish species from Maga Lake, Cameroon[17].

Palmitic acid (C16:0), the predominant saturated fatty acid in both freshwater and marine fish[18], was very low in this study as compared to 2.3±0.05 g 100 g^{-1} in *P. annectens*[16] and 20.07±0.03 g 100 g^{-1} in *H. niloticus*[17]. Also, these results differ from the findings of Osibona *et al.*[8], who reported 22 and 32.2% for *C. gariepinus* and *T. zilli*, respectively. Lauric acid has many properties of medium-chain fatty acids that help to prevent infection upon consumption[19]. Lauric contents found in this study was higher than the findings of Paul *et al.*[20], who reported 2.73% for *Channa striatus* and 4.55% for *Channa marulius*. However, the authors did not find Lauric acid in *H. niloticus* and *C. gariepinus*. Also, high lauric values were reportedly found in *C. gariepinus* (3.1%) and *T. zilli* (0.1%) from Makoko and Epe Landing sites, Lagos[8]. According to Všetičková *et al.*[21] factors that influence fat content and composition of fish muscle include size or age, reproductive status, geographic location and season.

Amino acids, often referred to as the building blocks of proteins, are compounds that play many critical roles in the body. They are needed for vital processes like the building of proteins and the synthesis of hormones and neurotransmitters. According to Osibona *et al.*[8], the essential amino acids cannot be synthesized in the human body, so they are obtained from fish consumption. Kaya *et al.*[22] however, opined that the type and the number of amino acids are related to fishing season, locality, feeding habit and fish life cycle. In the current study, the range values obtained for essential amino acid composition compared well with those observed by ElShehawy *et al.*[23], for the most important fish species of Saudi Arabia. This is an indication that the species studied are nutrient-rich and could help in body development upon consumption. The investigated species contained a superior amount of lysine in comparison to *Gymnarchus niloticus*[24], *Clarias lazera*[25] and *Tilapia mosambis*[9], all from freshwater bodies in Nigeria. Similar observations were made in five different freshwater fish species investigated by Elaigwu[11] except for *Clarias anguillaris*. The methionine and threonine levels in this study were within the ranges reported by Elaigwu[11], who studied proximate composition, amino acid profile and chemical indices in five freshwater fishes from Tiga Dam Reservoir, Nigeria. Tengyang *et al.*[17], however, found much higher methionine and threonine contents in catfish, mullet and red carp caught from the Wouri river coast in Douala, Cameroon. Meanwhile, the isoleucine concentration recorded in the present study compared well with findings of Elaigwu[11] on five different freshwater fish species. This value was, however, superior to the level found in *G. niloticus*[24] and *T. mosambis*[9].

About other species[9,11,17,26], leucine contents which is an essential amino acid for protein synthesis in the body was superior in both species investigated in this study. Phenylalanine is described as a "building block" of protein with an anti-depressant agent[27]. Previous findings on phenylalanine contents by Elaigwu[11] on five different freshwater fish species corroborated the results obtained in this study, however, reports from Mohamed *et al.*[26] on five commercial Nile fishes show a comparatively low value. Valine is an essential amino acid that helps stimulate muscle growth and regeneration and is involved in energy production[28]. The valine contents obtained in the study were similar to the findings of Salma *et al.*[29] in *Scomber scombrus* and Elaigwu[11] in five freshwater fishes. Similarly, tryptophan levels observed in this study was superior to the values found by Tenyang *et al.*[17] in six fish species of Wouri river coast in Douala, Cameroon. This is an indication that eating *H. niloticus* and *P. annectens* could help to provide nitrogen balance in adults and growth in infants. The histidine contents in this study range between 3.07 ± 0.9 and 3.70 ± 0.23 g 100 g^{-1}, which is higher than 48.11 ± 2.10 mg g^{-1} in *Arius maculatus*, 37.78 ± 0.30 mg g^{-1} in *Semotilus atromaculatus* and 27.70 ± 0.55 mg g^{-1} in *Cyprinus carpio* from Wouri River coast, Cameroon[17].

