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Compositional Evaluation of Local Smoked Nigerian Mackerel (*Scomber scombrus*)

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Abstract

Effects of different energy sources using sawdust, melon husk, rice bran and electric oven (control) were investigated on the chemical composition of local fresh mackerel (*Scomber scombrus*). For this purpose, proximate, mineral and amino acid compositions of the smoked fish were determined using standard analytical technique. The results showed the range of crude protein, crude fat, crude fibre, ash, moisture and carbohydrate contents (%) as; 57.80 – 70.20, 7.41 – 17.51, 8.48 – 11.25, 4.20 – 5.70, 3.33 – 5.28 and 0.79 – 3.42, respectively. Sodium was found to be more abundant in all the samples (7.10 – 12.25 mg/100g) compared with potassium (4.40 – 9.90 mg/100g) and magnesium (5.05 – 9.70 mg/100g) while phosphorus was the highest concentrated mineral (12.90 mg/100g) recorded in fish sample smoked with melon husk heat source. Harmful heavy metals such as lead and cadmium were not at the detectable range of atomic absorption spectrophotometer (AAS). The amino acid revealed that only *Scomber scombrus* fish sample smoked with melon husk enhanced the contents of total amino acid (TAA) and total essential amino acid (TEAA) by 1.05 and 1.20%, respectively while sawdust and rice bran heat treatments reduced TAA and TEAA. The essential aromatic amino acids (EArAA) and total sulphur amino acids (TSAA) contents were increased in all the samples smoked with different heat sources. Predicted protein efficiency ratio ranged between 2.21 and 2.61. The first limiting amino acid (LAA) for all the smoked samples was Ile except sample smoked with rice bran which has Val as LAA. Although the results of smoked fish samples showed deviations in nutrients from the results of sample dried with electric oven but over 80% of the mineral and more than 85% of the protein were still retained in smoked fish.

Keywords: Agricultural wastes, Heat sources, *Scomber scombrus*, Chemical composition.

1. Introduction

Fish has an important role in food security and poverty alleviation in both rural and urban areas of Nigeria, but only little is known about the nutritional value of the fishes that are normally utilized either fresh or preserved dried, salted or smoked. Fish is however susceptible to damage as soon as it is harvested. Some factors responsible for this include the prevailing high temperatures in Nigeria and the facilities for processing; storing and distributing the fish caught are frequently inadequate or non-essential in most cases. There is therefore enormous waste through spoilage of both fresh and dried fish (Rawson, 1996).

In order to maintain the freshness of fish, the catch must be stored in cold rooms until it is ready for processing. However, some bacteria (e.g. salmonella) which survive in refrigerator and brine can only be destroyed by heating (Bender, 1982). Preservation methods are applied with an intention to making the fish safer and to extend its shelf-life (Ghazala, 1994). Several fish processing methods include fermentation, drying, frying, canning, salting and smoking. Smoke contributes to fish preservation by acting as an effective antioxidant and bacteriostatic and bactericidal agent as well as by providing a protective film on the surface of smoked fish (Gilbert, 1995). Although consumers are generally attracted by the flavour of smoked fish, its nutritive value is of paramount important since every consumer would want to obtain good quality protein from fish consumption. It has been observed that different processing and drying methods have different effects on nutritional composition of fish. This is because heating, freezing and exposure to high concentration of salt lead to chemical and physical changes and therefore digestibility is increased, due to protein denaturisation, but the content of thermolabile compounds and polyunsaturated fatty acids is often reduced (Eyo, 1977).

Most of the work on 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. This is being one of the reasons for carrying out this research work. Therefore, this work is aimed at evaluating the proximate, mineral and amino acid compositions of a smoked commercial and most preferred species of mackerel (*Scomber scombrus*) by using sawdust, melon husk and rice bran as energy sources in a smoking kiln, and electric oven as the control.

2. Materials and Methods

2.1 Collection of the samples

Three pieces of fresh sample of mackerel (*Scomber scombrus*) of average weight 350 g and length 36 cm and about 3 months old were purchased from Akwanga market while samples of sawdust, melon husk and rice bran wastes were also collected from Akwanga market and Angwan Sabo Timber Shed in Akwanga metropolis, Nasarawa State, Nigeria. All samples were collected in May, 2012.

