



Evaluation of the Biochemical Composition of Some Cultivable Cichlids (Tilapia Species) in Nigeria

Adunola Abosedo Bello^{1*}, Oluwafunmike Blessing Adepoju¹,
Oluwasola Toluwalope Moradeyo¹, Olayinka Josephine Okuneye¹
and Oluwafemi Akinsola Omole¹

¹Chemical, Fibre and Environmental Technology Department, Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author AAB designed the study, performed the statistical analysis and wrote the protocol. Authors OBA and OTM sourced for the samples and managed the literature searches. Authors OJO and OAO managed the analyses. Authors AAB and OAO wrote the first draft of the manuscript. All Authors read and approved the final manuscript.

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ABSTRACT

The biochemical composition of three cultured cichlids (*Tilapia zilli*, *Tilapia guineensis* and *Oreochromis aureus*) were evaluated and compared. The proximate composition of the cichlids was determined using official methods of analysis, mineral composition was determined using Atomic Absorption Spectrophotometer and the amino acid composition was analyzed using Amino Acid Analyzer. The proximate composition of the three cultured species of tilapia fish (*T. zilli*, *T. guineensis* and *O. aureus*) indicated that moisture content, crude fat, crude fiber and ash content showed significant difference ($p < 0.05$) among the three species while crude protein and carbohydrate content showed no significant difference ($p < 0.05$) among the three species. The mineral contents such as zinc, magnesium and manganese showed significant difference ($p < 0.05$) among the three species of tilapia (*T. zilli*, *T. guineensis* and *O. aureus*) while sodium, potassium, calcium, iron, phosphorus and copper contents showed no significant difference ($p < 0.05$) among the three species. The amino acid composition showed lysine as the most abundant amino acids present in all the cultured cichlids studied. This shows that these cultured cichlids are highly nutritious and would be of great value to consumers.

*Corresponding author: Email: b_adunola@yahoo.com;

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1. INTRODUCTION

Fish is a very important source of protein in Nigeria, fish products are relatively cheaper compared to beef, pork and other animal protein sources in the country [1]. However, the gap between the demand and supply of fish cannot be met through wild fishes alone [2] due to various human activities and increase in population [3]. Therefore, there is need to cultivate fish species to be able to close the gap between the demand and supply. The major fish species cultured in Nigeria include tilapias, catfish and carp.

Fish has four major components such as water, protein and lipid along with ash in smaller quantities that comprise overall edible structure of fish body. The percentage of moisture, protein, fat and ash contents overall comprises of approximately 96-98% [4]. Still, the fish species of different groups lack equal nutrient quality levels for their consumers [5,6] because chemical composition in fish body changes with the environment which may be due to different water quality parameters, different feeding conditions, sex of the species, maturity [7] and capturing situations [8]. Protein contents of fish provide rich source of some important amino acids as methionine, tryptophan, lysine, threonine and cysteine, [9,10]. These vital amino acids ultimately provide health benefits for humans [11]. Most of the countries of tropical region are facing enormous nutritional deficiency problems due to low levels of proteins in their diet [12]. The utilization of fish as part of diet has overall beneficial effects [11] in major problems for diseases in heart [13], stroke, degeneration of muscle in elder people and ultimately the prevention of brain damage [14].

Tilapia belongs to the Cichlidae family which is second most farmed species throughout world after carp (Cyprinidae) [15]. Tilapias known to have around 100 species are of East Africa origin spread in many parts of world [15]. *Tilapia* is generally considered as a freshwater species but will tolerate brackish conditions. Tilapias are produced most economically in tropical and sub-tropical countries which have favorable temperatures for their growth [16,17]. Wild tilapia is typically found in waters where temperature ranges in 13.5°C to 33°C (56°F to 91°F). The extended temperature range for this species is

however 8°C to 42°C (47°F to 108°F) [18]. *Tilapia* are suited to low technology farming systems due to their fast growth rate, efficient use of natural aquatic foods, ability to consume a variety of supplementary feeds, omnivorous food habits, resistance to disease and handling, ease of reproduction in captivity, and tolerance to wide ranges of environmental conditions [19]. *Tilapia zilli*, *Tilapia guineensis*, *Sarotherodon galilaeus*, *S. melanotheron*, *Oreochromis niloticus* and *Oreochromis aureus* are some of the tilapia species commonly found in Nigeria. This research work focused on the evaluation and comparison of the biochemical composition of *Tilapia zilli*, *Tilapia guineensis* and *Oreochromis aureus* tilapia species cultured in Nigeria.

