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Effect of Different Sources of Heat on Nutritional Composition of Tilapia Fish (*Oreochromis niloticus*)

M. O. Aremu [1*], B. S. Namo[2], Y. Mohammed[2], C. S. Archibong[1] and E. Ogah[1]
[1]Department of Chemical Sciences, Federal University Wukari, PMB 1020, Taraba State, Nigeria
[2]Department of Chemistry, Nasarawa State University, PMB 1022, Keffi, Nigeria
*Corresponding author: lekearemu@gmail.com

Abstract
A study was conducted to investigate the effect of traditional smoking methods on fresh tilapia fish (*Oreochromis niloticus*). For this purpose, proximate, mineral and amino acid compositions of tilapia fish smoked with sawdust, rice bran, melon husk and electric oven (control) heat treatments were determined using standard analytical technique. The results showed that crude protein content (%) ranged between 55.10 to 64.16% with the highest value recorded in sample smoked with rice bran heat treatment while crude fat had the highest value (18.10%) also in rice bran smoked sample. Sodium was found to be more abundant in all the samples (5.75 – 10.10 mg/100g) compared with magnesium (5.45 – 9.15 mg/100g), potassium (4.55 – 6.45 mg/100g) and phosphorus (4.70 – 6.00 mg/100g) while the least abundant mineral was chromium (0.05 – 0.15 mg/100g). The harmful metals such as cadmium and lead were not at detectable range of atomic absorption spectrophotometer (AAS). The amino acid profile revealed that only *Oreochromis niloticus* fish sample smoked with sawdust enhanced the contents of total amino acid (TAA), total essential amino acid (TEAA) and total sulphur amino acid (TSAA) by 3.77, 3.95 and 7.03%, respectively while melon husk and rice bran heat treatments reduced TAA, TEAA and TSAA. The limiting amino acid (LAA) for all the samples with different heat treatments was Ile except sample smoked with rice bran which has Val as LAA. Generally, all the smoked samples contained nutritionally useful quantities of total essential amino acids.
Keywords: *Oreochromis niloticus,* agricultural wastes, smoke, proximate, amino acids.

1. Introduction

Fish is an important source of cheap first class protein, providing essential amino acids (Paul&Southgate, 1978). Fish is low in fat and cholesterol; it is also rich in calcium, phosphorus, vitamin A and D (Brigette *et al.,* 1994). Fishes such as herrings, mackerel, sardine and tuna contain omega-3 fatty acids, which prevent heart disorders. According to some workers (Mayhew&Peny, 1998), fish is quicker to cook and is more easily digested than meat of other animals. The results of a study conducted by Sipe (1978) have shown a positive correlation between the amounts of fish consumed and life span of the consumer. This author reported that majority of Americans and Japanese who depend on fish as their main source of protein therefore have longer life span.

In spite of the importance of fish and the fishing industry, fish is an extremely perishable commodity, spoiling soon after death, due to enzymatic and microbial actions, resulting in disagreeable taste, smell and texture, thereby reducing consumer acceptability (Brigette *et al*., 1994; Garrow&James, 1994). These authors also asserted that high ambient temperature of the tropics are a major environmental factor prompting rapid spoilage of fish. Madison *et al.* (1993) suggested refrigeration as means of preventing the fast rate of deterioration in fish. They also cited careful handling and rapid processing as essential steps to overcome the problem of rapid fish spoilage.

The use of smoke from smouldering wood for the preservation of perishable foods dates back to civilization. The method might have been developed in the ancient times by hanging perishable food over a fire, which was used for heating purposes. Among the raw materials cured in this way, fish and fish products were the most vulnerable to deterioration Clucas 1992). The bacteriostatic, bactericidal and antioxidant functions of smoke and the dehydration effect of the process were used inadvertently by the early fish processors in the preservation of fish. Although consumers are generally attracted by the flavour of smoked fish, its nutritive value is of paramount important since every consumer want to obtain good quality protein from fish consumption. Most of the work in the nutritional value of smoked fish has centred on lysine, an essential amino acid which is limiting in cereal root crops which are the stable food of most inhabitants of tropical countries. Lysine is the most sensitive basic amino acid to heat damage (Vognarova & Dvorok, 1995). Therefore, the work was aimed to determine proximate, mineral and amino acid compositions of tilapia fish (*Oreochromis niloticus*) that was smoked using different heat sources with a view to providing necessary information and for future reference purpose.

