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Nutritional Evaluation and Functional Properties of *Clarias lazera* (African Catfish) from River Tammah in Nasarawa State, Nigeria

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Abstract: Evaluation of nutritional composition was carried out on *Clarias lazera* fish while functional properties were also investigated. The proximate composition were total ash (8.6%), moisture (7.5%), crude protein (73%), crude fat (8.3%) and carbohydrate (2.5%); crude fibre was not in the detectable range. The available energy was high (1.59 MJ/100 g). The proportion of energy due to protein and fat were 78.0 and 2.7%, respectively. The fish sample was low in sodium Na, potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), chromium (Cr) and lead (Pb). Calcium (Ca) was the most highly concentrated mineral (63.7 mg/100 g sample). The total amino acid was 925.2 mg g^{-1} crude protein while lysine (Lys) was the most highly concentrated essential amino acid (79.0 mg g^{-1}). The fish sample had a balanced content of essential amino acid in isoleucine (Ile), leucine (Leu), lysine (Lys), methionine (Met) + cystine (Cys), phenylanine (Phe) + tyrosine (Tyr) and threonine (Thr), with respect to the FAO pattern while supplementation may be required only in valine (Val). The calculated isoelectric point (pI) was 5.6, Predicted Protein Efficiency Ratio (P-PER) was 26.1 and first limiting amino acid was Val. Results of functional properties were: foaming capacity (4.9%), foaming stability (3.7%, 8 h), water absorption capacity (280.5%), oil absorption capacity (280.6%), oil emulsion capacity (20.0%), oil emulsion stability (19.5, 12 h), lowest gelation concentration (10.0%) and bulk density (470 g L^{-1}). The results showed that *Clarias lazera* could be a good source of most of the parameters determined in this study.

Key words: *Clarias lazera*, nutritional composition, functional properties

INTRODUCTION

Peasant scale fish farming has been practiced in various forms in Nigeria for many years. The major species presently cultivated are *Oreochromis niloticus* L., *Cyprinus carpio* L., *Clarias lazera* (Cuvier and Vallenciennes), *Heterobranchus bidorsalis* (Geoffrey St. Halaire), *Heterotis niloticus* (Cuvier) and *Gymarchus niloticus* (Cuvier). Farmers' preferences are for *Clarias*, *Hetero-branchus*, *Carp* and *oreochromis* in that order (FAO, 1990).

Fish, an important source of animal protein of high biological value, vitamins A and D and also contain several minerals such as Ca, Fe, Cd, Pb, Cu, Zn etc., which may be beneficial or toxic to man depending on the exposure level (Bowen, 1997; Mudambi and Rajagopal, 1981). Fish is in increasing demand in Nigeria due to high population growth rate, increasing national income cost of meat and other sources of animal protein (Adeyeye, 1997a). The relatively high percent consumption of fish has been attributed to greater availability of this product at relatively cheaper prices (Osajuyigbe, 1981).

Clarias lazera (syn. *Clarias gariepinus*) of the family Clanidae is generally considered to be one of the most important tropical catfish species for aquaculture. It has an almost Pan-African distribution, ranging from the Nile to West Africa and from Algeria to Southern Africa, up to the Mediterranean coast including Asia Minor. It is a slow moving omnivorous predatory fish, which feeds on a variety of food items from microscopic zooplankton to fish half its length or 10% of its own body weight (Welcome, 1979).

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River Tammah/Kwoto is located in Nasarawa town of Nasarawa State, Nigeria. The host communities have taken advantage of this river by practicing fish farming for commercialization. Despite the high nutritional value of fish, there is paucity of information on the nutritional and protein quality and particularly the functional properties of the tropical freshwater fish species.

This works aim at evaluating the proximate, mineral and amino acid composition as well as investigating the functional properties of *Clarias lazera* caught from River Tammah/Kwoto in Nasarawa State, Nigeria.

MATERIALS AND METHODS

Samples Collection and Treatment

Fish samples of *Clarias lazera* specie making four in number were purchased from the fishermen at the site of River Tammah/Kwoto in Nasarawa State, Nigeria. The samples were brought into the laboratory; all bones and viscera removed, oven-dried at about 60°C, cooled and blended into fine powder using Kenwood major blender. The ground portions were kept in plastic container and kept in a refrigerator at about 4°C prior to use.