2. MATERIALS AND METHODS

2.1 Sources of Fish Samples

Tilapia zilli, *Tilapia guineensis* and *Oreochromis aureus* species of *Tilapia* were purchased from Aquaborne farms, Lagos (latitude 40 15' north latitude 40 17' north and longitude 130 15' east and 130 20' east). The tilapia species were fed with oilseed cakes, fish meal and poultry by products. They were collected between the month of August – September 2019 at the age of six months with the weight of *Tilapia zilli* – 200 g, *Tilapia guineensis* –180 g and *Oreochromis aureus*- 150 g. They were kept in ice-box and transported to the laboratory where they were prepared and pre-treated before analysis.

2.2 Determination of Proximate Components

The crude fat, crude fibre, ash content and carbohydrate content of the fish samples were determined according to the methods of [20] while the crude protein was determined according to the method of [21] with some modifications.

2.2.1 Moisture content

The fish samples (5g) each was dried in an oven at 105°C for 6 hours, it was cooled in the desiccator and weighed again. This process was repeated until constant weight was obtained. The percentage moisture content was calculated as:

$$\% \text{ Moisture} = \frac{(\text{Weight loss due to drying}) \times 100}{(\text{Weight of sample})}$$

2.2.2 Crude fat

The samples (5 g) each were weighed into a thimble and placed in a soxhlet apparatus. A 500 ml round bottom flask was attached to the base of the extractor and clamped to a retort stand. 300 mL petroleum ether was poured into the thimble. The set up was placed on heating mantle with the top of the extractor connected to the reflux condenser. The source of heat was turned on as well as water source supplied to enable the solvent in the flask to boil and extract the lipid in the sample. The extraction was completed in 12 hours and the solvent was recovered using rotary evaporator. The extracted lipid in the flask was placed in an oven at 70°C for 30 mins to completely remove all the solvent residues and then placed in a desiccator to cool. The percentage of lipid was calculated using the equation below:

Weight of lipid = Weight of flask and content after extraction – Weight of flask before extraction.

2.2.3 Crude protein

The crude protein content was determined using microkjeldahl method. The digested samples were diluted, made alkaline with NaOH and distilled water. Liberated ammonia gas was trapped in a conical flask containing boric acid solution. The conical flask was positioned such that the stem of the condenser dipped into the boric acid solution. After collecting about 50cm³ of the distillate, the receiver was lowered and the tip of the condenser was washed with distilled water, the ammonia solution in the distillate was titrated against 0.1M HCl. A blank determination was carried out using the same amount of the reagents in the absence of the sample.

$$\% \text{ Nitrogen Content} = \frac{(\text{Titre value} \times M \times 0.0014 \times Df \times Cf)}{(\text{Weight of sample})}$$

Where:

M = Molarity of HCl = 0.01M

Df = Dilution factor = 50

Cf = Correction factor = 10

% Crude protein = % Nitrogen x 6.25

% Nitrogen was converted to percent crude protein by multiplying with 6.25, the conversion factor. Most proteins contain 16% Nitrogen, hence, the conversion factor is 6.25 (100/16 = 6.25).

2.2.4 Crude fibre

100 ml of 0.25M H₂SO₄ was added to 2 g each of the fish samples and brought to boil for 30 mins after which the hot mixture was filtered. The residue was washed free of acid with plenty of warm water. Each residue was transferred into round bottom flasks to which 100 ml of 0.25M of NaOH was added and boiled for again for 30 minutes. The mixture was then filtered and the residue washed free of alkali with warm water. The residue was then transferred into a dried, weighed silica dish and dried to a constant weight at 105°C for 90 mins, cooled in a desiccator and weighed. The weighed samples were burnt off and reweighed. The percentage crude fiber content was determined as follows:

Initial weight of residue - Final weight of residue x 100

2.2.5 Ash content

The sample (5 g) each was weighed into a previously dried, cooled and weighed silica crucible. The crucible containing the sample was transferred into a muffle furnace and ignited at 550°C until a white ash was obtained. The ash was moistened with distilled water, dried on steam bath and then on hot-plate and re ashed at 550°C to constant weight. The percentage ash content was calculated as follows:

$$\text{Ash content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

2.2.6 Carbohydrate

The carbohydrate content was determined by difference i.e.