2 Materials and Methods

2.1 Collection of the samples

Two pieces of fresh fish samples of tilapia (*Oreochromis niloticus*) of average weight 300 g and length 36 cm and about 3 months old were purchased from Akwanga market while samples of sawdust, rice bran and melon husk wastes were also collected from Akwanga market and Angwan Sabo Timber Shed in Akwanga metropolis, Nasarawa Sate, Nigeria. All samples were collected in July, 2012.

2.2 Preparation of the samples

The fish samples collected were killed, gutted and washed thoroughly with clean tap water. The energy sources which were sawdust, rice bran and melon husk wastes took one week to completely dry when collected, although factors such as rainfall and relative humidity may have affected the drying duration.

2.3 Smoking of the samples

Smoking of the fish samples was carried out at a distance of 58 cm from the fire point by burning of saw dust, rice bran and melon husk wastes which were the energy sources using the Altona smoking kiln to simulate what is practiced by local fish mongers (Salan *et al.,* 2006). Smoking with saw dust was affected for 13 h, rice bran 22 h, and melon husk 32 h. The fish samples were also smoked using electric oven as the control at a temperature of 120°C for 2 h. After smoking, the fire was extinguished and the samples were allowed to cool down sufficiently and blended into fine powder in the laboratory using Kenwood food blender and the various product were packed in transparent polyethylene bags, sealed with a sealing machine to reduce microbial infestation and stored in a refrigerator at a temperature of 4°C prior to the analysis (Salan *et al.,* 2006; Abolagba & Melle, 2008).

2.4 Proximate analysis

The proximate analysis of the samples for moisture, total ash, ether extract, crude protein and crude fibre were carried out in triplicate using the methods described in AOAC (2000) while carbohydrate was also determined by difference as shown below;

% Carbohydrate = 100 – (% moisture + % crude protein + crude fat + % ether extract + % ash).

All the proximate values were reported in g/100g sample. All chemicals used were of Analar grade.

2.5 Mineral analysis

Sodium and potassium were determined using a flame photometer (Model 405, Corning UK) while all the other metals were determined by Atomic Absorption Spectrophotometer (Solar 969 Unicam).

2.6 Amino acid analysis

The amino acids were quantitatively measured by the procedure of Spackman *et al.* (1958) using automated amino acid analyzer (Technicon Sequential Multi–Sample Analyzer, TSM). Sample was hydrolyzed for determination of all amino acids except tryptophan in consistent boiling hydrochloric acid for 22 h under nitrogen flush.

2.7 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 & Akintayo (2000).

$$p\,\mathrm{Im} = \sum_{i=1}^{n=1} pI_i X_i$$

Where

pIm = The isoelectric point of the mixture of amino acid

pI_i = The isoelectric point of the i^{th} amino acids in the mixture

X_i = 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 protein concentrate compared with needs expressed as a ratio (FAO, 1970). Amino acid score (AMSS) was then estimated by applying the FAO/WHO (1990) formula.

$$\text{AMSS} = \frac{mg\ of\ amino\ acid\ in\ 1g\ of\ test\ protein}{mg\ of\ amino\ acid\ in\ 1g\ reference\ protein}\ x\ \frac{100}{1}$$

The predicted protein efficiency ratio (P–PER) of the fresh sample was calculated from their amino acid composition based on the equation developed by Alsmayer *et al.* (1974): P–PER = 0.468 + 0.454 (Leu) –0.105 (Tyr).

2.8 Statistical analysis of the samples

The energy values were calculated by adding up the carbohydrate x 17 kJ, crude protein x 17kJ and crude fat x 37 kJ for each of the samples. Errors of three determinations were computed as standard deviation (SD) for the proximate composition. The grand mean, SD, coefficient variation (CV%) were also determined.