All samples were collected at 6.00 h Green-Wich Time (GWT) or 7.00 local time while temperature of the water was 28°C at the time of collection.

Proximate Analysis

The total ash, moisture, crude protein (Nx6.25), ether extract (crude fat) and fibre were determined in accordance with AOAC methods (AOAC, 1995). Both organic matter and carbohydrate were determined by difference. All the proximate analyses were carried out in triplicate and reported in percent. All chemicals were of Analar grade.

Mineral Analysis

The minerals were analysed by dry-ashing, the sample at 550°C to constant weight and by dissolving the ash in volumetric flask using distilled, deionised water with a few drops of conc. nitric acid. Calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), chromium (Cr) and lead (Pb) were determined by means of atomic absorption spectrophotometer (PYE Unicam Sp 9, Cambridge, UK).

Amino Acid Analysis

The amino acids in *Clarias lazera* were quantitatively determined by using the Ion Exchange Chromatography (IEC). The samples were defatted, hydrolysed, evaporated in a rotatory evaporator and then loaded into the Technicon Sequential Multsample amino acid analyzer. The full experimental details have been reported by Aremu *et al*. (2006a).

Estimation 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 (2000);

$$pIm = pIiXi$$

Where:

pIm = The isoelectric point of the mixture of amino acids
pIi = The isoelectric point of the ith amino acid in the mixture
Xi = The mass or mole fraction of the ith amino acid in the mixture

The quality of dietary protein was measured by finding the ratio of available amino acids in the protein concentrate compared with needs expressed as a ratio (FAO, 1970; Bender, 1992). Amino acid score (AMSS) was then estimated by applying the FAO/WHO (1991) formula;

$$\text{AMSS} = \frac{\text{mg of amino acid per g test protein}}{\text{mg of amino acid per g ref. protein}} \times \frac{100}{1}$$

The predicted protein efficiency ratio (P-PER) of the fish sample was calculated from their amino acid composition based on the equation developed by Alsmeyer *et al*. (1974) as stated thus;

$$\text{P-PER} = -0.468 + 0.454\ (\text{leucine}) - 0.105\ (\text{tyrosine})$$

Amino acid composition was classified and evaluated as Total Essential Amino Acids (TEAA), Essential Aliphatic Amino Acids (EAAA), Essential Aromatic Amino Acids (EArAA), Total Sulphur Amino Acids (TSAA), Total Acid Amino Acids (TAAA), Total Basic Amino Acids (TBAA) and Total Neutral Amino Acids (TNAA).

Functional Properties Determinations

Foaming Capacity (FC) and Foaming Stability (FS) were determined by the method described by Coffman and Garcia (1977). Full experimental details have been reported by Aremu *et al*. (2007a). Water and oil absorption capacities were measured by the Beuchat (1977) procedures. Oil emulsion capacity was determined by the procedure of Beuchat (1977), as modified by Adeyeye *et al*. (1994) and oil emulsion stability by the method of Beuchat (1977). Bulky density was determined using the procedure of Chou and Morr (1979) as modified by Akpapunam and Markakis (1981) and Narayana and Narasinga Rao (1984). Least Gelation Concentration (LGC) was determined by employing the method of Coffman and Garcia (1977) with slight modification as described by Aremu *et al*. (2007a).

RESULTS AND DISCUSSION

Proximate Composition

Table 1 presents proximate composition of *Clarias lazera*. The value of total ash compared favourably with the value of 8.93% reported for *Gymnarchus niloticus* by Adeyeye and Adamu (2005). The organic matter of 91.4% is higher than all the values reported by Abdullahi and Abolude (2002) for four freshwater fishes of *Mormyrops deliciosus* (86.4%), *Bagrus bayad* (75.0%), *Synodontis budgetti* (84.0%) and *Hemichronis lasciatus* (76.0%). Both the protein content and motabolizable energy content of the *Clarias lazera* are higher than their corresponding parameters in the four fish samples cited above. However, the present protein report of 73.1% is close to the value, 74.50% reported for *Gymnarchus niloticus* by Adeyeye *et al*. (2003) and some sea foods; *Parapenacopsis atlanta* (74.95%), *Penacus duorarum* (71.89%) and *Penanus kerathurus* (79.13%) reported by