The composition of non-essential amino acids in the species reported here was comparable to the pattern reported by El-Shehawy *et al.*[23], for the most important fish species of Saudi Arabia. *Protopterus annectens* and *H. niloticus* tissues contained a higher amount of serine in comparison with *Schilbe mystus* (2.74 ± 0.10 g 100 g^{-1}), *Bagrus bayad* (2.12 ± 0.06 g 100 g^{-1}), *Oreochromis niloticus* (3.03 ± 0.06 g 100 g^{-1}) and *Petrocephalus bane* (2.28 ± 0.12 g 100 g^{-1}) as reported by Elaigwu[11]. Also, a lower value than what was recorded in our study was reported by Adefemi[9] and Elaigwu[11] for cysteine in freshwater fishes from Nigerian Reservoirs. Similarly, Ibhadon *et al.*[10] and Salma *et al.*[29] also obtained lesser values of cysteine and tyrosine for Atlantic Mackerel, African catfish, *Synodontis schall* and *Brycinus nurse*, however, they obtained higher values of alanine and aspartic acid for these species. Adefemi[9] reported much lower glutamic acid values for *T. mosambi* caught from the major dam in Ekiti, Nigeria while Ibhadon *et al.*[10] determined higher glutamic acid content as 14.30% for *C. gariepinus* caught from River Kaduna. Meanwhile, Elaigwu[11] recorded higher glycine levels for the different five fish species studied as compared to the current study. The values of proline (3.03 ± 0.22-3.78 ± 0.59 g 100 g^{-1}) obtained in the present study compared well with the results verified for *T. zilli* (3.95 ± 0.21%) and *C. gariepinus* (3.81 ± 0.21) reported by Osibona *et al.*[8], whereas, higher values were observed for River catfish (6.00) and Atlantic Mackerel (6.02 ± 0.59%) by Ibhadon *et al.*[10] and Salma *et al.*[29], respectively.

CONCLUSION

The study discovered that *Protopterus annectens* and *Heterotis niloticus* from Lake Alau were the good sources of monosaturated omega-9 fatty acid and dodecanoic acid, though in trace amounts. The species were, however, rich in essential and non-essential amino acids and compared well with other freshwater fish species and Atlantic Mackerel. Therefore, consumption of these species is highly recommended since these fish species are nutritious.

SIGNIFICANCE STATEMENT

This study has brought forward the nutritive quality of *Protopterus annectens* and *Heterotis niloticus*, which is beneficial for human consumption. This study will help the nutritionist to create awareness of the nutritive value of the species. Thus, these species can be aquaculture candidates in the near future as many researchers in Nigeria are already working on this.

ACKNOWLEDGMENT

The author is thankful to Mr. Agbelege O. Olusegun, Provost, Federal College of Freshwater Fisheries Technology Baga, Nigeria for providing genuine support towards the successful completion of the research.

REFERENCES

1. Kareem, O.K. and A.N. Olanrewaju, 2015. Effect of different stocking density on nutrient utilization, growth performance and survival of african catfish (*Clarias gariepinus*, Burchell, 1822) fry in recirculatory system. J. Fish. Aquat. Sci., 10: 400-404.

