Nutritional Evaluation of *Clarias gariepinus* and *Tilapia quineesis* Fishes from River Doma in Nasarawa State, Nigeria

Matthew Olaleke Aremu [a*]**, Hashim Ibrahim** [a,b]**, Al–Qasim Suleiman Gwadabe** [a]**,**
Saratu Stephen Audu [c]**, Mohammed Alhaji Mohammed** [a,d]**,**
Mary Omolola Omosebi [e] **and Esther Damilola Aremu** [e]

[a] *Department of Chemistry, Federal University of Lafia, PMB 146, Nasarawa State, Nigeria.*
[b] *Department of Chemistry, University of Nairobi, Nairobi, Kenya.*
[c] *Department of Chemistry, Nasarawa State University, Keffi, P.M.B 1022, Nigeria.*
[d] *Department of Chemistry, University of Malaya, Kuala Lumpur, Malaysia.*
[e] *Department of Food Science and Technology, Mountain Top University, Magoki, Ogun State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This work evaluates the nutritional quality of *Clarias gariepinus* and *Tilapia guineensis* fishes from River Doma in Nasarawa State, Nigeria.
Study Design: African catfish (*Clarias gariepinus*) and tilapia (*Tilapia guineensis*) contribute enormously to the developing nation's nutritional, growth, and development needs, especially in terms of high protein retention in the human body.
Methodology: Oven-dried *Clarias gariepinus* and *Tilapia guineensis* were analyzed using standard analytical techniques for proximate, mineral and amino acids compositions.
Results: The respective proximate values (g/100 g sample dry weight) of *Clarias gariepinus* and *Tilapia guineensis* were high in crude protein (48.33 and 67.82) and crude fat (26.11 and 14.83) but low in crude fibre (3.22 and 3.91) and moisture (0.23 and 0.33). The calculated fatty acids and metabolizable energy for the two fish samples were (20.89 and 11.86 %) and (2004.98 and 1799.48

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*Corresponding author: Email: lekearemu@gmail.com, moaremu@science.fulafia.edu.ng;

KJ/100 g), respectively. The most abundant minerals in the samples were potassium (321.72 and 364.23 mg/100 g) and phosphorus (210.54 and 213.74 mg/100 g), whereas manganese, iron, and copper were of low concentration (< 0.5 mg/100 g). Leucine, phenylalanine, and lysine were the most abundant essential amino acids in both samples. At the same time, glutamic and aspartic acids together with arginine account for more than 35 % of total amino acids in each of the investigated samples. Total essential amino acids (TEAA) with histidine and total sulphur amino acids (TSAA) were (33.10 and 2.54 g/100 g cp) for *Clarias gariepinus* and (36.18 and 2.92 g/100 g cp) for *Tilapia quineensis*, respectively. Meanwhile, valine and lysine were the first and second limiting amino acids in this study's samples, respectively.

Conclusion: The fish samples were found to be good sources of quality proteins and both have the functional and essential amino acids.

1. INTRODUCTION

Diet quality is critical in the fight against malnutrition in all of its forms and non-communicable diseases (NCDs) like diabetes, heart disease, stroke, and cancer. A healthy diet consists of a well-balanced, diverse, and appropriate variety of foods consumed over time. Furthermore, a healthy diet ensures that a person's needs for macronutrients (proteins, fats, and carbohydrates, including dietary fibres) and essential micronutrients (vitamins and minerals) are met, based on their gender, age, level of physical activity, and physiological state. In the form of nutritional deficiencies and overconsumption of unhealthy foods, malnutrition is on the rise, especially in developing countries [1]. In 2019, for example, the prevalence of undernourishment in Africa was 19.1 % of the population, or more than 250 million people. This rate is more than double the global average (8.9 %) and the highest across all regions [2]. Unlike some staple foods like cereals, fish can help with various areas of food security and nutrition. It is an excellent source of lean protein, fatty acids, and essential micronutrients that can help combat malnutrition and nutritional deficiencies while contributing to a healthy weight and body composition [3].

Fish are a source of high-quality protein, vitamins (A, D, and B), essential minerals (Fe, Zn, P, Ca, and I), and essential fatty acids, especially long-chain polyunsaturated fatty acids (LCPUFA) [4]. Fish's nutrient profiles differ depending on species, processing and preparation methods, and habitat. Micronutrients in fish have been linked to many health benefits, including a lower risk of cardiovascular disease, improved maternal health and pregnancy outcomes, and increased early childhood physical and cognitive development [5,6]. They also improved the immune system function and minimized the risk of anaemia, rickets, childhood blindness, and stunting associated with micronutrient deficiencies [7]. Furthermore, fish also contains a good concentration of essential amino acids, such as lysine, which is low in cereals. Therefore, fish protein can complement the amino acid pattern and the overall protein quality of a mixed diet.

