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CHEMICAL COMPOSITION AND FOOD PROPERTIES OF *Gymnarchus niloticus* (TRUNK FISH)

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ABSTRACT

Dry samples of *Gymnarchus niloticus* (Trunk fish) were analysed for proximate, mineral and amino acid compositions as well as the food properties. The protein was high (72.89%), organic matter was high (91.07%) and available energy was also high (1.5 MJ/100g). The proportion of energy due to protein was 50.26%. The sample was low in Cu, Cd, Pb, Fe, Co and Cr but slightly high in Na, Ca, P, Mg and K. The total amino acid was 647.6mg/g crude protein while the essential amino acid was 354.8 (or 54.79%). The amino acid scores ranged from 0.60 –1.09 showing valine to be the limiting acid. The protein solubility was very low with pI of 1.2 at pH = 4 and the theoretical pI was pH 3.8. The absorption capacities were high for water and oil but low stabilities for foam and oil, bulk density was high (514.6g/l). The results showed that Trunk fish is a good source of most parameters determined in this report.

Key words: Trunk fish, Chemical composition, Food properties.

INTRODUCTION

Developing nations (including Nigeria) have shown higher mortality rate of 10-20 times that of developed countries due to protein-energy malnutrition (PEM)[1]. In Nigeria, it has been estimated that 8000 children might die from malnutrition before the age of 4 years[1]. PEM appear serious at about age of 6 months when breast milk alone becomes inadequate for energy needs, this has been implicated in the incidence of low autoimmune deficiency systems[2,3], resulting in growth retardations. Fish is important for Fish for Food Development. The current status of fisheries in Nigeria can only be said to pose serious developmental challenges. Nigeria's demand for fish annually is about 1.5million metric tonnes but presently produces 511,700 metric tonnes while the shortfall is met by importation of 680,000 metric tonnes.

Freshwater fish sources constitute 69.9% of the total fish supply available to Nigeria. This represents a major source of animal protein supply in Nigeria, which has a low per capita protein consumption[4].

Despite the high nutritional value of fish, there is paucity of information on the nutritional and protein quality and particularly the food properties of the tropical freshwater fish species.

The main aim of this project is to investigate the proximate, mineral and amino acid compositions as well as the food properties of *Gymnarchus niloticus* Cuvier, 1829 in the family Gymnarchide. Its local names are *Osan* (Yoruba) and Dan sarki (Hausa). Maximum size = 1.5m; habitat and remarks = swamps; piscivorous. It is a valuable food fish with fatty flesh[5].

MATERIALS AND METHODS

Collection and treatment of samples

Dry samples of *G. niloticus* were purchased at the market in Ado Ekiti, Nigeria. The samples were brought into the laboratory, all bones and viscera removed and further oven-dried at about 55^0C. The cooled dried samples were ground using morta and pestle into fine flour. About 10 fish samples were purchased for this exercise and the ground portions were kept in plastic rubbers in freezer pending analysis.

Proximate analysis

Moisture, ash, crude fat and crude fibre were determined by the AOAC methods[6], while nitrogen was determined by the micro-Kjeldahl method[7] and the percentage of nitrogen was converted to crude protein by multiplying by 6.25. both carbohydrate and organic matter were determined by difference.

Mineral analysis

The minerals were analysed from solution obtained by first dry ashing the sample at 550^0C. Cu, Cd., Fe, Pb, Co, Zn, Cr, Na, K, Mg, Ca were determined by means of atomic absorption spectrophotometer (PYE Unicam Sp 9, Cambridge, UK) and phosphorus was determined colorimetrically by Spectronic 20 (Gallenkamp, UK) using the phosphovanado molybdate method[6].

Amino acid analysis

The method of amino acid analysis was by ion-exchange chromatography (IEC)[8] using the Technicon Sequential Multisample Amino Acid Analyzer (TSM) (Technicon Instruments Corporation, New York). Details of procedure had been given earlier[9].