2.2 Preparation of samples

The fish samples collected were killed, gutted and washed thoroughly with clean tap water. The energy sources which were sawdust, melon husk and rice bran 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

The smoking of the fish samples was carried out at a distance of 60 cm from the fire point by burning of sawdust, melon husk and rice bran wastes which were the energy sources using the Altona Smoking kiln to simulate what is practised by local fish mongers (Salan *et al.*, 2006). Smokings with sawdust, melon husk and rice bran heat sources were affected for 13, 32 and 22 h, respectively. The fish sample was also smoked using electric oven as the control at a temperature of 120^{o}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 product was packed in a transparent polyethylene bags, sealed with a sealing machine in order to reduce microbial infestation and stored in a refrigerator at a temperature of 4^{o}C prior to analysis.

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

All the metals were determined by Atomic Absorption Spectrophotometer (Solar 969 Unicam) with exception of sodium and potassium that were determined using a flame photometer (Model 405, Corning UK).

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 axcept 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 and 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 formula (1990).

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

The predicted protein efficiency ratio (P–PER) of the fresh sample was calculated from the amino acid composition based on the equation developed by Alsmeyer *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 17 kJ and crude fat x 37 kJ for each of the samples. Errors of three determinations were computed as standard deviation for the proximate composition.

3. Results and Discussion

The result of proximate composition of *Scomber scombrus* smoked with different sources of heat is presented in Table 1. From the result, the protein content of 57.80% was obtained when the sample was smoked using electric oven which is the control. This value is lower when compared with that for melon husk heat treatment (70.24%) but is comparable with 62.14% reported for *Clarias gariepinus* (Kumolu and Ndimele, 2010). The values of protein content in this report are higher than 26.25% reported for *Scomber scombrus* (Agu and Bhandary, 2004). The range values of fat content from 7.41 to 17.51% were recorded in the samples smoked using different heat sources. However, the 9.14% obtained for heat treatment from saw dust agrees with the reported work of Agu and Bhandary (2004). The high moisture content of 5.28% was observed in the fish sample smoked using electric oven and is almost the same with 5.43% reported by Adeyi (2010) in *Scomber scombrus* using coconut husk as heat treatment. However, the value (5.28%) obtained for electric oven heat treatment is comparable with that of saw dust smoking (5.18%). The ash content of 5.70% obtained for heat treatment using sawdust in this report compares favourably with 6.01% reported for mackerel fish (Agu and Bhandary, 2004). Also in this report, the ash content (4.04%) obtained for heat treatment using rice bran is highly comparable to the work of Ogbonnaya and Ibrahim (2009) in smoked catfish. The range values from 4.04% to 5.70% in the current report are comparable with values of 4.3 ± 0.13% in cream coat bambara groundnut and 4.6 ± 0.32% in cranberry beans which are leguminous seeds (Aremu *et al.*, 2006a).

The calculated metabolizable energy values had range of 1506.59 to 1721.59 kJ/100g sample (Table 1). This shows that *Scomber scombrus* is favourably comparable to some plant foods in terms of its energy content (Brain & Allan, 1977). The calculated fatty acid values range between 5.93 in heat treatment using rice bran to 14.01 of electric oven smoking. These observed values for all the studied samples suggest that the oils may be edible and utilized for industrial purposes. The CV% levels were generally low although fat content was 38.58 varied and the highest variability was recorded in the carbohydrate content (49.78).

The various energy values as contributed by protein, fat and carbohydrate were shown in Table 2. The daily energy requirement for an adult range between 2500 – 3000 k cal (10455 – 12548 kJ) depending on his physiological state while that of infants is 740 kcal (3094.68 kJ) (Bingham, 1978; Adeyeye & Adamu, 2005). This implies that an adult man would require the range values between 6.21 to 7.45, 7.28 to 8.74, 6.93 to 8.32 and 7.39 to 8.87 g of *Scomber scombrus* 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 between 1.84 to 2.19 g using the same fish species and heat treatments. The utilizable energy due to protein (UEDP%) for *Scomber scombrus* (assuming 60% utilization) in the present study range between 34.68 to 42.14. These range obtained is far higher than the recommended safe level of 8% (Beaton & Swiss, 1974) for an adult man who requires about 55 g protein per day. This undoubtedly indicates that the protein concentration in *Scomber scombrus* in terms of energy would be more than enough to avert a disease known as malnutrition in children and adult who feed solely on *Scomber scombrus* as a main source of protein (Adeyeye & Adamu, 2005).