% Carbohydrates = 100 - (%Mo + % As + % Cf + % Cp)

Where:

%Mo= Percentage moisture content

%As= Percentage ash content

%Cf= Percentage crude fat

%Cp= Percentage crude protein

2.3 Determination of Amino Acid Composition of *T. zilli*, *T. guineensis* and *O. aureus*

The amino acid profile of the fish samples were determined using amino acid analyser, technicon TSM-1 (model: DNA 0209) and methods

described by [22]. The fish samples were dried to constant weight, defatted, hydrolysed, evaporated in a rotary evaporator and loaded into the Technicon sequential Multi-sample Amino Acid Analyser (TSM). Approximately 200 mg each of the fish samples was dissolved in 0.7 mL distilled H₂O and 0.5 mL 20 mM norleucine (internal standard). 500 mL each of the extract was mixed with 50 mL 20 mM norleucine. Concentrated hydrochloric acid (HCl, 12 M) was added, to a final concentration of 6 M. The sample mixture was flushed with nitrogen gas for 15 s in order to minimize oxidation, before hydrolysis at 110°C for 24 h. Following hydrolysis, 100 mL aliquots of the hydrolysates were evaporated under nitrogen gas until complete dryness and re-dissolved to a suitable concentration in lithium citrate buffer at pH 2.2. All amino acids were analyzed chromatographically using an ion exchange column followed by ninhydrin post column derivatization on a Biochrom 30 amino acid analyser (Biochrom Co., Cambridge, UK). Amino acid residues were identified using the A9906 physiological amino acids standard (Sigma Chemical Co., St. Louis, MO, USA).

2.4 Determination of Mineral Composition of *T. zilli*, *T. guineensis* and *O. aureus*

The mineral composition of the fish samples were determined according to the method adopted by [20].

Accurately weighed (2.0 g) each of the fish samples was transferred into a silica crucible and subjected to dry ashing in a muffle furnace at 550°C. The ash gotten was dissolved in 5 mL HNO₃/HCl/H₂O (1:2:3) and heated gently using heating mantle until the brown fumes disappeared. Distilled water (5 mL) was added to the remaining content of the crucible and heated. The solution was filtered using whatman No 4 filter paper and made up to 100 mL. Working standard solutions were prepared by diluting the stock solution. Mg, Fe, Ca, Zn and P in the fish samples were analyzed using atomic absorption spectrophotometer, (Model 215 VGP BUCK Scientific) equipped with flame and graphite furnace. Na and K was determined using flame photometer.

2.5 Statistical Analysis

Statistical analyses were performed using SPSS (version 20). All data collected were subjected to analysis of variance (ANOVA) using PostHoc

analysis. Means were used to compare differences between the treatment means at 5% probability level. The means were separated using LSD at 0.5%.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of *T. zilli*, *T. guineensis* and *O. aureus*