Estimation of quality of dietary protein

The amino acid score was done by the following formula[10]:

$$\text{Amino acid score} = \frac{\text{mg of amino acid per g of test protein}}{\text{mg of amino acid per g protein in reference pattern}}$$

Determination of the total essential amino acid (TEAA) to the total amino acid (TAA), i.e. (TEAA/TAA); total sulphur amino acid (TSAA); percentage cystine in TSAA (% Csy/ TSAA); total aromatic amino acid (ArAA) while the predicted protein efficiency ratio was determined using one of the equations developed by Alsmeyer *et al.*[11], i.e.

$$\text{P-PER} = -0.468 + 0.454\,(\text{LEU}) - 0.105\,(\text{TYR}).$$

Food properties

The protein solubility was examined from pH 1-12 by the method of Adeyeye *etal*[12]*.* The foaming capacity (FC) and foaming stability (FS) were measured by the method of Coffman and Garcia[13]. Oil and water absorption capacities were measured by the Sosulski[14] procedures. Oil emulsion capacity was determined by the procedure of Inklaar and Fortuin[15], as modified by Adeyeye *et al.*[12], and oil emulsion stability by the method of Beuchat[16]. The bulk density (BD) was determined as described in Cherry[17].

All chemicals were BDH analytical grade. All determinations were in duplicate.

Theoretical estimation of isoelectric point (pI)

(p^I) – This can be carried out by the equation of the form[18].

$$IPm = \sum_{i=1}^{n} IP_i X_i$$

where IPm is the isoelectric point of the mixture of amino acids, IPi is the isoelectric point of the i^{th} amino acid in the mixture and Xi is the mass or mole fraction of the i^{th} amino acid in the mixture[19].

RESULTS AND DISCUSSION

Proximate composition

The proximate values of the *G. niloticus* are shown in Table 1. The organic matter (OM) of 91.07% was higher than all the values reported by Abdullahi and Abolude[20] for four freshwater fishes of *Mormyrops deliciosus* (86.4%), *Bagrus bayad* (75.0%), *Synodontis budgetti* (84.0%) and *Hemichronis fasciatus* (76.0%). Both the protein content and the calory content of the *G. niloticus* were much higher than their corresponding parameters in the four fish samples cited above. The current protein report (72.89%) was close to

Table -1:Proximate composition of Trunk fish on dry weight (% of sample)

Parameter	Concentration
Total ash	8.93 ±0.03
Organic matter	91.07 ± 0.03
Moisture content	10.50 ± 0.02
Crude protein	72.89 ± 0.57
Crude fat	5.21 ±0.01
Crude fibre	Not detected
Available energy	1479.19 ± 0.54 (k J)
Available carbohydrate	2.48 ±0.50

an earlier report (74.50%)[21] for *G. niloticus*. The protein content was higher than those reported in beef (18%), lamp (16%), pork (10%), haddock (17%), sardine (20%), mackerel (17%) and oyster (11%) [22, 23, 20].

Table -2 shows the various energy values as contributed by protein, fat and carbohydrate. The daily energy requirement for an adult is between 2500 to 3000 kcal (10455-12548kJ) depending on his physiological state while that of infants is 740kcal (3094.68k J)[24,25]. This implies that while an adult man would require between 7.07-8.48g of *G. niloticus* to meet his minimum requirement, infants would require about 2.09g. The utilizable energy due to protein (UEDP%) for *G. niloticus* (assuming 60% utilization) was 50.26. This value is far higher than the recommended safe level of 8%[26] for an adult man who requires about 55g protein per day with 60% utilization. This definitely shows that the protein concentration in *G. niloticus* in terms of energy, would be more than enough to prevent malnutrition in children and adult fed solely on *G. niloticus* as a main source of protein.

Table –2: Energy values as contributed by protein, fat and carbohydrate in Trunk fish

Paremeter	Value
Total calculated energy*	1479.19kJ
PEP%	83.77
PEF%	13.38
PEC%	2.84
UEDP%	50.26

*Measured in kJ per g using the Atwater factors.
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.