Table 1: Proximate composition of *Clarias lazera* dry weight (% of sample)

Parameters	Concentrations
Total ash	8.60±0.07
Organic matter	91.40±0.07
Moisture content	7.50±0.05
Crude protein	73.10±1.50
Crude fat	8.00±0.50
Crude fibre	ND
Available carbohydrate	2.50±0.20
Available energy (KJ)	1593.24±4.20

*: Calculated metabolizable energy (Protein×17+fat×37 + carbohydrate×17), ND: Not Detected

Table 2: Energy values as contributed by protein, fat and carbohydrate in *Clarias lazera*

Parameters	Value
Total calculated energy (%)	1583.24 KJ
PEP	78.00
PEF	19.40
PEC	2.70
UEDP	46.80

PEP = Proportion of total energy due to protein, PEF = Proportion of total energy due to fat, PEC = Proportion of total energy due to carbohydrate, UEDP = Utilizable energy due to protein

Table 3: Mineral composition of *Clarias lazera* on dry weight (mg/100 g sample)

Minerals	Concentrations
Ca	63.7
Na	2.4
K	0.9
Mg	9.0
Fe	2.5
Zn	0.4
Mn	0.4
Cu	3.0
Cr	1.6
Pb	6.8
Na/K	2.6
Ca/Mg	7.1
[K/(Ca + Mg)]	0.013 meq*

*: Milliequivalent

Ogunlade *et al*. (2005). The protein content is higher than those reported in beef (18%), lamp (16%), pork (10%), haddock (17%), sardine (20%), mackerel (17%) and Oyster (11%) (Abdullahi and Abolude, 2002; Bhuiyan *et al*., 1986; Brain and Allan, 1977). The fat content in this report is higher than the value (5.21%) of *Gymnarchus niloticus* (Adeyeye and Adamu, 2005) and that of sea foods (Ogunlade *et al*., 2005; Adeyeye and Adubiaro, 2004).

The various energy values as contributed by protein, fat and carbohydrate are given in Table 2. The daily energy requirement for an adult is between 2500 to 3000 kcal (10455-12548 KJ) depending on his physiological state while that of infants is 740 kcal (3094.68 KJ) (Bingham, 1978; Adeyeye and Adamu, 2005). This implies that while an adult man would require between 6.56-7.88 g of *Clarias lazera* to meet his minimum requirement, infants would require about 1.94 g. The Utilizable Energy Due to Protein (UEDP%) for *Clarias lazera* (assuming 60% utilization) was 46.8. This value is far higher than the recommended safe level of 8% (Beaton and Swiss, 1974) for an adult man who requires about 55 g protein per day with 60% utilization. This definitely shows that the protein concentration in *Clarias lazera* in terms of energy would be more than enough to prevent malnutrition in children and adult fed solely on *Clarias lazera* as a main source of protein (Adeyeye and Adamu, 2005).

Minerals

Table 3 shown the mineral composition of *Clarias lazera*. The value of Na in this report is higher than K. This agrees excellently with the report of Adeyeye and Adamu (2005) on *Gymnarchus niloticus* with values of 78.44 and 54.25 mg/100 g, respectively. However the values of Na and K were too low far below the 2,500 mg Recommended Daily Allowance (RDA) (NRC, 1989). The respective Na and K value of *Clarias lazera* to be consumed would be 1.04 and 2.78 kg. These values might lead to dietary stress if depended upon as the sole source of Na and K. The higher level of Na than K contrasted to what was observed in vegetable materials (Olaofe and Sanni, 1988; Aremu *et al*., 2005, 2006a; Oshodi *et al*., 1999), which is the reverse of the current report. The Fe, Cu and Zn were low with respective values of 2.5 mg/100 g, 0.4 mg/100 g and 0.4 mg/100 g but they will still be available for biochemical functions. The daily Fe requirements by humans are 10-15 mg for children, 18 mg for women and 12 mg for men. Cu requirement is 2 mg daily. Fe and Cu are present in the enzyme cytochrome oxidase involved in energy metabolism (NAS, 1976). Calcium had the highest concentration (63.7 mg/100 g) among the minerals determined. The body requires 800 mg per day. Thus 12.56 g of *Clarias lazera* would have to be consumed daily to meet body requirement since all would likely be absorbed by the body. Calcium behaves as a kind of coordinator among inorganic elements; if excessive amounts of K, Mg or Na are present in the body, Ca is capable of assuming a corrective role. If the amount of Ca is adequate in the diet, Fe is utilized to better advantage. This is an instance of sparing action (Fleck, 1976). The magnesium value (9.0 mg/100 g) in this report is lower than the values of Mg in *Cyprinus carpio* and *Clarias gariepinus* fish (Adeyeye *et al*., 1996). Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves (Shills, 1973; Shills and Young, 1992). The reported value for lead concentration was 6.8 mg/100 g. Lead is toxic even at very low concentration and has no known function in biochemical processes. Sources of lead include storage batteries, agricultural chemicals, use of chemicals for fishing, type of metal and anti-knock compounds in petrol (Crossby, 1977; Obodo, 2002). The maximum permissible level of lead in the fish muscle by the US-FDA (Adeyeye, 1993) is 2.0 ppm-wet weight. This implies that *Clarias lazera* cannot be said to be polluted.