The mineral composition in mg/100g of *Scomber scombrus* is presented in Table 3. From the result, phosphorus was found to be the most abundant mineral in the fish sample smoked with melon husk (12.90 mg/100g) followed by sodium which ranged from 7.10 to 12.25 mg/100g sample. Calcium was the third abundant mineral ranging from 2.60 mg/100g in electric oven smoking to 5.25 mg/100g in melon husk heat treatment and it behaves as a kind of coordinator among inorganic elements; if excessive amount of K, Mg or Na are present in the body, calcium is adequate in the diet, iron is utilized for better advantage. This is an instance of sparing action (Fleck, 1976).

Magnesium is an important mineral element in connection with circulating diseases, such as ischaemic heart disease and calcium metabolism in bone (Ishida *et al.*, 2000). The higher level of sodium than potassium in the studied sample is contrasted to what was observed in vegetable material (Olaofe & Sani, 1988; Aremu *et al.*, 2005; Adeyeye & Fagbohun, 2005; Aremu *et al.*, 2006a) which is the reverse of the current report. Both sodium and potassium are required to maintain osmotic balance of the body fluid and the pH of the body; regulate muscles and nerve irritability, control glucose adsorption and enhance normal retention of protein during growth (NRC, 1989). The iron, copper and zinc were low with respective ranges of 0.75 to 2.25, 0.61 to 2.46 and 1.15 to 2.45 mg/100g sample, but they will still be available for biological functions. The daily iron requirements by humans are 10 to 15 mg for children, 18 mg for women and 12 mg for men. Copper requirement is 2 mg daily. Iron and copper are present in the enzymes cytochrome oxidase involved in energy metabolism (NAS, 1976). The sodium to potassium ratios which ranged from 1.48 to 2.01 mg/100g sample in this report are greater than the recommended value (Nieman *et al.*, 1992), hence the smoked fish sample may not have the capacity to hinder high blood pressure. The calcium to phosphorus ratio (Ca/P) of the fish sample smoked using sawdust, rice bran and electric oven smoking ranged between 0.41 and 0.75. This is an indication the samples may not serve as good source of mineral for bone formation (Nieman *et al.*, 1992). The observed values for [K/(Ca + Mg)] ratio in this report ranged between 0.36 to 0.66 mg/100g milliequivalent. To prevent hypomagnesaemia, Marten & Anderson (1975) reported that the milliequivalent of [K/(Ca + Mg)] must be less than 2.2, hence, smoked *Scomber scombrus* may have the capacity not to lead to hypomagnesaemia. The CV% levels were highly varied with the highest variability recorded in chromium (75%). Arsenic and chromium were not detected in the fish sample smoked with rice bran and melon husk heat treatments, respectively. It is also interesting to note that harmful heavy metals such as cadmium and lead were not at the detectable range of AAS for all the samples. Cadmium and lead even at low concentration are known to be toxic and have no known function in biochemical process (Table 3). Lead can impair the nervous system and affect foetus, infants and children resulting in lowering of intelligent quotient (IQ) even at its lowest dose (UN, 1998).