Minerals

Table -3 depicts the mineral composition of *G. niloticus.* Cd and Pb shared the similar level of 0.01mg/100g. Both metals are not needed for any physiological activity in the body and their presence (although low) could be due to an onset of environmental pollution. The P content was 24.48mg/100g which is far below the 800mg recommended daily allowance (RDA) and 32.7g of *G. niloticus* must be consumed to meet this RDA since there is no interfering phytic acid. To meet the RDA levels (2, 500mg)[27] of Na and K, respective values of *G. niloticus* to be consumed would be 31.9g and 46.1g. These values might lead to dietary stress if depended upon as the sole source of Na

Table – 3: Mineral composition of Trunk fish on dry weight (mg/100g of sample)

Parameter	Concentration
Cu	1.27
Cd	0.01
Fe	2.55
Pb	0.01
Co	0.01
Zn	9.20
Cr	1.96
Na	78.44
K	54.25
Mg	61.69
Ca	31.34
P	24.48
[K/ (Ca + Mg)]	1.17meq*
K/Na	0.69
Na/K	1.45
Ca/P	1.28
Ca/Mg	0.51

*Milliequivalent.

Table –4: Amino acid profile of Trunk fish on dry weight (mg/g of sample)

Amino acid	Concentration	Scores
Lysine (Lys)*	45.2	0.82
Histidine (His)*	21.7	
Arginine (Arg)*	50.4	
Aspartic acid (Asp)	64.7	
Threonine (Thr)*	24.8	0.62
Serine (Ser)	31.8	
Glutamic acid (Glu)	120.0	
Proline (Pro)	21.3	
Glycine (Gly)	25.0	
Alanine (Ala)	30.0	
Methionine + Cystine (Met+Cys)*	31.9	0.91
Valine (Val)*	30.2	0.60
Isoleucine (Ile)*	29.5	0.74
Leucine (Leu)*	56.0	0.80
Phenylalanine + Tyrosine (Phe+Tyr)*	65.1	1.09
Total AA** for scoring	282.7	0.81

*Essential amino acid.
**AA = Amino acid.

Table – 5: Essential, non-essential, acidic, neutral, aromatic (mg/g crude protein) of Trunk fish (dry weight of sample)

Amino acid	Conc.
Total amino acid (TAA)	647.6
Total non-essential amino acid (TNEAA)	292.8
Total essential amino acid (TEAA)	
- with His	354.8
- no His	333.1
% TNEAA	45.21
% TEAA	
- with His	54.79
- no His	51.44
Total neutral amino acid (TNAA)	280.5
%TNAA	43.31
Total acidic amino acid (TAAA)	184.7
% (TAAA)	28.52
Total basic amino acid (TBAA)	117.3
% TBAA	18.11
Percentage of Cys in TSAA*	29.78
P-PER**	22.59
Total aromatic amino acid (TArAA)	65.1
% TArAA	10.05

*TSAA = Total sulphur amino acid
**Predicted protein efficiency ratio

and K. The higher level of Na than K contrasted to what is observed in vegetable materials[28] which is the reverse of the current report. The amount of Ca in *G. niloticus* was 31.34mg/100g. Ca is an important mineral for bone and teeth formation[29] as well as body structure and in blood clotting [30]. The body requires 800mg per day, thus about 25.5g of *G. niloticus* would have to be consumed daily to meet body requirement since all would likely be absorbed by the body. The Mg level was about double the Ca level. Co level was low (0.01mg/100g) and it forms about 4% of vitamin B_{12}. The Fe and Cu contents were low with respective values of 2.55mg/100g and 1.27mg/100g but they will still be available for biochemical functions. Fe presence from animal source enhances Fe absorption from plant sources. The Zn content of 9.20mg/100g was below the Zn allowances of about 15-20mg per day[31]. The daily Fe requirement by humans are 10-15mg for children, 18mg for women and 12mg for men. Cu requirement is 2mg daily. Cu and Fe are present in the enzyme cytochrome oxidase involved in energy metabolism [31]. Ca behaves as a kind of co-ordinator 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'[32].