Table 3 also shows Na/K, Ca/Mg and [K/(Ca + Mg)] ratios. Both Na and K are required to maintain osmotic balance of body fluid and the pH of the body; regulate muscle and nerve irritability, control glucose absorption and enhance normal retention of protein during growth (NRC, 1989). The Na/K ratio less than one is recommended (Nieman *et al*., 1992). Sodium to potassium ratio (2.6) in this report is greater than one, hence the fish sample may not have capacity to hinder high blood pressure. The Ca/Mg ratio is higher than the recommended value of 1.0 (NRC, 1989). The observed value for [K/(Ca + Mg)] was 0.013 milliequivalent. To prevent hypomagnesemia, Marten and Andersen (1975) reported that the milliequivalent of [K/(Ca + Mg)] must be less than 2.2 hence, *Clarias lazera* may have capacity not to lead to hypomagnesemia.

Amino Acid Composition

The amino acid profile is presented in Table 4. Lysine (Lys) was the most concentrated (79.0 mg g^{-1} crude protein) essential amino acid in all the samples while the most concentrated amino acid was glysine (Gly) (141.1 mg g^{-1}). Phenylalanine (Phe) with its sparing partner tyrosine (Tyr) had

Table 4: Amino acid composition (mg g^{-1} crude protein) of *Clarias lazera* on dry weight

Amino acid	Concentrations
Lysine (Lys)[a]	79.0
Histidue (His)[a]	30.0
Arginine (Arg)[a]	63.0
Aspartic acid (Asp)	95.0
Threonine (Thr)[a]	40.0
Serine (Ser)	38.5
Glutamic acid (Glu)	141.1
Proline (Pro)	46.2
Glycine (Gly)	69.0
Alanine (Ala)	59.6
Cystine (Cys)	8.0
Valine (Val)[a]	41.6
Methionine (Met)[a]	29.0
Isoleucine (Ile)[a]	40.0
Leucine (Leu)[a]	70.0
Tyrosine (Tyr)	32.0
Phenylalanine (Phe)[a]	43.0
Isoelectric point (pI)*	5.6
P-PER	26.1

[a]: Essential amino acid; *: Calculated isoelectric point; P-PER: Predicted Protein Efficiency Ratio

Table 5: Essential, non-essential, acidic, basic, neutral and aromatic (mg g^{-1} crude protein) of *Clarias lazera* on dry weight

Classification	Concentration
Total Amino Acids (TAA)	925.20
Total Essential Amino Acids (TEAA)	
With histidine	435.80
Without Histidine	405.80
TEAA (%)	
With Histidine	47.10
Without Histidine	43.86
Total Non-Essential Amino Acids (TNEAA)	489.40
TNEAA (%)	52.90
Essential Alphatic Amino Acids (EAAA)	191.80
EAAA (%)	20.73
Essential Aromatic Amino Acids (EArAA)	43.00
EArAA (%)	4.65
Total Acidic Amino Acids (TAAA)	23.61
TAAA (%)	25.52
Total Basic Amino Acids (TBAA)	172.00
TBAA (%)	18.59
Total Neutral Amino Acids (TNAA)	517.10
TNAA (%)	55.89
Total Sulphur Amino Acids (TSAA)	37.00
TSAA (%)	4.00
Cystine in TSAA (%)	21.62