3. Results and Discussion

The result of proximate composition of smoked *Oreochromis niloticus* is presented in Table 1. The protein content of 64.16% for the sample smoked with rice bran was higher while the same fish sample smoked using saw dust is lower (55.10%). However, the present protein content which ranged between 55.10% to 64.16% are comparable to the 56.9% for *Tilapia quineensis* reported by Aremu *et al.* (2007) and higher than those reported for the three local Malaysian fish *Channa spp* (19.6%, 22.1% and 23.0%) by Zuraini *et al.* (2006) and varieties of meat and fish samples; beef (18%), lamp (16%), pork (10%), haddock (17%), sardine (20%), mackerel (17%) and oyster (11%) (Abdullahi & Abolude, 2002; Bhuiyan *et al.* 1986; Brain & Allan, 1977). The result indicated that *Oreochromis niloticus* fish is a good source of protein. The fat content 18.10% for the fish smoked with rice bran was higher however treatment from saw dust recorded the lowest fat content of 11.24%. The fat contents in this report are higher than the 5.21% for *Gymnarchus niloticus* (Adeyeye & Adamu, 2005). Crude fibre content of 18.39% obtained by smoking with melon husk appears to be high compared to 7.65% obtained using rice bran heat treatment. Dietary fibre is considered to be helpful in the prevention of many of the diseases of Western civilization, such as diverticulitis, constipation, obesity and diabetes mellitus (FAO/WHO, 1991). Communities' consuming diets with high fibre content rarely have any of these diseases. The moisture content (7.16%) obtained for melon husk heat treatment is higher while the 2.78% for electric oven (control) smoking is lowest. The moisture content ranged between 2.78% to 7.16% though higher than those reported for some plant foods; rare cowpea (1.8%), cranberry bean (1.7%) and kerstings groundnut (1.7%) (Aremu *et al.*, 2006a); *Prosopis africana* (1.9%) (Aremu *et al.*, 2006b). The high moisture content may make the *Oreochromis niloticus* highly susceptible to microbial attack. The ash content which ranged from 4.02% for treatment using rice bran to 7.2% for an electric oven smoking of *Oreochromis niloticus* are comparable with 8.2% for *Tilapia quineensis* as reported by Aremu *et al.* (2007) however, it is lower than the value reported for *Oreochromis niloticus* fish (25.33%) by Anta & Ogueji (2006). The calculated metabolizable energy values which ranged between 1515.76 to 1774.02 kJ/100g showed that all the studied smoked fish samples of *Oreochromis niloticus* have energy concentrations favourable comparable to some plant foods such as cereals and legumes (Paul & Southgate, 1978). The values of calculated fatty acid range between 8.99 and 14.48 in saw dust and rice bran heat treatments, respectively. Despite the effect of smoking, the coefficient of variation (CV%); levels were relatively close ranging from 5.78% for crude protein to 67.79% (carbohydrate). The carbohydrate content which ranged between 0.80 to 12.12% in this report is highly comparable with 4.8% reported by Aremu *et al.* (2007).

The various energy values as contributed by crude protein, crude fat and carbohydrate were presented in Table 2. The daily energy requirement for an adult is between 2500 – 3000 k cal (10455 – 12548 kJ) depending on his physiological state while that of infants is 740 k cal (3094.68 kJ) (Bingham, 1978; Adeyeye & Adamu, 2005). This implies that while an adult man would require the range between 6.38 to 7.66, 6.71 to 8.05, 6.90 to 8.28 and 5.89 to 7.07 of *Oreochromis niloticus* smoked with electric oven, saw dust, melon husk and rice bran heat treatments, respectively to meet his daily minimum requirement; infants would require the range values between 1.74 to 2.04 using the same fish species and heat sources. The utilizable energy due to protein (UEDP%) for *Oreochromis niloticus* (assuming 60% utilization) in the current study had values which range is far higher than the recommended safe level of 8% (Beaton & Swiss, 1974) for an adult man who requires about 55g protein per day with 60% utilization. This definitely signifies that the protein concentration in *Oreochromis niloticus* fish in terms of energy would be more than enough to prevent malnutrition in children and adult who feed solely on *Oreochromis niloticus* fish as a main source of protein (Adeyeye & Adamu, 2005).