The Na/K and K/Na levels are depicted in Table 3. Both Na and K are required to maintain osmotic balance of body fluid, the pH of the body, regulate muscle and nerve irritability, control glucose absorption and enhance normal retention of protein during growth [27]. The K/Na ratio of the Trunk fish was 0.69. K/Na enhances the salt balance of the body fluid. Also the Na/K ratio was 1.45 which were higher than 0.60 to avoid high blood pressure [33]. The Ca/P and Ca/Mg weight ratios ranged between 1.28 and 0.51 respectively. These values are comparatively close to the recommended values of 1.0[27]. The Ca/P ratio is reported to have some effect on Ca in the blood of many animals[27]. The [K/ (Ca +Mg)] obtained was 1.17 milliequivalent. To prevent hypomagnesemia, Marten and Andersen[34] reported that the milliequivalent of [K/ (Ca + Mg)] must be less than 2.2 hence, *G. niloticus* may not lead to hypomagnesemia. The results in the current report were close to some results obtained in *Illisha africana* fish caught in various freshwater ponds: Fe (2.00-2.33mg/kg), Cd (0.10-0.23mg/kg) and Pb (0.56-1.12mg/kg) on dry weight basis[35]. In the case of major metals, the current report showed that (mg/100g): Na (78.44) >Mg (61.69) > K (54.25)> Ca (31.34) respectively. From literature, however, *Illisha africana* fish gave the following values (mg/kg): Na (103.0) > K (87.0) >Ca (13.82) > Mg (1.38) as observed in ponds I and II whereas it was K (64.0) > Na (62.2) > Ca (13.56) > Mg (1.56) in pond III[36]. These different observations could have been due to differences in species, environment and age of the fishes.

Protein quality

Table -4 shows the amino acid (AA) composition and the essential amino acid scores (EAAS). Glutamic (120.0mg/g) and aspartic (64.7mg/g) were the most concentrated AA. Both of these acids are acidic AA. Phenylalanine with its sparing partner tyrosine constituted the highest essential amino acid (EAA) with a value of 65.1mg/g and followed by leucine (56.0mg/g). Arginine (50.4mg/g) is an essential AA for children growth[37] and it is high in this sample. The lysine content of the sample (45.2mg/g) was close to the content of the reference egg protein (63mg/g), it will therefore serve as a good source for fortification of cereal weaning foods. The total essential AA (TEAA) of *G. niloticus* was 354.8mg/g crude protein (cp) without tryptophan (which was not determined) which is close to the value of egg reference protein (566mg/gcp)[38]. The current TEAA is comparable to some literature values: it is 351mg/g cp in *Zonocerus variegatus* [39]; it is 350.3mg/gcp in *Macrotermes bellicosus*[40]; it is 428mg/gcp in *Limicolaria* sp, 361mg/g cp in *Archatina archatina* and 450mg/g cp in *Archachatina marginata*[41]. The total suphur AA (TSAA) was 31.9mg/gcp which was lower than the 58mg/gcp recommended for infants[42]. The aromatic AA (ArAA) of *G. niloticus* was 65.10mg/gcp which is close to the range suggested for ideal infant protein (68-118mg/gcp)[42]. The percentage ratio of EAA to the total amino acids (TAA) in the sample was 54.79 (Table 5); this value is well above the 39% considered to be adequate for ideal protein food for infants, 26% for children and 11% for adults[42]. The percentage of EAA/TAA in *G. niloticus* is strongly comparable to that of egg. (50%)[43]; 43.6% reported for pigeon pea flour[44] and 43.8-44.4% reported for beach pea protein isolate[45]. The predicted protein efficiency ratio (P-PER) was 22.59 due to the high level of leucine (56.0mg/gcp). The current P-PER was better than 1.21 (cowpea), 1.82 (pigeon pea)[46]; 4.06 (corn *ogi*), 1.62 (millet *ogi*) and 0.27 (sorghum *ogi*)[47]; reference casein with PER of 2.50[47].

Table – 6: Protein solubility of Trunk fish as a function of pH

pH level	Solubility %	Isoelectric point (pI)
1	3.6	
2	2.4	
3	2.1	
4	1.2	
5	3.0	pI
6	3.6	
7	4.8	
8	3.0	
9	3.6	
10	4.8	
11	5.4	
12	4.2	
Theoretical pI	3.8	

Table – 7: Some food properties of Trunk fish

Parameter	Value (%)
Water absorption capacity (WAC)	275.0 ± 7.07
Oil absorption capacity (OAC)	148.96 ± 0.0
Foaming capacity (FC)	6.0 ± 0.1
Foaming stability (FS) at 30min	2.0± 0.1
Oil emulsion capacity (OEC)	20.5 ± 0.71
Oil emulsion stability (OES) at 4min	35.0 ± 0.2
Lowest gelation concentration (LGC)	8.0 ± 0.2
Bulk density (BD)	514.6g/l