Table 1 shows the proximate composition of three species of tilapia fish (*T. zilli*, *T. guineensis* and *O. aureus*). Parameters such as moisture content, crude fat, crude fiber and ash content showed significant difference ($p < 0.05$) among the three species of tilapia. However, crude protein and carbohydrate content showed no significant difference ($p < 0.05$) among the three species. The highest moisture content was found in *O. aureus* (61.89%) while the lowest moisture content was recorded in *T. zilli* (57.93%). The highest crude fat (10.02%) was observed in *T. zilli* while the lowest crude fat (7.68%) was found in *O. aureus*. Conversely, *O. aureus* gave highest values for crude fibre (1.62%) and ash content (1.21%). The moisture contents (57.93%, 60.74% and 61.89%) for *T. zilli*, *T. guineensis* and *O. aureus* obtained in this study were in close agreement with 60.05% reported by [20] for *T. guineensis* and within the range of 50.96% - 64.22% reported by [23] for *T. guineensis*, *O. aureus* and *T. zilli* respectively. The percentage of moisture in fish species indicates the protein, lipid and carbohydrate contents. The lower the moisture content, the higher the lipid, protein and carbohydrate contents [23]. Also, high moisture content makes fishes more susceptible to microbial spoilage and oxidative degradation of available polyunsaturated fatty acids [23]. All the cichlids are high lipid fishes which made them have low moisture and high protein contents. The lipid content is higher than 6.53% reported by [20] for *T. guineensis* and those reported by [23] for *T. guineensis*, *O. aureus* and *T. zilli*. This may be attributed to environmental conditions and the composition of fish feed given to the fishes in the controlled rearing system. [24] reported that feed composition is a major factor influencing the proximate composition and mineral contents of fishes. *T. zilli* had the highest protein content of 28.31%, though all the cichlids evaluated in this study have high protein contents which shows they are good source of protein. *O. aureus* had the highest ash content, the ash contents obtained indicates the fishes are good source of minerals. The carbohydrate content and crude fiber were low, this is expected as fish is not a

good source of carbohydrate and fiber. However, there is no importance attached to this as fish is usually consumed with other foods rich in carbohydrate and fiber.

3.2 Mineral Contents of *T. zilli*, *T. guineensis* and *O. Aureus*

Table 2 shows the mineral contents of three species of tilapia fish (*T. zilli*, *T. guineensis* and *O. aureus*). Parameters such as zinc, magnesium and manganese showed significant difference ($p < 0.05$) among the three species of tilapia. Meanwhile, sodium, potassium, calcium, iron, phosphorus and copper contents showed no significant difference ($p < 0.05$) among the three species. The results showed that *O. aureus* possessed the highest magnesium (226.40 mg/kg), phosphorus (98.17 mg/kg), zinc (214.34 mg/kg) and manganese (209.01 mg/kg) contents. However, *T. zilli* contained the least magnesium content (218.60 mg/kg), phosphorus (92.15 mg/kg), zinc (206.19 mg/kg) and manganese (203.74 mg/kg). The concentration of sodium, potassium, iron, magnesium, calcium, zinc, magnesium, manganese and phosphorus were high in all the fishes but most abundant in *O.*

aureus, this may be due to the fact that *O. aureus* had the highest ash content. Vital body functions such as acid-base and water balance are dependent on minerals. Iron is an important constituent of hemoglobin [25] while zinc plays important roles in the management of diabetes which could result from insulin malfunction [26]. High concentration of sodium observed in this study indicates that the ponds from which the fishes were collected is very rich in sodium which is responsible for an active movement of this ion across the gill structure. The high concentration of sodium boosts the osmoregulatory activities in the organisms [27,28].

3.3 Amino acids Composition of *T. zilli*, *T. guineensis* and *O. aureus*

Table 3 shows the amino acids composition of three species of tilapia fish (*T. zilli*, *T. guineensis* and *O. aureus*). Parameters such as methionine, isoleucine, threonine, phenylalanine, arginine, lysine, proline, glycine, serine and cysteine showed significant difference ($p < 0.05$) among the three species of tilapia. However, valine, tryptophan, glutamic acid, alanine, tyrosine, leucine, histidine and aspartic acid showed no

Table 1. Proximate composition of *T. zilli*, *T. guineensis* and *O. aureus*

Parameters (%)	<i>T. zilli</i>	<i>T. guineensis</i>	<i>O. aureus</i>
Moisture Content	57.93±0.005 ^c	60.74±0.023 ^b	61.89±0.012 ^a
Crude Fat	10.02±0.008 ^a	8.64±0.014 ^b	7.68±0.023 ^c
Crude Protein	28.31±0.015	26.19±0.014	25.45±0.013
Crude Fibre	1.12±0.018 ^c	1.44±0.016 ^b	1.62±0.008 ^a
Ash Content	0.87±0.005 ^c	1.02±0.008 ^b	1.21±0.014 ^a
Carbohydrate by difference	1.75±0.025	1.97±0.014	2.15±0.023