concentration of 102.2 mg g^{-1}. Arginine (63.0 mg g^{-1}) is an essential amino acid for children growth (Robinson, 1987) and it was high in the sample. Tryptophan was not determined. The calculated isoelectric point (pI) was 5.6. This is useful in predicting the pI for protein in order to enhance a quick precipitation of protein isolate from biological samples (Olaofe and Akintayo, 2000). The Predicted Protein Efficiency Ratio (P-PER) is one of the quality parameters used for protein evaluation (FAO/WHO, 1991). The P-PER (26.1) in this report is higher than the reported P-PER values of some legume flours/concentrates; *Phaseolus coccineus* (19.1 cp) (Aremu *et al*., 2007b), *Prosopis africana* (23cp) (Aremu *et al*., 2007c), *Lathyrus sativus* (10.3 cp) (Salunkhe and Kadam, 1989). However, it can be said that the protein concentrates in all the samples satisfied the FAO requirements (FAO/WHO/UNU, 1985). The evaluation report on amino acid based on classification is shown in Table 5. The total amino acids, TAA (925.2 mg g^{-1} crude protein) in this report is far higher than reported values in plant foods which range between 393.0-765.0 mg g^{-1} (Olaofe *et al*., 1994; Akobundu *et al*., 1982; Aremu *et al*., 2006c; Aisegbu, 1987; Adeyeye, 1997b); also higher than TAA value of *Gymnarchus niloticus* fish (647.6 mg g^{-1}). The Total Sulphur Amino Acid (TSAA) was 37.0 mg g^{-1}, which is lower than the 58 mg g^{-1} recommended for infants (FAO/WHO/UNU, 1985). The Essential Awmatic Amino Acid (EArAA) of *Clarias lazera* (43.0 mg g^{-1}) is lower than the range suggested for ideal infant protein (68-118 mg g^{-1}) (FA/WHO/UNU, 1985). Table 5 also depicts the percent of Total Acidic Amino Acids (TAAA) which was found to be greater than the percent of Total Basic Amino Acids (TBAA) indicating that the protein is probably acidic in nature (Aremu *et al*., 2006c). The percentage total essential amino acids (TAA) of *Clarias lazera* in this report is comparable to that of egg (50%) (FAO/WHO, 1991); *Vigna subterranean* concentrate (49.76%) (Aremu *et al*., 2007b) and beach pea protein isolate (44.4%) (Chavan *et al*., 2001).

The scoring Table 6 shows that valine had the lowest amino acid score with a value of 0.83. This is in agreement with the report of Adeyeye and Adamu (2005) on *Gymnarchs niloticus* which had valine (0.60) as the lowest score. Although valine would have been described as the limiting amino acid, however, the EAA most often acting in a limiting capacity are Lys, Met + Cys, Thr and Try (Bingham, 1977). In this report, the AMSS values for the three EAA were Lys (1.44), Met + Cys (1.06) and Thr (1.0) while Try was not determined. When comparing the essential amino acids in the fish sample with

Table 6: Amino acid scores of *Clarias lazera*

Amino acid	PAAESP[a]	EAAC	AMSS
Ile	40	40.0	1.00
Leu	70	70.2	1.00
Lys	55	79.0	1.44
Met + Cys (TSAA)	35	37.0	1.06
Phe + Tyr	60	102.2	1.70
Thr	40	40.0	1.00
Try	10	nd	na
Val	50	41.6	0.83
Total	360	410.0	8.03

[a]: Source: Belschant *et al.* (1975), PAAESP = Provisional Amino Acid (Egg) Scoring Pattern, EAAC = Essential Amino Acid Composition (see Table 4), AMSS = Amino Acid Scores, nd = Not determined, na = Not available

Table 7: Some functional properties of *Clarias lazera*

Parameters	Value (%)
Foaming Capacity (FC)	4.9±0.5
Foaming Stability (FS) at 8 h	3.7±0.2
Water Absorption Capacity (WAC)	280.5±4.1
Oil Absorption Capacity (OAC)	280.6±2.5
Oil Emulsion Capacity (OEC)	20.0±0.3
Oil Emulsion Stability (OES) at 12 h	19.5±0.7
Lowest Gelation Concentration (LGC)	10.0±0.1
Bulk Density (BD)	470.0±1.0 ($g\ L^{-1}$)

the recommended FAO/WHO (1991) provisional pattern, *Clarias lazera* was superior with respect to Lys, Phe + Tyr while they were adequate in Ile, Leu, TSAA and Thr. It was only for Val that supplementation maybe required (Table 6).