The mineral composition in mg/100g of *Oreochromis niloticus* is presented in Table 3. Lead and cadmium were not at the detectable range of AAS in all the smoked fish samples. Arsenic and chromium were not also detected in the sample smoked in an electric oven (control). The abundant minerals in the studied samples were sodium and magnesium with values ranging from 5.75 mg/100g sample in melon husk heat treatment to 10.10 mg/100g in rice bran heat treatment, and 5.45 mg/100g in electric oven smoking to 9.15 mg/100g in rice bran smoking for magnesium. Magnesium is an activator of many enzymes systems and maintains the electrical potential in nerves. This is followed by potassium with range values between 4.55 mg/100g sample in electric oven smoking to 6.45 mg/100g in saw dust heat treatment. It has been reported that calcium in conjunction with phosphorus, magnesium, manganese, vitamin A, C and D, chlorine and protein are all involved in bone formation (Fleck, 1976). Phosphorus ranged between 4.70 mg/100g sample in saw dust smoking to 6.00 mg/100g in rice bran and electric oven heat treatments while manganese had range values between 3.30 mg/100g in rice bran heat treatment to 4.45 mg/100 g sample in electric oven smoking. The least abundant minerals in the studied samples were chromium (0.05 to 0.15 mg/100g) and arsenic (0.10 to 0.90 mg/100g). Calcium and iron were found in appreciable amount while zinc and copper were generally low. Iron is an essential component in the transfer of oxygen in the body and a deficiency of iron in the body may lead to anaemia (Fleck, 1976). Harmful heavy metals such as lead and cadmium were not at the detectable range of AAS (Table 3).
The ratios of sodium to potassium (Na/K) and calcium to phosphorus (Ca/P) were also shown in Table 3. The Na/K ratio in the body is of great concern for prevention of high blood pressure. Na/K ratio of less than 1 is recommended (Nieman *et al.*, 1992). The range between 1.10 to 2.22 mg/100g sample of Na/K ratios in this report are greater than 1, hence the smoked fish sample may not have the capacity to hinder high blood pressure.
If the Ca/P ratio is low (low calcium, high phosphorus intake) more than normal amount of calcium may be loss in the urine, decreasing the calcium level in bones. Food is considered “good” if the ratio is above 1 and “poor” if the ratio is less than 0.5 (Nieman *et al.*, 1992). With the exception of 0.44 mg/100 g in rice bran smoking, the range values of Ca/P ratios from 0.53 to 0.94 mg/100 g in the present study indicated they would serve as good sources of mineral for bone formation. The co-efficient of variation (CV%) was variously varied with a range of 10.55% in manganese to 68.75% in arsenic.
The observed values for potassium to sum of calcium and magnesium ratio [K/(Ca + Mg)] ranged between 0.39 to 0.62 mg/100 g sample. To prevent hypomagnesaemia, Marten & Anderson (1975) reported that the milliequivalent of [K/(Ca + Mg)] must be less than 2.2 hence, *Oreochromis niloticus* may have the capacity not to lead to hypomagnesaemia.

The amino acid composition of smoked samples of *Oreochromis niloticus* is presented in Table 4. Lysine was the most concentrated (6.81 – 7.73 g/100 g crude protein, cp) essential amino acid in all the smoked fish samples followed by leucine with range values between 6.39 to 7.45 g/100 g cp while the most concentrated acidic amino acid was glutamin (CV, 6.40%) which ranged between 12.27 g/100 g cp in the sample smoked with melon husk heat treatment and 14.31 g/100 g cp for sawdust heat treatment. Tryptophan concentration could not be determined. Cystine was found to be the least concentrated amino acid. It had range values between 0.79 to 0.93 g/100 g cp. Arginine is essential for children and reasonable levels were present in this report. Arginine which ranged between 5.70 to 6.30 g/100 g cp in this report is comparable with 5.90 g/100 g cp of *Tilapia quineensis* (Aremu *et al.*, 2007). The calculated isoelectric point (pI) varied between 4.80 to 5.52. This is useful in predicting the pI for protein in order to enhance a quick precipitation of protein isolate from biological samples (Oshodi *et al.*, 1993).
The predicted protein efficiency ratio (P-PER) is one of the quality parameter used for protein evaluation (FAO/WHO, 1991). The P-PER in this report ranged between 2.13 in melon husk heat treatment to 2.58 in sawdust smoking. This result is highly comparable to the 2.62 (liver) and 2.32 (heart) of *Cricetomys gambianus* (Adeyeye & Aremu, 2011) and 2.6 of *Clarias lazera* (Aremu & Ekunode, 2008) but lower in values than 4.06 report for corn ogi (Oyarekua & Eleyinmi, 2004).
The evaluation report based on classification of amino acids of smoked *Oreochromis niloticus* is shown in Table 5. The total amino acid (TAA) values in this report which ranged between 81.62 to 94.06 g/100 g cp are close to the TAA of 88.3 g/100 g cp in *Tilapia quineensis* (Aremu *et al.*, 2007), however higher than the reported value of 64.76 g/100g cp for G*ymnarchus niloticus* (Adeyeye & Adamu, 2005). The total sulphur amino acids (TSAA) which range between 3.13 to 3.36 g/100 g cp in the current report are lower than the 5.8 g/100 g cp recommended for infants (FAO/WHO/UNU, 1985). The essential aromatic amino acid (EArAA) of *Oreochromis niloticus* had range values from 3.63 to 4.22 g/100 g cp in the current study. This values compares favourably with the 4.20 g/100 g cp reported for *Tilapia quineensis*, but is lower than the range suggested for ideal infant protein of 6.8 to 11.8 g/100 g cp (FAO/WHO/UNU, 1985). Table 5 also depicts the TAAA which