Values are mean ± standard deviation of triplicate determinations

abc: Means within each row with different superscripts are significantly different ($p < 0.05$)

Table 2. Mineral composition of *T. zilli*, *T. guineensis* and *O. Aureus*

Metals (mg/kg)	<i>T. zilli</i>	<i>T. guineensis</i>	<i>O. aureus</i>
Sodium	340.31±0.05	351.20±0.025	360.25±0.014
Potassium	298.12±0.025	300.41±0.08	305.32±0.014
Magnesium	218.60±0.018 ^c	220.70±0.05 ^b	226.40±0.012 ^a
Calcium	190.08±0.034	196.12±0.024	198.86±0.05
Phosphorus	92.15±0.017	96.50±0.023	98.17±0.012
Iron	274.50±0.03	277.60±0.034	279.75±0.016
Zinc	206.19±0.023 ^c	210.20±0.02 ^b	214.34±0.08 ^a
Manganese	203.74±0.012 ^c	207.19±0.12 ^b	209.01±0.06 ^a
Copper	0.12±0.05	0.15±0.028	0.17±0.013

Values are mean ± standard deviation of triplicate determinations

abc: Means within each row with different superscripts are significantly different ($p < 0.05$)

Table 3. Amino Acid Composition of *T. zilli*, *T. guineensis* and *O. aureus*

Amino acids (g/100 g)	<i>T. zilli</i>	<i>T. guineensis</i>	<i>O. aureus</i>
Methionine	5.67±0.018 ^a	4.33±0.02 ^b	1.98±0.028 ^c
Isoleucine	4.01±0.034 ^c	6.92±0.013 ^a	5.01±0.07 ^b
Leucine	7.25±0.02	3.14±0.018	5.79±0.025
Valine	5.14±0.015	4.23±0.016	3.97±0.023
Histidine	2.78±0.014	2.99±0.06	1.95±0.012
Threonine	3.96±0.025 ^c	4.57±0.026 ^b	4.61±0.03 ^a
Phenylalanine	3.99±0.03 ^c	7.02±0.018 ^a	4.36±0.016 ^b
Lysine	12.14±0.04 ^a	7.17±0.012 ^c	10.52±0.015 ^b
Tryptophan	8.07±0.021	5.19±0.03	4.63±0.013
ΣEAA	53.01	51.71	47.96
Arginine	6.09±0.05 ^b	6.15±0.014 ^a	5.14±0.023 ^c
Proline	2.85±0.016 ^c	4.02±0.034 ^a	3.76±0.013 ^b
Glycine	4.02±0.05 ^a	3.19±0.034 ^c	3.45±0.045 ^b
Glutamic acid	9.04±0.012	7.62±0.023	7.12±0.04
Alanine	4.98±0.018	5.02±0.016	5.64±0.05
Serine	3.58±0.026 ^c	3.61±0.012 ^b	5.34±0.034 ^a
Tyrosine	2.02±0.013	2.34±0.034	1.97±0.02
Aspartic acid	10.41±0.04	8.98±0.025	9.41±0.015
Cysteine	3.45±0.026 ^a	2.89±0.03 ^b	2.76±0.02 ^c
ΣNEAA	46.44	37.67	39.45
TAA	99.45	89.38	87.41

Values are mean ± standard deviation of triplicate determinations

abc: Means within each row with different superscripts are significantly different ($p < 0.05$)

significant difference ($p < 0.05$) among the three species. The highest methionine content (5.67 g/100 g) was found in *T. zilli* while the lowest methionine content (1.98 g/100 g) was found in *O. aureus*. Moreover, the highest lysine (12.14 g/100 g), tryptophan (8.07 g/100 g), glycine (4.02 g/100 g) and cysteine (3.45 g/100 g) were found in *T. zilli*. The highest isoleucine content (6.92 g/100 g), phenylalanine (7.02 g/100 g), arginine content (6.15 g/100 g), proline (5.19 g/100 g) and tyrosine (2.34 g/100 g) were found in *T. guineensis*. However, the highest threonine content (4.61 g/100 g) and serine (5.34 g/100 g) were found in *O. aureus*. Lysine was found to be the most abundant amino acid in all the fish samples evaluated in this study, this was in close agreement with the values reported by [15] in which lysine also had the highest concentration in all the Tilapia species studied. *T. zilli* had the highest essential amino acid concentration in all the cichlids evaluated in this study. Essential amino acids (leucine, isoleucine, lysine, valine, methionine, phenylalanine, threonine and tryptophan) cannot be synthesized in the body but they are necessary for the body system because they play important roles [29]. The presence of amino acids makes marine species important source of food as vegetable proteins