2. Olanrewaju, A.N., O.K. Kareen and P.O. Oforishe, 2020. Proximate and micronutrient composition of Bayad (*Bagrus bajad*) and upside-down catfish (*Synodontis resupinatus*) from Lake Alau, Nigeria. Anim. Res. Int., 17: 3706-3712.
3. Barua, P. and S. Chakraborty, 2011. Proximate composition of egg, stomach content and body composition of Pacu (*Piaractus brachypomus*) collected from aquatic environment of Bangladesh. Curr. Biotica, 5: 330-343.
4. Taşbozan O. and M.A. Gökçe, 2017. Fatty Acids in Fish. In: Fatty Acids, Catala, A. (Ed.), IntechOpen, London, pp: 144-159.
5. Skåre, J.U., A.L. Brantsæter, L. Frøyland, G.I. Hemre, H.K. Knutsen, I.T.L. Lillegaard and B. Torstensen, 2014. Benefit-Risk Assessment of Fish and Fish Products in the Norwegian Diet – An Update. Norwegian Scientific Committee for Food Safety (VKM), Norway, ISBN: 978-82-8259-159-1, Pages: 293.
6. Dhaneesh, K.V., K.M. Noushad and T.T.A. Kumar, 2012. Nutritional evaluation of commercially important fish species of Lakshadweep archipelago, India. Plos One, Vol. 7. 10.1371/journal.pone.0045439.
7. Olaosebikan, B.D. and A. Raji, 1998. Field Guide to Nigerian Freshwater Fishes. Federal College of Freshwater Fisheries Technology, New Bussa, Niger State, Nigeria, Pages: 106.
8. Osibona, A.O., K. Kusemiju and G.R. Akande, 2009. Fatty acid composition and amino acid profile of two freshwater species, African catfish (*Clarias gariepinus*) and tilapia (*Tilapia zillii*). Afr. J. Food Agric. Nutr. Dev., 9: 608-621.
9. Adefemi, O.S., 2011. Chemical composition of *Tilapia mosambis* fish from major dams in Ekiti-State, Nigeria. Afr. J. Food Sci., 5: 550-554.
10. Ibhadon, S., M.S. Abdulsalami, M.C. Emere and V. Yilwa, 2015. Comparative study of proximate, fatty and amino acids composition of wild and farm-raised African catfish *Clarias gariepinus* in Kaduna, Nigeria. Pak. J. Nutr., 14: 56-61.
11. Elaigwu, A.M., 2019. The proximate composition, amino acid profile and chemical indices in five freshwater fishes from Tiga Dam Reservoir, Nigeria. Croatian J. Fish., 77: 87-92.
12. Olanrewaju, A.N., O.K. Kareem, R.E. Nyaku and M.T. Tubo, 2017. Length-weight and length-length relationships of *Heterotis niloticus* (Cuvier, 1829) and *Raiamas senegalensis* (Steindachner, 1870). J. Aquacult. Res. Dev., Vol. S2. 10.4172/2155-9546.S2-011.
13. Bligh, E.G. and W.J. Dyer, 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol., 37: 911-917.
14. Gladyshev, M.I., N.N. Sushchik, G.A. Gubanenko, S.M. Demirchieva and G.S. Kalachova, 2006. Effect of way of cooking on content of essential polyunsaturated fatty acids in muscle tissue of humpback salmon (*Oncorhynchus gorbuscha*). Food Chem., 96: 446-451.
15. Baker, D.H. and Y. Han, 1994. Ideal amino acid profile for chicks during the first three weeks posthatching. Poult. Sci., 73: 1441-1447.
16. Mohamed, H.A.E. and J.N. Al-Sabahi, 2014. The composition of fatty acids stored in liver, muscle and fat tissues of the African lungfish *Protopterus annectens* (Owen, 1839). Afr. J. Biochem. Res., 8: 19-24.
17. Tengyang, N., R. Ponka, B. Tiencheu and F.T. Djikeng and H.M. Women, 2016. Proximate composition, fatty acid and mineral contents of four freshwater fish from Maga Lake (Far North Region of Cameroon). Am. J. Food Sci. Technol., 4: 64-69.
18. Islam, R., M.M. Islam, M. Shoeb and N. Nahar, 2018. Fatty acid compositions in marine fish samples of Bangladesh. J. Nutr. Food Sci., Vol. 8. 10.4172/2155-9600.1000723.
19. Dayrit, F.M., 2015. The properties of lauric acid and their significance in coconut oil. J. Am. Oil Chem. Soc., 92: 1-15.
20. Paul, D.K., R. Islam and M.A. Sattar, 2013. Physico-chemical studies of lipids and nutrient contents of *Channa striatus* and *Channa marulius*. Turk. J. Fish. Aquatic Sci., 13: 487-493.
21. Všetičková, L., P. Suchý and E. Straková, 2020. Factors influencing the lipid content and fatty acids composition of freshwater fish: A review. Asian J. Fish. Aquat. Res., 4: 1-10.
22. Kaya, Y., M.E. Erdem and H.H. Turan, 2014. Monthly differentiation in meat yield, chemical and amino acid composition of wild and cultured brown trout (salmo trutta forma fario linneaus, 1758). Turk. J. Fish. Aquat. Sci., 14: 479-486.
23. ElShehawy, S.M., A.A. Gab-Alla and H.M.A. Mutwally, 2016. Amino acids pattern and fatty acids composition of the most important fish species of Saudi Arabia. Int. J. Food Sci. Nutr. Eng., 6: 32-42.
24. Adeyeye, E.I. and A.S. Adamu, 2005. Chemical composition and food properties of *Gymnarchus niloticus* (trunk fish). Biosci. Biotech. Res. Asia, 3: 265-272.
25. Aremu, M.O. and O.E. Ekunode, 2008. Nutritional evaluation and functional properties of *Clarias lazera* (African Catfish) from River Tammah in Nasarawa State, Nigeria. Am. J. Food Technol., 3: 264-274.
26. Mohamed, H.A.E., R. Al-Maqbaly and H.M. Mansour, 2010. Proximate composition, amino acid and mineral contents of five commercial Nile fishes in Sudan. Afr. J. Food Sci., 4: 640-654.
27. Akram, M., M. Daniyal, A. Ali, R. Zainab, S.M.A. Shah, N. Munir and I.M. Tahir, 2020. Role of Phenylalanine and its Metabolites in Health and Neurological Disorders. In: Synucleins - Biochemistry and Role in Diseases, Surguchov, A. (Ed.), IntechOpen London, pp: 1-13.
28. Taya, Y., Y. Ota, A.C. Wilkinson, A. Kanazawa and H. Watarai *et al*., 2016. Depleting dietary valine permits nonmyeloablative mouse hematopoietic stem cell transplantation. Science, 354: 1152-1155.
29. Salma, E.L.O., D. Cyrine and M. Nizar, 2016. Fatty acids and amino acids contents in *Scomber scombrus* fillets from the South East of Tunisia. Afr. J. Biotechnol., 15: 1246-1252.