The amino acid composition of smoked samples of *Scomber scombrus* is depicted in Table 4. Glutamic acid (CV%, 3.79) which ranged between 13.63 to 15.11 g/100 g crude protein, cp was the most concentrated non-essential amino acid (NEAA) in the smoked fish samples. These values are highly comparable with that for glutamic acid value of 13.3 g/100 g cp obtained for *Prosopis africana* flour sample (Aremu *et al.*, 2007). The second most concentrated acidic amino acid in this report was aspartic acid. The aspartic acid ranged between 9.49 g/100 g cp in electric oven (control) heat treatment to 9.77 g/100 g cp in melon husk smoking. Arginine which had range values between 6.21 to 6.47 g/100 g cp is an essential amino acid for children growth. Phenylalanine (CV%, 2.25) with its sparring partner tyrosine had concentration range of 3.88 to 4.02 g/100 g cp and 3.33 to 3.49 g/100 g cp, respectively. However, the range value of tyrosine in this report is lower than tyrosine value of 6.3 g/100 g cp reported in *Luffa cylindrica* kernel by Olaofe *et al.* (2008), but highly comparable with tyrosine value reported for some plants food such as cashew nut (3.2 g/100 g cp) by Aremu *et al.* (2006c). Tryptophan concentration could not be determined. Cystine which range between 0.79 to 0.93 g/100 g cp was found to be the least concentrated amino acid in all the smoked fish samples. The calculated isoelectric point (pI) ranged from 5.34 g/100 g cp in rice bran heat treatment to 5.61 g/100 g cp for melon husk smoking. 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) in this report ranged from 2.21 g/100 g cp for rice bran heat treatment to 2.61 g/100g cp for electric oven drying. These values are higher than the reported P-PER values in some legumes flour concentrates such as *Phaseolus coccineus* (1.03 g/100 g cp) (Salunkhe, 1989; Aremu *et al.*, 2008), however close in agreement with that of *Prosopis africana* (2.3 g/100 g cp) (Aremu *et al.*, 2007). It could be said that *Scomber scombrus* under investigation could satisfy the FAO (1985) requirements. The evaluation report based on classification of amino acids of smoked *Scomber scombrus* samples is shown in Table 5. The total amino acid (TAA) with range values between 90.74 to 95.08 g/100 g cp is comparable with 91.42 g/100 g cp of giant rat liver (Adeyeye *et al.*, 2011). However, higher than some plant foods which ranged between 39.3 to 76.50 g/100 g cp as reported by some workers (Akintayo *et al.*, 1999; Aremu *et al.*, 2012; Adeyeye, 2004). The total sulphur amino acid (TSAA) which ranged from 2.39 g/100 g cp in the control to 3.57 g/100 g cp in sawdust heat treatment is lower in values than the 5.8 g/100 g cp recommended for infants. The essential aromatic amino acid (EArAA) which ranged between 3.88 to 4.13 g/100 g cp in the current study is lower than the range (6.8 to 11.8 g/100 g cp) suggested for ideal infant protein. The total acidic amino acid (TAAA) is also shown in Table 5. This was found to be greater than the total basic amino acid indicating that the protein is probably acidic in nature (Aremu *et al.*, 2006a). Despite the effect of heat, the co-efficient of variation (CV%) levels were relatively close with hot spot at 7.20% for valine whereas others ranged from 1.04 to 7.06%.

The EAA scores of all the smoked samples based on the provisional amino acid scoring pattern (FAO/WHO, 1991) are displayed in Table 6. The contents of some essential amino acids are greater than FAO/WHO (1991) recommendation. The number of the ones that are higher than the recommended values increased from three in fish sample smoked with rice bran to four in samples smoked with sawdust and melon husk and to five in sample with electric oven smoking. Thus, for a healthy diet based on some methods of smoking, *Scomber scombrus* will require supplementation with essential amino acids such as Ile and TSAA for sample smoked with electric oven; Ile, Leu and Val for sample with sawdust smoking method; Ile, TSAA and Val for sample with melon husk heat treatment; Ile, Leu, TSAA and Val for sample with rice bran smoking method. Tryptophan concentration was not determined in this report. The first limiting amino acid (LAA) for all the smoked samples was Ile except sample smoked with rice bran which has Val as LAA.

4. Conclusion

The proximate, mineral and amino acid compositions of local fresh mackerel (*Scomber scombrus*) which was smoked using different heat sources were presented in this study. The results of the fish samples smoked with sawdust, melon husk and rice bran heat sources showed deviations in nutrients from the samples dried with electric oven (control) but over 80% of the mineral and more than 85% of the protein were still retained in the smoked *Scomber scombrus* fish. Generally all the samples contained nutritionally mineral content and useful qualities of total essential amino acids.