African catfish (*Clarias gariepinus*) is one of the most important freshwater fish species being cultured today. Its disease resistance, high fecundity and ease of larval production make it commercially important in aquaculture. It can withstand extreme environmental conditions such as high temperatures and low oxygen levels. The importance of catfish to the Nigerian population cannot be overemphasized. It provides food for the populace and allows for improved protein nutrition in terms of high protein retention in the body. Catfish is one of the safest animal protein sources and a great source of omega-3 fatty acids [8]. *Tilapia guineensis*, a typical estuarine cichlid species on Africa's West Coast, is an important fish species due to its enormous contribution to many African countries' nutritional, growth, and development needs. It possesses good aquaculture, economic, and dietary qualities, especially in terms of the protein nutrition of West Africans [9].

In Nigeria, the demand for freshwater fish such as *Clarias gariepinus* and *Tilapia guineensis* has risen because of their affordability and availability. Information on the chemical composition of fish is vital as the nutritional and medicinal value of fish and its products depend on its proteins, lipids, minerals, and vitamins. The knowledge of such fish constituents as proximate, amino acid and mineral compositions allows for assessing fish health status and the

quality of the nutrients available to the consumer. This work, therefore, evaluates the nutritional quality of *Clarias gariepinus* and *Tilapia guineensis* fishes from River Doma in Nasarawa State, Nigeria.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Samples

The fresh catfish (*Clarias gariepinus*) and tilapia fish (*Tilapia guineensis*) were purchased from fishermen at the site of River Doma in Doma Local Government Area, Nasarawa State, Nigeria in February 2021. The samples were brought into the laboratory; all bones and viscera were removed, oven-dried at about 60 ^{o}C, cooled and blended into a fine powder using Kenwood major blender. The ground portions were put in a plastic container and kept in a refrigerator at about 4 ^{o}C before use. All samples were collected at 6.00 h Green-Which Time (GWT) or 7.00 local time while the water temperature was 28 ^{o}C at the time of collection.

2.2 Proximate Analysis

The moisture, ash, crude fat, crude protein (N x 6.25), crude fibre and carbohydrate (by difference) were determined following the standard methods of AOAC [10]. All proximate analyses of the sample flour were carried out in triplicate and reported in percentage. All chemicals were of Analar grade.

2.3 Mineral Analysis

A flame photometer (Model 405, Corning UK) was used to determine the concentration of potassium and sodium, while phosphorus was determined by Vanadomolybdate colourimetric method [11]. All other metals were determined by atomic absorption spectrophotometer (Perkin–Elmer Model 403, Norwalk CT). All the minerals determined were reported in mg/100 g sample.

2.4 Amino Acids Analysis

The amino acids analysis was done by Ion Exchange Chromatography (IEC) [12] using the Technico Sequential Multisample (TSM) Amino Acids Analyzer (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 mLmin^{-1} at 60 ^{o}C with reproducibility

consistent within ± 3 %. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. Amino acid values reported were the averages of two determinations. Nor–leucine was the internal standard. Tryptophan was determined after alkali (NaOH) hydrolysis by the colorimetric method [13].

2.5 Determination of Isoelectric Point (pI), Quality of Dietary Protein and Predicted Protein Efficiency Ratio (P–PER)

The predicted isoelectric point was evaluated according to Olaofe and Akintayo [14]:

$$plm = \sum_{i=1}^{n=1} pliXi \quad ----------(1)$$

Where:

plm = the isoelectric point of the mixture of amino acids;
pli = the isoelectric point of the ith amino acids in the mixture;
Xi = the mass or mole fraction of the amino acids in the mixture.

The quality of dietary protein was measured by finding the ratio of available amino acids in the sample protein compared with the needs expressed as a ratio. Amino acid score (AAS) was then estimated by applying the FAO/WHO [12] formula:

$$AAS = \frac{mg\ of\ amino\ acid\ in\ 1g\ of\ test\ protein}{mg\ of\ amino\ acid\ in\ reference\ protein} \times 100 \quad ----(2)$$

The predicted protein efficiency ratio (P–PER) of the seed sample was calculated from their amino acid composition based on the equation developed by Alsmeyer *et al.* [15] as stated thus;

P–PER = –0.468 + 0.454 (Leu) – 0.105 (Tyr) - - - - - - - - - - - - - - - - - - (3)

2.6 Statistical Analysis of the Samples

The fatty acid values were obtained by multiplying crude fat value of each sample with a factor of 0.8 (i.e. crude fat x 0.8 = corresponding to fatty acids value). The energy values were calculated by adding up the carbohydrates x 17

kJ, crude protein x 17 kJ and crude fat x 37 kJ for each of the samples [16]. Errors of three determinations were computed as standard deviation (SD) for the proximate composition by using MS Excel Spread Sheet. The mean, standard deviation and coefficient of variation (%) for variability test on the fish samples were also analysed.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