was found to be greater than the TBAA indicating that the protein is probably acidic in nature (Aremu *et al.*, 2006d; Olaofe *et al.*, 2008). The percentage ratios of TEAA to TAA (with histidine) in the current study which ranged between 46.35 to 47.15% are above the 39% considered to be adequate for ideal protein food for infants, 26% for children and 11% for adult (FAO/WHO/UNU, 1985).

The TEAA/TAA percentage contents were strongly comparable to the range from 43.8 to 44.4% reported for beach pea protein isolate (Chavan *et al.*, 2001). The co-efficient of variation percent (CV%) was variously varied with a range of 2.92% in methionine (Met) and 14.21% in proline (Pro) (Table 5).

The result of amino acid scores is also presented in Table 6. With exception of Leu in sawdust heat treatment, Lys, Phe + Tyr, Thr in melon husk and rice bran smoking, the essential amino acid contents are lower than the FAO/WHO (1991) recommended pattern. Thus by implication, dietary formula based on the protein content of smoked *Oreochromis niloticus* will require some essential amino acids supplementation such as Met + Lys (TSAA), Ile, Val, Leu in electric oven (control) smoking, Leu and Thr for treatment using melon husk, Leu and Thr in rice bran heat treatment since tryptophan concentration was not determined. Also, in the present study, Ile was the limiting amino acid (LAA) for all the smoked samples except for rice bran smoking which was found to be Val.

4. Conclusion

The work has presented effect of different heat sources using sawdust, rice bran, melon husk and electric oven (control) on proximate, mineral and amino acid compositions of Tilapia fish (*Oreochromis niloficus*). The study showed deviations in nutrients when the fish sample was smoked with heat generated from fuel (sawdust, rice bran and melon husk) compared with electric oven. Generally, all the samples contained nutritionally mineral content and useful quantities of total essential amino acids. However, more elaborate study to optimize smoking methods is required before an appropriate source of heat from fuel can be recommended for smoking this important fish.

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Table 1: Proximate Composition (%)[a] of *Oreochromis niloticus* Smoked with Different Sources of Heat

	Heat Fuel Treatments						
Parameter	**Electric Oven**	**Sawdust**	**Melon Husk**	**Rice Bran**	**Mean**	**SD**	**CV%**
Crude Protein	60.21 ± 0.05	55.10 ± 0.06	57.14 ± 0.79	64.16 ± 0.03	59.15	3.42	5.78
Crude Fat	14.19 ± 0.12	11.24 ± 0.04	12.14 ± 0.03	18.10 ± 0.11	14.42	2.44	16.92
Crude Fibre	10.24 ± 0.04	11.19 ± 0.08	12.39 ± 0.15	7.65 ± 0.12	11.87	3.98	33.53
Moisture	2.78 ± 0.08	5.17 ± 0.03	7.16 ± 0.03	5.27 ± 0.05	5.10	1.55	30.39
Ash	7.28 ± 0.05	5.18 ± 0.02	5.57 ± 0.10	4.02 ± 0.09	5.51	1.17	21.23
[b]Carbohydrate	5.30 ± 0.03	12.12 ± 0.03	5.60 ± 0.02	0.80 ± 0.09	5.96	4.04	67.79
[c]Fatty Acids	11.35	8.99	11.31	14.48	11.54	1.95	13.54
[d]Energy (kJ/100g)	1638.70	1558.62	1515.76	1774.02	1621.78	98.35	6.06

[a]Each value represents the mean ± standard deviation of three replicate determinations;
[b]Carbohydrate percent calculated as (100 – total of other components);
[c]Calculated fatty acid (crude fat x 0.8)
[d]Calculated metabolizable energy (kJ/100g): (protein x 17 + fat x 37 + carbohydrate x 17);
SD = Standard deviation;
CV = Coefficient of variation.