Functional Properties

Table 7 shows the functional properties of *Clarias lazera*. Values of both foaming capacity (4.9%) and foaming stability (3.7%, 8h) were very low. Foaming Capacity (FC) in this report is lower than FC in most vegetables protein and some animals protein; benni seed (18.0%), pear millet and quinoa (19.0%) reported by Oshodi *et al.* (1999), selected sea foods (6-14%) (Ogunlade *et al.*, 2005), varieties of legume seeds (7.9-15.5%) (Aremu *et al.*, 2007a), soybean (66%) (Lin *et al.*, 1974), great Northern bean (32%) (Sathe *et al.*, 1982), varieties of African yam bean (54.0-55.0%) (Oshodi *et al.*, 1997). Consequently, *Clarias lazera* would not be attractive for products like cakes or whipping toppings where foaming is important (Kinsella, 1979). The Water Absorption Capacity (WAC) value (280.5%) of *Clarias lazera* is higher than that of soya flour (130%); sun flower flour 9107%) (Lin *et al.*, 1974); various liman bean (130-142%) (Oshodi and Ekperigin, 1989) and *Zonecerus variegatus* (127.5%) (Olaofe *et al.*, 1998), so the fish sample could be a useful replacement in viscous food formulations such as soups or baked goods. The Oil Absorption Capacity (OAC) was also high (280.6%). The value is higher than *Gynarchus niloticus* fish (148.96%) (Adeyeye and Adamu, 2005), *Zonecerus variegatus* (33.3%) (Olaofe *et al.*, 1998), pigeon pea flour (89.7%) (Oshodi and Ekperigin, 1989), wheat (84.2%) and soya flour (84.4%) (Lin *et al.*, 1974). OAC is important as oil acts as a flavour retainer and improves the mouth feel of foods (Kinsella, 1979). So *Clarias lazera* product would be a good sample for this property better than most of the materials cited.

The Oil Emulsion Capacity (OEC) and stability (OES) are also presented in Table 7. The fish sample in the present study had a low value of OEC (20.0%) in comparison with benniseed, pearmillet and quinoa (63.0, 89.0 and 104.0%, respectively) (Oshodi *et al.*, 1998) but higher than the values reported for soybean (18%) (Lin *et al.*, 1974) and pigeon peas (7.11%) (Oshodi and Ekpergin, 1989). This indicates that *Clarias lazera* might be useful in the production of sausages, soups and cakes (Kinsella, 1979). The OES value was 19.5%, being the volume of water separated after 12 h. The least gelation concentration value (10%) is lower than the values reported for some legumes; lupin seed (14%) (Sathe *et al*., 1982); *Vigna subterranean*, *Kerstingiella geocarpa* and *Vigna unguiculata* (14, 14 and 16%, respectively (Aremu *et al*., 2007a). *Clarias lazera* may therefore provide good consistency to food body and be used in cheese and curd making (Altschul and Wilcke, 1985). The bulk density value (470 g L^{-1}) is higher the values reported for various samples of extrusion texturized soya products with varied protein and soluble sugar contents (238.2-446.0 g L^{-1}) (Cherry, 1981) and various processed defatted fluted pumpkin seed flours (180-380 g L^{-1}) (Fagbemi *et al*., 2006).

CONCLUSIONS

This study has presented data on the concentrations of crude protein, crude fat, organic matter, nutritive and non-nutritive minerals, amino acids and some functional properties of *Clarias lazera* fish from River Tammah/Kwoto in Nasarawa State Nigeria. This being the most detailed study of edible fish from the area and since mineral exploitation, which could cause an upsurge in the levels of the metals vis-à-vis biocumulation factor in fish, is yet to commence; the data thus serve among other things, as baseline information with which future environmental impact assessment of mineral exploitation activities could be progressively monitored.

The study also reveals that *Clarias lazera* contained nutritionally useful quantities of most of the essential amino acids and that the fish specie should be an economic and alternative protein source with great potential to alleviate protein malnutrition in developing countries and to improve the overall nutritional status of functional foods in developed countries.

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