The proximate composition of the study fish species varied significantly as shown in Table 1. Moisture content influences the shelf life of seafood and impacts the taste, texture, and resistance to bacterial contamination. The moisture content of the dried fish powders was 0.23 ± 0.02 % in *Clarias gariepinus* and 0.33 ± 0.01 % in *Tilapia quineensis.* The values are lower than the reported 10.27 % moisture contents of smoked *Clarias gariepinus* [8]. Drying fish extends its edibility for a longer period and increases the availability of other nutrients that greatly benefit human health [17]. The ash content of food samples is directly proportional to the inorganic minerals. The level of ash content was higher in *Tilapia quineensis* (11.19 ± 0.12 %) than in *Clarias gariepinus* (10.21 ± 0.14 %). Similar results were reported for the filet of *Tirchius lepturus* (10.65 %) and *Arius maculatus* (10.98 %) [18]. The ash contents obtained in this study are higher than that values found in *C. gariepinus* by Olagbemide [8] (6.87 – 8.00 %). The moderately good ash contents of *Clarias gariepinus* and *Tilapia quineensis* indicate that the samples may be rich in inorganic minerals. Fish are an important source of high-quality and easily digestible proteins with a good proportion of peptides and essential amino acids that are scarce in terrestrial meat proteins. Proteins are an essential source of antibodies and enzymes, which are components of muscles, hair, and other body parts [17]. The mean value of crude protein content in the investigated samples were 48.33 ± 0.39 and 67.82 ± 0.26 g/100 g dw for *Clarias gariepinus* and *Tilapia quineensis,* respectively. These values are within the range of 44.83 % to 72.29 %, as found by Glover-Amengor *et al.* [19] in some dried underutilized fish species. In this study, the crude protein contents were higher than the protein levels obtained from four species of dried fishes (*Puntius* sp., *Amblypharyngodon mola*, *Channa punctatus* and *Glossogobius giuris*) (ranging from 32.02 to 41.38 %) [20].

Fish lipids contain high levels of n-3 polyunsaturated fatty acids (PUFA) (i.e. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)), which have many health benefits. The beneficial effects of EPA and DHA include improving cardiovascular health [21], prevention of arthritis, inflammation, ageing, and insulin resistance. In addition, the essential fatty acids found in fish oils were reported to retard the progress of different kinds of cancers [22], improve depression and enhance cognitive development in children and adolescent [23]. The total crude fat content of *Tilapia quineensis* and *Clarias gariepinus* were 14.83 ± 0.46 and 26.11 ± 0.56 g/100 g dw, respectively. These values compared well with the observed lipid contents in seven SIS dried fishes (12.20 % to 22.70 %) [24], but are higher than the lipid contents in dried *Wallago attu* (6.21 %), *Channa striatus* (6.81 %), and *Glossogobius giuris* (5.98 %) [25]. Based on the results obtained, the two fish species under investigation can be classified as high-fat fishes (having > 8 % fat contents) following the Ackman grouping methods [26]. The variation may be due to age, season and/or maturity. When consumed, the two fish samples (which can be termed oily or fatty fishes) can be better sources of healthy lipids.

Table 1. Proximate composition (g/100 g dry weight) of *Clarias gariepinus* and *Tilapia quineensis*

Parameter/Sample	*C. gariepinus*	*T. quineensis*	Mean	SD	CV (%)
Moisture	0.23	0.33	0.28	0.05	17.86
Ash	10.21	11.19	10.70	0.49	4.58
Fat	26.11	14.83	20.47	5.64	27.55
Crude protein	48.33	67.82	58.08	9.75	16.79
Crude fibre	3.22	3.91	3.57	0.35	9.80
NFE	11.90	1.92	6.91	4.99	72.21
[*]Fatty acids	20.89	11.86	16.38	4.52	27.59
Energy (kJ/100 g)	2004.98	1799.48	1902.23	102.75	5.40

NFE = Nitrogen free extract; dw = dry weight; SD = Standard deviation; CV = Coefficient of variation, [^]Calculated fatty acids