Table 2: Energy Values as Contributed by Crude Protein, Crude Fat and Carbohydrate in Smoked *Oreochromis niloticus*

	Heat Treatments			
Parameter	**Electric Oven**	**Sawdust**	**Melon Husk**	**Rice Bran**
Total Calculated Energy (KJ/100g)	1638.70	1558.62	1515.76	1774.02
PEP	60.21	55.10	57.14	64.16
PEF	14.19	11.24	12.14	18.10
PEC	5.30	12.12	5.60	0.80
UEDP	36.13	33.06	34.28	38.50

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

Table 3: Mineral Composition (mg/100 g) of *Oreochromis niloticus* Smoked with Different Sources of Heat

	Heat Treatments						
Mineral	**Electric Oven**	**Sawdust**	**Melon Husk**	**Rice Bran**	**Mean**	**SD**	**CV%**
Na	6.45	7.90	5.75	10.10	7.55	1.66	21.99
K	5.50	6.45	5.25	4.55	5.44	0.68	12.50
Mg	5.45	7.80	6.40	9.15	7.20	1.40	19.44
Fe	1.45	2.55	0.60	2.75	1.84	0.87	47.28
Zn	1.00	0.60	0.60	0.80	0.75	0.17	22.67
Cu	0.49	0.68	1.71	1.33	1.05	0.49	46.67
Pb	ND	ND	ND	ND	ND	ND	ND
As	ND	0.10	0.90	0.45	0.48	0.33	68.75
Cr	ND	0.05	0.15	0.05	0.08	0.05	62.50
Cd	ND	ND	ND	ND	ND	ND	ND
Mn	4.45	4.16	4.05	0.30	3.98	0.42	10.55
Ca	3.40	4.40	2.55	2.65	3.25	0.74	22.77
P	6.00	4.70	4.80	6.00	5.38	0.63	11.71
Na/K	1.17	1.22	1.10	2.22	1.43	0.46	32.17
Ca/P	0.57	0.94	0.53	0.44	0.62	0.19	30.65
[K/(Ca + Mg)]	0.62	0.53	0.59	0.39	0.53	0.09	16.98

Na/K = Sodium to potassium ratio;
Ca/P = Calcium to potassium ratio;
[K/(Ca + Mg)] = Potassium to sum of calcium and magnesium ratio;
SD = Standard deviation;
CV = Coefficient of variation;
ND = Not detected.

Table 4: Amino Acid Concentration (g/100 g crude protein cp) of *Oreochromis niloticus* Smoked with Different Sources of Heat

	Heat Treatments						
Amino Acid	**Electric Oven**	**Sawdust**	**Melon Husk**	**Rice Bran**	**Mean**	**SD**	**CV%**
Lysine (Lys)[a]	7.73	7.62	6.81	6.91	7.27	0.41	5.64
Histidine (His)[a]	2.59	2.40	2.08	2.24	2.33	0.19	8.15
Arginine (Arg)[a]	6.21	6.30	5.70	6.04	6.06	0.23	3.80
Aspartic Acid (Asp)	9.68	9.86	8.84	8.90	9.32	0.45	4.83
Threonine (Thr)[a]	4.49	4.77	3.84	3.92	4.26	0.39	9.15
Serine (Ser)	4.12	4.50	3.80	3.77	4.05	0.30	7.41
Glutamic Acid (Glu)	13.94	14.31	12.27	12.65	13.29	0.85	6.40
Proline (Pro)	4.07	4.27	3.05	3.26	3.66	0.52	14.21
Glycine (Gly)	6.92	6.92	6.00	5.60	6.36	0.58	9.12
Alanine (Ala)	5.93	6.42	6.00	5.74	6.02	0.25	4.15
Cystine (Cys)	0.79	0.93	0.79	0.86	0.84	0.06	7.14
Valine (Val)[a]	4.75	4.89	4.02	3.94	4.40	0.42	9.55
Methionine (Met)[a]	2.34	2.42	2.34	2.50	2.40	0.07	2.92
Isoleucine (Ile)[a]	3.32	3.61	3.20	8.20	3.33	0.17	5.11
Leucine (Leu)[a]	6.88	7.45	6.39	6.55	6.82	0.41	6.01
Tyrosine (Tyr)	3.18	3.17	2.86	2.86	3.02	0.16	5.30
Tryptophan (Try)	ND	ND	ND	ND	ND	ND	ND
Phenylalanin (Phe)[a]	3.71	4.22	3.63	3.63	3.80	0.25	6.58
Isoelectric Point (pI)	5.34	5.52	4.80	4.87	5.13	0.31	6.04
P-PER	2.32	2.58	2.13	2.21	2.31	0.17	7.36