contain limited amount of essential amino acids [30]. Deficiency of essential amino acids may hinder healing recovery processes and leads to degradation of the muscle proteins in the body [23]. Leucine promotes the healing of bones, skin and muscles tissue while Isoleucine is necessary for haemoglobin formation, stabilizing and regulating blood sugar and energy [23]. Glycine, alanine, proline, arginine, serine, isoleucine and phenylalanine which are major components of human skin collagen form polypeptides for growth and tissue healing [23]. All the cichlids studied contains the essential amino acids needed by the body, thus, they will provide good nutritive value when consumed.

4. CONCLUSION

Considering the nutrient composition of the three cultured Tilapia species, *T. zilli* is the richest source of protein and amino acids while *O. aureus* is the highest source of mineral contents. However, all the cichlids studied are good sources of nutrients for consumers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Amao JO, Oluwatayo IB, Osuntope FK. Economics of Fish Demands in Lagos State, Nigeria. *Journal of Human Ecology*. 2006;19(1):25–30.
2. FAO. Aquaculture development and research in Sub-Saharan Africa. CIFA Technical Paper; 1994.
3. Rajbanshi, KG. Why Grow Fish. *Handbook on Fish Culture*; 1996.
4. Nowsad AK. In participatory training of trainers: A new approach applied in Fish Processing. *Bangladesh Fisheries Research Forum*; 2007.
5. Soriguier FS, Serna E, Valverde J, Hernando A, Martín-Reyes M, Soriguier A, et al. Lipid, protein, and calorie content of different Atlantic and Mediterranean fish, shellfish, and molluscs commonly eaten in the south of Spain. *European Journal of Epidemiology*. 1997;13(4):451-63.
6. Takama KT, Suzuki, KY, Arai, H, Mitsui, T. Phosphatidylcholine levels and their fatty acid compositions in teleost tissues and squid muscle. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*. 1999;124(1):109-16.
7. Javaid MYA, Salam MNK, Naeem M. Weight-length and condition factor relationship of a fresh water wild Mahaseer (*Tor putitora*) from Islamabad (Pakistan). In *Proceeding of Pakistan Congress of Zoology*. 1992;12:335-340.
8. Oliveira ER, Agostinho, AA, Matsushita, M. Effect of biological variables and capture period on the proximate composition and fatty acid composition of the dorsal muscle tissue of *Hypophthalmusedentatus* (Spix, 1829). *Brazilian Archives of Biology and Technology*. 2003;46(1):105-14.
9. Fisheries, FA. Aquaculture Department. *Global Aquaculture Production Statistics for the year*; 2013.
10. Laghari MY, Narejo NT, Abbasi AR, Jalbani S, Khan P, Kalhor N, et al. Biochemical Composition and Nutrient contents of Tilapia Zilli from Barechil AKE, District Badin, Sindh. *Pakistan Sindh Univ. Res. Jour. (Sci. Ser.)*. 2019;51(01):65-70.
11. Limin, LXF, Jing, H. Amino acids composition difference and nutritive evaluation of the muscle of five species of marine fish, *Pseudosciaenacrocea* (large yellow croaker), *Lateolabrax japonicus* (common sea perch), *Pagrosomus major* (red seabream), *Serioladumerili* (*Dumeril's amberjack*) and *Hapalogenys nitens* (blackgrunt) from Xiamen Bay of China. *Aquaculture Nutrition*. 2006;12(1):53-9.
12. Eyo AA. Fish processing technology in the tropics. *National Institute for Freshwater Fisheries Research*. University of Ilorin press. 2001;66-70.
13. Mozaffarian D, Lemaitre RN, Kuller LH, Burk GL, Tracy RP, Siscovick DS. Cardiac benefits of fish consumption may depend on the type of fish meal consumed. *Circulation*. 2003;107(10):1372–1377.
14. Peet M, Stokes C. Omega-3 fatty acids in the treatment of psychiatric disorders. *Drugs*. 2005;65(8):1051-9.
15. Tasbozan O, Ozcan, F, Erbas, C, Unidag, E, Atici, AA, Adakli A. Determination of proximate and amino composition of five different Tilapia species from the Cukurova Region (Turkey). *Journal of Applied Biological Sciences*. 2013;7(3):17-22.
16. Mensah, ET, Attipoe, FK, Ashun, Johnson M. Effect of different stocking densities on growth performance and profitability of *Oreochromis niloticus* fry reared in hapa-in-pond system. *International Journal of Fisheries and Aquaculture*. 2013;5(8):204-209.
17. Adams FY, Nkemakolam AN, James, OA, Ebenezer DO, Temitope, EA. Economic profitability of Nile Tilapia (*Oreochromis niloticus* Linnaeus 1757) in semi flow through culture system. *Journal of Aquatic Science*. 2014;2(1):1-4.
18. Zenebe, T, Ahlgren, G, Gustafsson, IB, Boberg, M. Fatty acid and lipid content of *Oreochromis niloticus* L. in Ethiopian lakes-dietary effects of phytoplankton. *Ecology of Freshwater Fish*. 1997;7(3):146–158.
19. Adesulu, EA, Sydenham, DHJ. The freshwater fishes and fisheries of Nigeria. *Macmillan Nigeria Publishers Ltd.*, Ibadan. 2007;397.
20. Adeniyi SA, Orikwe CL, Ehiagbonare, JE, Joshia, J. Nutritional composition of three different fishes (*Clarias gariepinus*, *Malapterurus electricus* and *Tilapia guineensis*). *Pak J. Nutri*. 8;793-797.
21. Job, BE, Antai, EE, Inyang, Etoh, AP, Otego, GA, Ezekiel HS. Proximate composition and mineral contents of cultured and wild tilapia (*Oreochromis niloticus*) (Pisces: Cichlidae) (Linnaeus, 1758). *Pakistan Journal of Nutrition*. 2015;14(4):195.