Though fish are generally not good sources of carbohydrate and fibre, the crude fibre content of *Tilapia quineensis* (3.91±0.12 g/100 g dw) and *Clarias gariepinus* (3.22±0.11) were higher than the reported values of 1.2 – 2.05 % for *Oreochromis niloticus* and 1.02 % for *C. gariepinus* [27]. The fibre contents in the study samples are comparable with the expected crude fibre contents of most leguminous crops (3 – 5 g/100 g) [28]. Diets deficient in fibre are associated with constipation, hiatus hernia, appendicitis, diabetes, obesity, coronary heart diseases, and gallstones [29]. Furthermore, epidemiological studies provide strong evidence that a high fibre diet may reduce not only colon cancer risk and mortality but also all-cancer mortality and all-cause mortality, thereby increasing lifespan [30]. The Nitrogen Free Extract (NFE) and metabolizable energy value of both the *Tilapia quineensis* and *Clarias gariepinus* were 11.90±0.90 % and 2004.98±0.33 kJ/100 g, and 1.92±0.61 % and 1799.48±0.43 kJ/100 g, respectively. In terms of variability of proximate results within the two fish samples, NFE was the most highly varied value (CV% = 72.21) and the least was ash content (CV% = 4.58).

3.2 Mineral Composition

Minerals (such as Ca, Na, Mg, P, K, Fe and Mn) play essential roles in maintaining normal life processes due to their vital physiological and biochemical functions. Calcium, phosphorus and magnesium are critical in the growth and development of bone mass and their involvement in physiological and cellular functions in the human body. Potassium and sodium are essential for maintaining body electrolyte balance, physiological homeostasis and transmission of nerve impulses. On the other hand, manganese and iron are required for maturation of bones and cartilage, wound-healing, energy production, and metabolism [31].

The mineral compositions in mg/100 g of *Tilapia quineensis* and *Clarias gariepinus* are depicted in Table 2. The result showed that potassium (321.72 and 364.23 mg/100 g), phosphorus (210.54 and 231.74 mg/100 g), and sodium (91.62 and 80.57 mg/100 g) are the most abundant mineral in both samples (*Clarias gariepinus* and *Tilapia quineensis*), respectively. The samples' magnesium and calcium contents were found to be 26.33 and 16.93 mg/100 g (*Clarias gariepinus*), and 34.21 and 24.17 mg/100 g (*Tilapia quineensis*), respectively. The trace elements (Mn, Cu and Fe) were of very low concentration, with none of them being up to 0.5 mg/100 g . Thus, the study samples cannot be considered as sources of trace elements. In line with our findings, Adeyeye [32] and Njinkoue *et al.* [33] reported potassium and phosphorus as the most abundant minerals in fish species.

The low Na/K ratio (< 1, Table 2), which is due to the high concentration of potassium in both samples, makes the fish species under investigation a healthy meal for humans, particularly in the case of cardiovascular disease prevention. Ca/P ratio is an important determinant for calcium absorption and retention. The Ca/P ratios of *Clarias gariepinus* and *Tilapia quineensis* were found to be 0.08 and 0.10. Food is considered 'good' if the Ca/P ratio is above 1 and 'poor' if the ratio is less than 0.5, while the Ca/P ratio above 2 helps to increase the absorption of calcium in the small intestine [34]. Consumption of sample's fishes in this study may not be able to participate well in this function. Mn was the most highly varied value within the two fish samples (CV% = 50.00) while the least varied mineral content was P (CV% = 4.79).

Table 2. Mineral Composition (mg/100 g dry weight) of *Clarias gariepinus* and *Tilapia quineensis*

Mineral/Sample	*C. gariepinus*	*T. quineensis*	Mean	SD	CV (%)
Mg	26.33	34.21	30.27	3.94	13.02
Mn	0.01	0.02	0.02	0.01	50.00
Na	91.62	80.57	86.10	5.53	6.42
Ca	16.93	24.17	20.55	3.62	17.62
K	321.72	364.23	342.98	21.26	6.20
Cu	0.02	0.03	0.03	0.01	33.33
Fe	0.14	0.22	0.18	0.04	22.22
P	210.54	231.74	221.14	10.60	4.79
Na/K	0.28	0.22	0.25	0.03	12.00
Ca/P	0.08	0.10	0.09	0.01	11.11

Na/K = Sodium to potassium ratio; Ca/P = Calcium to phosphorus ratio; SD = Standard deviation; CV = Coefficient of variation

3.3 Amino Acids Profiles

Amino acids play important roles in human health by regulating vital metabolic pathways to improve health, survival, growth, development, lactation and reproduction. The amino acid profile of *Clarias gariepinus* and *Tilapia quineensis* samples is presented in Table 3. Leucine (Leu), Phenylalanine (Phe), and lysine (Lys) were the most abundant essential amino acids in both samples, with 5.91, 4.10, and 3.85 g/100 g cp for *Clarias gariepinus* and 6.29, 4.60, and 4.02 g/100 g cp for *Tilapia quineensis*, respectively. Leu is reported to be instrumental in the repairing and building of muscles, as well as in managing blood sugar levels through the facilitation of glucose uptake in the body cell and improvement of insulin response [35]. Phe deficiency is associated with impairment of growth and brain development [36]. Lys is essential for bone formation through calcium absorption and retention, hormone production, and lowering serum triglyceride levels [37]. The Phe contents in both samples (4.10 – 4.60 g/100 g cp) is comparable with the reported Phe levels in

Acanthurus monroviae (3.92 g/100 g cp) [32]. Leu and Lys were reported to be the most abundant essential amino acids in *Acanthurus monroviae* and *Lutjanus goreensis* [32].