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Table 1. Proximate Composition (%)[a] of *Scomber scombrus* Smoked with Different Sources of Heat

Parameter	Heat Treatments: Electric Oven	Sawdust	Melon Husk	Rice Bran	Mean	SD	CV%
Crude Protein	57.80±0.08	61.16±0.06	70.24±0.66	65.53±0.14	63.68	4.67	7.33
Crude Fat	17.51±0.03	9.14±0.03	8.12±0.02	7.41±0.03	10.55	4.07	38.58
Crude Fibre	8.48±0.05	11.25±0.04	9.15±0.03	9.45±0.03	9.58	1.02	10.65
Moisture	5.28±0.04	5.18±0.02	3.33±0.19	4.82±0.04	4.65	0.78	16.77
Ash	5.57±0.10	5.70±0.03	4.20±0.04	4.04±0.04	4.88	0.76	15.57
[b]Carbohydrate	5.36±0.03	7.57±0.02	4.96±0.17	8.75±0.03	6.66	1.11	49.78
[c]Fatty Acid	14.01	7.31	6.50	5.93	8.44	3.25	38.51
[d]Energy(kJ/100g)	1721.59	1506.59	1578.84	1536.93	1585.99	106.31	7.04

[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 Protein, Fat and Carbohydrate in Smoked *Scomber scombrus*

Parameter	Heat Treatments: Electric Oven	Sawdust	Melon Husk	Rice Bran
Total Calculated Energy	1684.70	1436.04	1507.95	1414.02
PEP	57.80	61.16	70.24	65.53
PEF	17.51	9.14	8.12	7.41
PEC	3.19	3.42	0.79	1.52
UEDP	34.68	36.70	42.14	39.32

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 (mg/100 g) of *Scomber scombrus* Smoked with Different Sources of Heat

	Heat Treatments						
Mineral	**Electric Oven**	**Sawdust**	**Melon Husk**	**Rice Bran**	**Mean**	**SD**	**CV%**
Na	7.10	8.45	12.25	8.85	9.16	1.90	20.74
K	4.80	5.30	9.90	4.40	6.10	2.22	36.39
Mg	5.05	5.55	9.70	9.40	7.43	2.13	28.67
Fe	1.80	1.95	0.75	2.25	1.69	0.57	33.73
Zn	1.55	1.55	2.45	1.15	1.68	0.48	28.57
Cu	0.61	0.64	2.46	0.81	1.13	0.77	68.14
Pb	ND	ND	ND	ND	NA	NA	NA
As	0.20	0.20	0.80	ND	0.40	0.28	70.00
Cr	0.05	0.05	ND	0.25	NA	NA	NA
Cd	ND	ND	ND	ND	NA	NA	NA
Mn	4.25	4.95	6.50	3.85	4.89	1.01	20.65
Ca	2.60	3.85	5.25	2.85	3.64	1.04	28.57
P	5.45	5.10	12.90	5.45	7.23	3.28	45.37
Na/K	1.48	1.59	1.24	2.01	1.58	0.28	17.72
Ca/P	0.48	0.75	0.41	0.52	0.54	0.13	24.07
[K/(Ca+Mg)]	0.63	0.56	0.66	0.36	0.55	0.12	21.82

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; **NA** = Not available

Table 4. Amino Acid Concentration (g/100 g crude protein) of *Scomber scombrus* 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	7.81	7.51	7.67	0.11	1.43
Histidine (His)[a]	2.65	2.71	2.81	2.81	2.75	0.07	2.55
Arginine (Arg)[a]	6.39	6.30	6.47	6.21	6.34	0.10	1.74
Aspartic Acid (Asp)	9.49	9.62	9.77	9.55	9.61	0.10	1.04
Threonine (Thr)[a]	4.58	4.66	4.69	4.55	4.62	0.06	1.30
Serine (Ser)	4.29	4.40	4.45	4.26	4.35	0.08	1.84
Glutamic Acid (Glu)	15.11	13.63	14.24	14.01	14.25	0.54	3.79
Proline (Pro)	3.87	4.07	4.27	4.07	4.07	0.14	3.44
Glycine (Gly)	7.01	6.58	7.21	7.01	6.95	0.23	3.31
Alanine (Ala)	6.00	6.19	6.31	5.89	6.10	0.16	2.62
Cystine (Cys)	0.79	0.86	0.93	0.80	0.85	0.06	7.06
Valine (Val)[a]	5.04	4.81	4.89	4.14	4.72	0.34	7.20
Methionine (Met)[a]	2.50	2.71	2.50	2.37	2.52	0.12	4.76
Isoleucine (Ile)[a]	3.68	3.49	3.87	3.61	3.66	0.14	3.83
Leucine (Leu)[a]	7.59	6.80	7.40	6.66	7.11	0.39	5.49
Tyrosine (Tyr)	3.49	3.18	3.33	3.33	3.33	0.11	3.30
Tryptophan (Try)	ND	ND	ND	ND	ND	ND	ND
Phenylalanin (Phe)[a]	3.88	4.02	4.13	3.96	4.00	0.09	2.25
Isoelectric Point (pI)	5.53	5.41	5.61	5.34	5.47	0.10	1.83
P-PER	2.61	2.29	2.54	2.21	2.41	0.17	7.05