Table -4 shows that Val had the lowest amino acid score with a value of 0.60 (60%). Although this 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[48]. In this report, the EAAS values for the three EAA were Lys, 0.82 (82.0), Met + Cys (TSAA), 0.911 (91.1%) and Thr 0.62 (62%) while Try was not determined. Therefore, in order to fulfil the day's needs for all the essential amino acids in *G. niloticus*, 100/62 (for Thr) or 1.61 times as much *G. niloticus* protein would have to be taken (eaten) when it is the sole protein in the diet. Cys has positive effects on mineral absorption, particularly zinc[49,50]. The % Cys in TSAA was 29.78 (Table -5).

Most animal proteins are low in Cys, for examples: 36.3% *M. bellicosus*[40]; 25.59% in *Z. variegatus* [39]; 35.3% in *A. marginata*; 38.8% in *A. archatina* and 21.0% in *Limicolaria* sp. respectively[41]. In contrast, many vegetable proteins, contain substantially more Cys than Met, example, 62.87% in coconut endosperm[9]. Thus for animal protein diets, or mixed diets containing animal protein, cystine is unlikely to contribute up to 50% of the TSAA[8]. Although FAO/WHO/UNU[42] did not give any indication of the proportion of TSAA which can be met by Cys in man, for the rat, chick and pig, the proportion is about 50%[8].

Functional properties

The effect of pH on the protein solubility of *G. niloticus* is shown in Table -6. There was low solubility in both acid and alkali, with an isoelectric point (the minimum solubility) around pH 4.0 with pI 1.2. The theoretical pI was 3.8. The solubility in both acid and alkali indicates that it may not be useful in formulating carbonated beverages[51] and very low-acid foods such as meat products[52]. The presence of only one pI suggests that *G. niloticus* has only one major protein constituent. The low protein solubility of *G. niloticus* was a clear indication of serious denaturation due to heat drying of the samples. The water absorption capacity (275%) (Table -7) was higher than that of sun flower flour (107%), soya flour (130%)[53] and *Z. variegatus* (127.5%)[51], so *G. niloticus* could be a useful replacement in viscous food formulations such as soups or baked goods. The oil absorption capacity (OAC) (Table -7) was also high (148.96%).

The value was higher than 33.3% (*Z. variegatus*)[51], 89.7% (pigeon pea flour)[54], wheat and soya flours (84.2 and 84.4% respectively)[53] but lower than cowpeas (281-310%)[52]. OAC is important, as oil acts as a flavour retainer and improves the mouth feel of foods[55], so the fish product would be a good sample for this property better than most of the materials cited. The oil emulsion capacity (20.5%) was close to 25.6% in *Z. variegatus*[51] but better than the 7.0-11.0% reported for wheat flour and 18.0% for soya flour[53], so *G. niloticus* might be useful in the production of sausages, soups and cakes[56].

The emulsion collapsed within 4min which meant that the protein would be of little use in products that depend on the formation of stable emulsions. The foaming capacity (FC) and foaming stability (FS) were both low, with only 6.0% (FC) and 2.0% (FS, 30min), being formed, most commercial products are stable for more than 2h. Consequently *G. niloticus* would not be attractive for products like cakes or whipping toppings where foaming is important[57]. The gelation concentration was low at 8.0% which is lower than the values reported for some legumes, e.g cow pea (10%)[58] and pigeon pea (10%)[54]. *G. niloticus* may therefore provide good consistency to food body and be useful in cheese and curd making[56]. The bulk density (BD) was 514.6g/l which was higher than the values reported for various samples of extrusion texturized soya products with varied protein and soluble sugar contents (238.2 - 446.0g/l)[17].

Gymnarchus niloticus was found to be good sources of metabolisable energy, high quality protein of almost adequate components of EAA and high degree of digestibility[42], low level of nitrite[21] good functionalities in OAC, WAC, LGC and BD, hence it can on its own serve as a good food fish or as a supplement /fortifier to lower quality protein foods.

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