Glutamic (12.90 – 14.51 g/100 g cp) and aspartic 7.90 – 9.04 g/100 g cp) acids together with arginine (5.17 – 5.60 g/100 g cp) account for more than 35 % of the total amino acids in each of the investigated sample. These amino acids, though classified as nutritionally non-essential, are referred to as functional amino acids due to their important roles in prevention and treatment of metabolic diseases, regulation of neurological development and function [38]. To evaluate the biochemically accessible protein level in human nutrition, the predicted protein efficiency ratio (P-PER) was calculated. The P – PER values in this report for *Clarias gariepinus* (1.94) and *Tilapia quineensis* (2.09), which are better than the 1.5 threshold value [39], qualifies the study samples as good candidates for providing proteins for human nutrition. The coefficient of variation (CV%) varied from 0.18 in glycine to 10.26 in threonine (Table 3).

Table 3. Amino acids composition (g/100 g crude protein) of *Clarias gariepinus* and *Tilapia quineensis*

Amino acid	*C. gariepinus*	*T. quineensis*	Mean	SD	CV (%)
Lysine (Lys)[e]	3.85	4.02	3.94	0.09	2.28
Histidine (His)[e]	2.43	2.80	2.62	0.19	7.25
Arginine (Arg)	5.17	5.60	5.39	0.22	4.08
Aspartic acid (Asp)	7.90	9.04	8.47	0.57	6.73
Threonine (Thr)[e]	3.06	3.76	3.41	0.35	10.26
Serine (Ser)	3.20	3.53	3.37	0.17	5.04
Glutamic acid (Glu)	12.90	14.51	13.71	0.81	5.91
Proline (Pro)[e]	3.66	3.85	3.76	0.10	2.66
Glycine (Gly)	3.52	3.51	3.52	0.01	0.18
Alanine (Ala)	3.00	3.03	3.02	0.02	0.66
Cystine (Cys)	1.09	1.32	1.21	0.12	9.92
Valine (Val)[e]	2.81	3.06	2.94	0.13	4.42
Methionine (Met)[e]	1.45	1.60	1.53	0.08	5.23
Isoleucine (Ile)[e]	3.21	3.30	3.26	0.05	1.53
Leucine (Leu)[e]	5.91	6.29	6.10	0.19	3.11
Tyrosine (Tyr)	2.60	2.75	2.68	0.08	2.99
Tryptophan (Trp)[e]	1.11	1.20	1.16	0.05	4.31
Phenylalanine (Phe)[e]	4.10	4.60	4.35	0.25	5.75
Isoelectric point (pI)	4.07	4.42	4.25	0.18	4.24
P–PER	1.94	2.09	2.02	0.08	3.96
Leu/Ile	1.84	1.91	1.88	0.04	2.13

[e]*Essential amino acid; P–PER = Predicted protein efficiency ratio; SD = Standard deviation; CV = Coefficient of variation*

Table 4. Concentrations of essential, non–essential acids, neutral, sulphur, aromatic, etc. (g/100 g crude protein) of *Clarias gariepinus* and *Tilapia quineensis*

Amino acid description	*C. gariepinus*	*T. quineensis*	Mean	SD	CV (%)
Total amino acid (TAA)	70.97	77.72	74.35	3.38	4.55
Total non–essential amino acid (TNEAA)	37.87	41.54	39.71	1.84	4.63
% TNEAA	53.36	53.45	53.41	0.05	0.09
Total essential amino acid (TEAA)					
With histidine	33.10	36.18	34.64	1.54	4.45
Without histidine	30.80	33.38	32.09	1.29	4.02
% TEAA					
With histidine	46.64	46.55	46.60	0.05	0.11
Without histidine	43.40	42.95	43.18	0.23	0.53
Essential alphatic amino acid (EAAA)	14.99	16.36	15.68	0.69	4.40
Essential aromatic amino acid (EArAA)	7.64	8.60	8.12	0.48	5.91
Total neutral amino acid (TNAA)	46.32	50.15	48.24	1.92	3.98
% TNAA	65.27	64.53	64.90	0.37	0.57
Total acidic amino acid (TAAA)	20.80	23.55	22.18	1.38	6.22
% TAAA	29.31	30.30	29.81	0.50	1.68
Total basic amino acid (TBAA)	11.45	12.42	11.94	0.49	4.10
% TBAA	16.16	15.98	16.07	0.09	0.56
Total sulphur amino acid (TSAA)	2.54	2.92	2.73	0.19	6.96
% Cystine in TSAA	42.91	45.21	44.06	1.15	2.61