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 *Scomber scombrus*

Parameter	Heat Treatments Electric Oven	Sawdust	Melon Husk	Rice Bran	Mean	SD	CV%
Total Amino Acid (TAA)	94.09	91.65	95.08	90.74	92.89	1.76	1.89
Total Non-Essential Amino Acid (TNEAA)	50.05	48.53	50.51	48.92	49.50	0.81	1.64
% TNEAA	53.19	52.95	53.12	53.91	53.29	0.37	0.69
Total Essential Amino Acid (TEAA)							
With Histidine	44.04	43.12	44.57	41.82	43.39	1.04	2.40
Without Histidine	41.39	40.41	41.76	39.01	40.64	1.06	2.61
% TEAA							
With Histidine	46.81	47.05	46.88	46.09	46.71	0.37	0.79
Without Histidine	43.99	44.09	43.92	43.00	43.75	0.44	1.01
Essential Aliphatic Amino Acids (EAAA)	20.89	19.76	20.85	18.96	20.12	0.81	4.03
Essential Aromatic Amino Acids (EArAA)	3.88	4.02	4.13	3.96	4.00	0.09	2.25
Total neutral Amino Acids (TNAAA)	52.72	51.77	53.98	50.65	52.28	1.22	2.33
% TNAA	56.03	56.49	56.77	55.82	56.28	0.37	0.66
Total Acidic Amino Acid (TAAA)	24.60	23.25	24.01	23.56	23.86	0.51	2.14
%TAAA	26.15	25.37	25.25	25.96	25.68	0.38	1.48
Total Basic Amino Acid	16.77	16.63	17.09	16.53	16.76	0.21	1.25
%TBAA	17.82	18.15	17.97	18.22	18.04	0.16	0.89
Total Sulphur amino Acids (TSAA)	2.39	3.57	3.43	3.17	3.14	0.46	14.65
% Cystine	33.05	24.09	27.11	25.24	27.37	3.45	12.61

SD = Standard deviation; **CV** = Coefficient of variation.

Table 6. Amino Acid Scores of Smoked *Scomber scombrus*

EAA	PAAESP (g/100g Protein)	Heat Treatments Electric Oven		Sawdust		Melon Husk		Rice Bran	
		EAAC	AAS	EAAC	AAS	EAAC	AAS	EAAC	AAS
Ile	4.0	3.68	0.92	3.49	0.87	3.87	0.97	3.61	0.90
Leu	7.0	7.59	1.08	6.80	0.97	7.40	1.06	6.66	0.95
Lys	5.5	7.73	1.41	7.62	1.39	7.81	1.42	7.51	1.37
Met + Cys (TSAA)	3.5	3.29	0.94	3.57	1.20	3.43	0.98	3.17	0.91
Phe + Tyr	6.0	7.37	1.23	7.20	1.20	7.46	1.24	7.29	1.22
Thr	4.0	4.58	1.15	4.66	1.17	4.69	1.17	4.55	1.14
Try	1.0	nd	na	nd	na	nd	na	nd	na
Val	5.0	5.04	1.01	4.81	0.96	4.89	0.98	4.14	0.83
Total	**36.0**	**39.28**	**7.74**	**38.15**	**7.58**	**39.55**	**7.82**	**36.93**	**7.32**

Source = Belschant *et al.* (1975); **EAA** = Essential amino acid; **PAAESP** = Provisional amino acid (egg) scoring pattern; **EAAC** = Essential amino acid composition (see Table 4); **AAS** = Amino acid scores;
nd = Not determined; **na** = Not applicable.