a = Essential amino acid;
pI = Calculated isoelectric point;
P-PER = Predicted protein efficiency ratio;
ND = Not determined;
SD = Standard deviation;
CV = Coefficient of variation.

Table 5: Classification of Amino Acid Composition (g/100 g crude protein) of Smoked *Oreochromis niloticus*

Parameter	Heat Treatments Electric Oven	Sawdust	Melon Husk	Rice Bran	Mean	SD	CV%
Total Amino Acid (TAA)	90.65	94.06	81.62	82.57	87.23	5.28	6.05
Total Non-Essential Amino Acid (TNEAA)	48.63	50.38	43.61	43.64	46.57	3.00	6.44
% TNEAA	53.65	53.56	53.43	52.85	53.37	0.31	0.58
Total Essential Amino Acid (TEAA)							
With Histidine	42.02	43.68	38.01	38.93	40.66	2.29	5.63
Without Histidine	39.43	41.28	35.93	36.69	38.33	2.14	5.58
% TEAA							
With Histidine	46.35	46.44	46.57	47.15	46.63	0.31	0.66
Without Histidine	43.50	43.89	44.02	44.44	43.96	0.34	0.77
Essential Aliphatic Amino Acids (EAAA)	19.44	20.72	17.45	17.61	18.81	1.35	7.18
Essential Aromatic Amino Acids (EArAA)	3.71	4.22	3.63	3.63	3.80	0.25	6.58
Total neutral Amino Acids (TNAAA)	50.50	53.57	45.92	45.83	48.96	3.27	6.68
% TNAA	55.71	56.95	56.26	55.50	56.11	0.56	1.00
Total Acidic Amino Acid (TAAA)	23.62	24.17	21.11	21.55	22.61	1.21	5.35
%TAAA	26.06	25.70	25.86	26.10	25.93	0.16	0.62
Total Basic Amino Acid	16.53	16.32	14.59	15.19	15.66	0.80	5.11
%TBAA	18.23	17.35	17.88	18.40	17.97	0.40	2.23
Total Sulphur amino Acids (TSAA)	3.13	3.35	3.13	3.36	3.24	0.11	3.40
% Cystine	23.24	27.76	25.24	25.60	25.46	1.60	6.28

SD = Standard deviation;
CV = Coefficient of variation.

Table 6: Amino Acid Scores of Smoked *Oreochromis niloticus*

EAA	PAAESP (g/100g Protein)	Heat Treatments Electric Oven EAAC	Electric Oven AAS	Sawdust EAAC	Sawdust AAS	Melon Husk EAAC	Melon Husk AAS	Rice Bran EAAC	Rice Bran AAS
Ile	4.0	3.32	0.83	3.61	0.90	3.20	0.80	3.20	0.80
Leu	7.0	6.88	0.98	7.45	1.06	6.39	0.91	6.55	0.94
Lys	5.5	7.73	1.41	7.62	1.39	6.81	1.24	6.91	1.26
Met + Cys (TSAA)	3.5	3.13	0.89	3.35	0.96	3.13	0.89	3.36	0.96
Phe + Tyr	6.0	6.89	1.15	7.39	1.23	6.49	1.08	6.49	1.08
Thr	4.0	4.49	1.12	4.77	1.19	3.84	0.96	3.92	0.98
Try	1.0	ND	NA	ND	NA	ND	NA	ND	NA
Val	5.0	4.75	0.95	4.89	0.98	4.02	0.80	3.94	0.79
Total	**36.0**	**37.19**	**7.33**	**39.08**	**7.71**	**33.88**	**6.68**	**34.37**	**6.81**

EAA = Essential amino acid; PAAESP = Provisional amino acid (egg) scoring pattern; EAAC = Essential amino acid composition (Table 4.12); AAS = Amino acid scores; ND = Not determined; NA = Not applicable; Source = Belschant *et al.* (1975).