SD = Standard deviation; CV = Coefficient of variation

Table 5. Amino acids scores of *Clarias gariepinus* and *Tilapia quineensis* based on FAO/WHO standards

EAA	PAAESP g/100g protein	*Clarias gariepinus*		*Tilapia quineensis*	
		EAAC	AAS	EAAC	AAS
Ile	4.0	3.21	0.80	3.30	0.83
Leu	7.0	5.91	0.84	6.29	0.90
Lys	5.5	3.85	0.70	4.02	0.73
Met + Cys (TSAA)	3.5	2.54	0.73	2.92	0.83
Phe + Tyr	6.0	6.70	1.11	7.35	1.22
Thr	4.0	3.06	0.77	3.71	0.93
Try	1.0	1.11	1.11	1.20	1.20
Val	5.0	2.81	0.56	3.06	0.61
Total	**36.0**	**29.19**	**6.62**	**31.85**	**7.25**

EAA = Essential amino acids; PAAESP = Provisional amino acids (Egg) scoring pattern; EAAC = Essential amino acid composition; AAS = Amino acids score

The nutritional value of protein is proportional to its ability to meet nitrogen and essential amino acid requirements. Table 4 depicts the different classes of amino acids from the study samples. Total amino acids (TAA) were 70.97 g/100 g cp for *Clarias gariepinus* and 77.72 g/100 g cp for *Tilapia quineensis*. The total essential amino acids (TEAA) with histidine and total sulphur amino acids (TSAA) were (33.10 and 2.54 g/100 g cp) for *Clarias gariepinus* and (36.18 and 2.92 g/100 g cp) for *Tilapia quineensis*, respectively. The TSAA is the most highly varied values within the two samples (CV% = 6.96). The proportion of essential amino acids to total amino acids was 46.64 % (*Clarias gariepinus*) and 46.55 % (*Tilapia quineensis*), and the ratio of the percentage of essential amino acids to non-essential amino acids was 0.87 in both samples, thereby meeting the FAO/WHO reference values (40% and 0.6 %) [12]. Even though the TEAA (%) for all the samples in this report are significantly higher than the 39 % considered adequate for ideal protein food for infants, 26 % for children, and 11 % for adults [40], the TSAA observed values are lower than the 5.8 g/100 g cp recommended for infants [12]. The percent of total acid amino acids (TAAA) (29.31 and 30.30) in both samples, which were greater than the

39

percent of total basic amino acids (TBAA) (16.16 and 15.98), indicates that the protein is most likely acidic. The essential aromatic amino acid (EArAA) was 7.64 g/100 g cp in *Clarias gariepinus* and 8.60 g/100 g cp in *Tilapia quineensis*. These values fall within the recommended range for infant protein (6.8 – 11.8 g/100 g cp) [40]. Essential aliphatic amino acids (EAAA) for both *Clarias gariepinus* and *Tilapia quineensis* were 14.99 and 16.63 g/100 g cp, respectively.

The essential amino acids scores (EAAS) based on the provisional amino acids scoring pattern (FAO/UN/WHO) is presented in Table 5. Result indicated that the *Tilapia quineensis* was superior to the *Clarias gariepinus* based on the amino acids scores. Except for phenylalanine + tyrosine and tryptophan in both samples, the essential amino acid contents in the samples are lower than the FAO/WHO [12] recommended provisional pattern. Thus, a diet with *Tilapia quineensis* or *Clarias gariepinus* as sole protein source will require supplementation for some of the EAAs. Val and Lys were the first and second limiting amino acid in both samples in this study, respectively. Both *Clarias gariepinus* and *Tilapia quineensis* can be used to supplement for phenylalanine + tyrosine and tryptophan (required for normal growth in infant) in preschool children's diets.

4. CONCLUSION

Generally, the fish samples were found to be good sources of quality proteins. The samples contained good quantities of both functional and essential amino acids. However, diet with *Tilapia quineensis* or *Clarias gariepinus* as sole protein source will require supplementation for some of the EAA, such as Val, Lys, and SAA. Furthermore, the analyzed fish samples also contained nutritionally important minerals such as sodium, potassium, phosphorus, and calcium. The proximate analysis of the samples revealed that the two fish species can be classified as high-fat fishes which when consume, can be better sources of healthy lipids capable of improving cardiovascular health.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nelson G, Bogard J, Lividini K, Arsenault J, Riley M, Sulser TB, Mason-D'Croz D, Power B, Gustafson D, Herrero M, Wiebe K, Cooper K, Remans R, Rosegrant M. Income growth and climate change effects on global nutrition security to mid-century. Nat. Sustain. 2018; 1: 773–781. DOI:10.1038/s41893-018-0192-z.