22. MaehreHK, Edvinsen, GK, Eilertsen, KE, Elvevoll EO. Heat treatment increases the protein bioaccessibility in the red seaweed dulse (*Palmaria palmata*), but not in the brown seaweed winged kelp (*Alaria esculenta*). *J. Appl. Phycol.* 2016;28:581–590
23. Ogundiran MA, Ayandiran, TA. Comparative Studies on the Nutritional Fitness of some Selected Cichlids Sampled from OBA Reservoir, South Western Nigeria. *J Aquac Res Development.* 2019;10:570.
24. El Zaeem, SY, Ezzat, ETN, Talent, NA. Effect of direct injection of shark DNA into skeletal muscles on the productive performance characteristics of red tilapia (*Oreochromis* sp.) Red at different directory requirement. *Afr. J. Agric. Res.* 2012;7:2456-2462.
25. Onwordi CT, Ogungbade, AM, Wusu, AD. The proximate and mineral composition of three leafy vegetables commonly consumed in Lagos, Nigeria. *Afri. J Pure and Applied Chem.* 2009;3:102-107.
26. OkakaJC, OkakaANO. Food composition spoilage and shelf life extension. *Ocjar Academic Publishers, Enugu Nigeria.* 2001;54-56.
27. VadivelV, Jonardhanan, K. Chemical composition of the underutilized legume cassia hirsute L. *Plant Foods for Human Nutrition.* 2000;55:369-381.
28. Watchman, II. Composition and quality of fish, Edinburgh, Tory Research Station; 2000.
29. Brown A. Understanding Food. Fish and Shellfish. Wadsworth/Thomson Learning, USA. 2000;299-318.
30. Turan C, OralM, Ozturk B, Duzgunes, E. Morphometric and meristic variation between stocks of Bluefish (*Pomatomus saltatrix*) in the Black, Marmara, Aegean and Northeastern Mediterranean Seas. *Fisheries Research.* 2006;79:139–147.

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