2. FAO, IFAD, UNICEF. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets, Rome; 2020. DOI:10.4060/ca9692en.

3. Bennett A, Patil P, Kleisner K, Rader D, Virdin J, Basurto X. Contribution of Fisheries to Food and Nutrition Security: Current Knowledge, Policy, and Research. NI Report 2018:18-02, Durham.

4. Yetunde KO. Biochemical composition of Micromesistus poutassou from agbalata market, Badagry Lagos West, Nigeria. Food Appl Biosci J. 2016; 4(1):12-24. DOI:10.14456/fabj.2016.2.

5. Tørris C, Småstuen MC, Molin M. Nutrients in fish and possible associations with cardiovascular disease risk factors in metabolic syndrome. Nutrients. 2018; 10(7):952. DOI:10.3390/nu10070952.

6. Abraha B, Admassu H, Mahmud A, Tsighe N, Shui XW, Fang Y. Effect of processing methods on nutritional and physico-chemical composition of fish: a review. MOJ Food Process Technol. 2018; 6(4):376–382. DOI:10.15406/mojfpt.2018.06.00191.

7. Ayeloja AA, George FOA, Dauda TO, Jimoh WA, Popoola MA. Nutritional comparison of captured Clarias gariepinus and Oreochromis niloticus. Int Res J Nat Sci. 2013;1(1): 9–13.

8. Olagbemide PT, Nutritional Values of Smoked *Clarias gariepinus* from Major

Markets in Southwest, Nigeria. GJSFR-D. 2015;15(6):33-42.

9. Ukenye EA, Taiwo IA, Anyanwu PE. Morphological and genetic variation in *Tilapia guineensis* in West African coastal waters: A mini review. Biotechnol Reports. 2019; 24(e00362):1-3. DOI:10.1016/j.btre.2019.e00362.

10. AOAC. Official Methods of Analysis. Assoc Off Anal Chem. 18th Edit; 2007.

11. James C. Analytical Chemists of Foods. Chapman and Hall, New York NY; 1996.

12. FAO/WHO. Protein quality evaluation report of joint FAO/WHO expert consultative FAO, Food and Nutrient, Rome; 1991.

13. Freidman M, Finely JW. Methods of tryptophan analysis. J Agric Food Chem. 1971;19(4):626–631.

14. Olaofe O, Akintayo ET. Prediction of isoelectric points of legume and oil seed proteins from amino acid composition. J Technoscience. 2000;4:48–53.

15. [Alsmeyer RH, Cunningham AE, Happich ML. Equation to predict protein efficiency ratio (PER) from amino acid analysis. Food Technol. 1974; 28:34–38.

16. Kilgore OFG. Mastering Nutrients., Macmillan Education Ltd., London, UK; 1987.

17. Rasul MG, Yuan C, Shah AKMA. Chemical composition and nutritional value of dried fish in bangladesh. Egypt J Aquat Biol Fish. 2021;25(4):379–399. DOI:10.21608/EJABF.2021.189666.

18. Tenyang N, Womeni HM, Linder M, Tiencheu B, Villeneuve P, Mbiapo FT. The chemical composition, fatty acid, amino acid profiles and mineral content of six fish species commercialized on the Wouri river coast in Cameroon. Riv Ital Delle Sostanze Grasse. 2014;91:129–138.

19. Glover-Amengor M, Atikpo O, Abbey LD, Hagan L, Ayin J, Toppe J. Proximate Composition and Consumer Acceptability of Three Underutilized Fish Species and Tuna Frames. World Rural Obs. 2012;4(2):65–70. Available: http://www.sciencepub.net/rural.

20. Islam MT, Ahmed S, Sultana MA, Tumpa AS, Flowra FA. Nutritional and Food Quality Assessment of Dried Fishes in Singra Upazila Under Natore District of Bangladesh. Trends in Fisheries Res. 2013; 2(1): 14-17.

21. Pal J, Shukla BN, Maurya AK, Verma HO. A review on role of fish in human nutrition with special emphasis to essential fatty acid. Int J Fish Aquat Stud. 2018; 6(2):427-430.

22. Dierge E, Debock E, Guilbaud C, Corbet C, Mignolet E, Mignard L, Bastien E, Dessy C, Larondelle Y, Feron O. Peroxidation of n-3 and n-6 polyunsaturated fatty acids in the acidic tumor environment leads to ferroptosis-mediated anticancer effects. Cell Metab. 2021; 33(8):1701-1715.e5. doi: 10.1016/j.cmet.2021.05.016.

23. Kwasek K, Thorne-Lyman AL, Phillips M. Can human nutrition be improved through better fish feeding practices? a review paper. Crit Rev Food Sci Nutr. 2020; 60(22):3822-3835. doi: 10.1080/10408398.2019.1708698.

24. Sultana S, Parween S, Hossain MA. Biochemical analysis of some dried sis fishes of the river Padma in Rajshahi. J Life Earth Sci. 2011; 6:39–43. DOI: 10.3329/jles.v6i0.9719.

25. Majumdar BC, Afrin F, Rasul MG, Khan M, Shah AKMA. Comparative study of physical, chemical, microbiological and sensory aspects of some sun dried fishes in Bangladesh. Brazilian J Biol Sci. 2017; 4(8):323–331. doi: 10.21472/bjbs.040811.

26. Ackman RG. Nutritional composition of fats in seafoods. Prog Food Nutr Sci. 1989; 13(3-4):161-289.

27. Oladipo IC, Bankole SO. Nutritional and microbial quality of fresh and dried Clarias gariepinus and Oreochromis niloticus. Int J Appl Microbiol Biotechnol Res. 2013; 1:1–6.

28. Borget M. Food Legumes. Technical centre for Agricultural and rural cooperation, Wageningen, the Netherlands. 1992.

29. Li YO, Komarek AR. Dietary fibre basics: Health, nutrition, analysis, and applications. Food Quality and Safety. 2017;1(1): 47–59. DOI: 10.1093/fqsafe/fyx007.

30. O'Keefe SJ. The association between dietary fibre deficiency and high-income lifestyle-associated diseases: Burkitt's hypothesis revisited. Lancet Gastroenterol Hepatol. 2019; 4(12):984-996. DOI: 10.1016/S2468-1253(19)30257-2.

31. Winiarska-Mieczan A, Kowalczuk-Vasilev E, Kwiatkowska K, Kwiecień M, Baranowska-Wójcik E, Kiczorowska B, Klebaniuk R, Samolińska W. Dietary Intake and Content of Cu, Mn, Fe, and Zn in

Selected Cereal Products Marketed in Poland. Biol Trace Elem Res. 2019;187(2):568-578.
DOI: 10.1007/s12011-018-1384-0.

32. Adeyeye EI, Proximate, minerals and amino acids composition of Acanthurus monronviae and Lutjanus goreensis fish muscle, BMR Biotechnol. 2014;1:1–21.

33. Njinkoue JM, Gouado I, Tchoumbougnang F, Ngueguim JHY, Ndinteh DT, Fomogne-Fodjo CY, Schweigert FJ. Proximate composition, mineral content and fatty acid profile of two marine fishes from Cameroonian coast: Pseudotolithus typus (Bleeker, 1863) and Pseudotolithus elongatus (Bowdich, 1825). NFS J. 2016; 4:27–31.
DOI:10.1016/j.nfs.2016.07.002.

34. Aremu MO, Namo SB, Salau RB, Agbo CO, Ibrahim H. Smoking methods and their effects on nutritional value of African catfish (Clarias gariepinus). Open Nutraceuticals J. 2013;6(1):105–112.
DOI: 10.2174/1876396020130830003.

35. Osmond AD, Directo DJ, Elam ML, Juache G, Kreipke VC, Saralegui DE, Wildman R, Wong M, Jo E. The Effects of Leucine-Enriched Branched-Chain Amino Acid Supplementation on Recovery After High-Intensity Resistance Exercise. Int J Sports Physiol Perform. 2019;14(8):1081-1088.
DOI: 10.1123/ijspp.2018-0579.

36. Foreman PK, Margulis AV, Alexander K, Shediac R, Calingaert B, Harding A, Pladevall-Vila M, Landis S. Birth prevalence of phenylalanine hydroxylase deficiency: a systematic literature review and meta-analysis. Orphanet J Rare Dis. 2021;16(1):253.
DOI: 10.1186/s13023-021-01874-6.

37. Gersten D. The 20 amino acids: What they are and how they keep you alive and vibrant. The Gersten Institute for Higher Medicine, San Diego, CA, USA; 2013.

38. Wu G. Functional amino acids in nutrition and health. Amino Acids. 2013;45(3): 407-11.
DOI: 10.1007/s00726-013-1500-6.

39. Friedman M. Nutritional value of proteins from different food sources. A review. Journal of Agricultural and Food Chemistry. 1996; 44(1):6-29.
DOI: 10.1021/jf9400167

40. FAO/WHO/UNU, Energy and Protein Requirements; Report of a Joint FAO/WHO/UNU Expert Consultation, WHO Tech Rep Ser no. 724., Geneva: WHO; 1985.