CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

AMINO ACID PROFILES OF FIVE COMMONLY CONSUMED INSECTS IN SOUTHWESTERN NIGERIA

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https://doi.org/10.34302/crpjfst/2020.12.5.3

Article history:
Received:
28 August 2020
Accepted:
25 December 2020

Keywords:
Amino Acids composition;
five insect types.

ABSTRACT

The amino acid (AA) content of *Apis mellifera* (AB), *Macrotermes bellicosusI* (WT), *Imbrasia belina* (MoW), *Oryctes boas* larva (SB), and *Sitophilus zeamais* (MaW) were investigated. The total amino acid values were high at (g/100g crude protein, cp): *A. mellifera* (89.6), *M. bellicosus* (89.3), *I belina* (89.7), *O boas* larva (95.6) and *S. zeamais* (89.0). Glutamic acid (Glu) had the highest concentration in all the samples ranging from 12.3-15.0 g/100g crude protein, cp. The least concentrated amino acid was tryptophan (Trp) (1.22-1.33 g/100g cp) across board. Leucine (7.74-8.42 g/100g cp) was the most abundant essential amino acid (EAA) in all. The total essential amino acid (TEAA) (with His) ranged between 44.9-46.0 g/100g cp. Leu/Ile range was 1.09-1.47. P-PER$_1$ and P-PER$_2$ ranges were 2.73-2.99 and 2.65-2.96 respectively. The essential amino acid index (EAAI) range was 36.1-38.7 while the biological value (BV) range was 27.6-30.5. The isoelectric point (pI) range was 5.15-5.54, showing the samples to be in acidic medium of the pH range. In amino acid scores based on whole hen's egg, serine (Ser) had the least scores range (0.500-0.613). On provisional amino acid scoring pattern, the limiting AA was threonine (Thr) in *A. mellifera* (0.864), *M. bellicosus* (0.820) and *S. zeamais* (0.920); lysine (Lys) in *I. belina* (0.952); valine (Val) in *O. boas* larva (0.848). On pre-school child requirements, Lys (0.903-0.941) was limiting except in *O. boas* where all the parameters were higher than 100% requirement. Generally, no significant difference existed among the samples in most of the parameters determined.

1.Introduction

Insects are group of animals found in nearly all environments including the oceans. They form a class of animals within the arthropod group. More than one thousand four hundred edible insects have been recorded (FAO, 2008). A number of insects and their products were used in the past and are to a certain extent still eaten by some West African tribes, especially by children. Insect consumption is all over the regions of the world as substitutes for conventional proteins. Winged termites (*Macrotermes bellicosus)* are the commonly eaten termites specie especially in south western Nigeria. They are usually collected while on their nuptial flight or picked from the ground after they have shed their wings. A honey bee (*Apis mellifera*) is any member of the genus *Apis*, primarily distinguished by the production and storage of honey and the construction of perennial, colonial nest from wax. Currently, only seven species of honey bee are recognized with a total of forty-four subspecies (Michael, 1999). Today's honey bees constitute three clades: drones (males) produced from unfertilized eggs, i.e. have only a mother; workers and queens (both females) result from fertilized eggs (i.e. have both a father and a mother) (Maria and Walter, 2005). Mopane worm (*Imbrasia belina*) is arguably the most popular among the moths. About 9.5 billion mopane caterpillars are harvested annually in southern Africa (Ghazoul, 2006). Vast number of people partakes in the mopane harvest and are willing to travel hundreds of kilometers across the mopane woodlands in search of the insects (Kozanayi and Frost, 2002). Though the caterpillars are important sources of nutrition in lean times, they also form a regular part of the diet (Stack *et al.,* 2003). Maize weevil (*Sitophilus zeamais*) is found in all warm and tropical parts of the word. It is a pest in stored maize, dried cassava, yam, common sorghum and wheat. Both adults and larvae feed on maize grains. Eggs, larval and pupal stages are all found within tunnels and chambers bored in the grains and are thus not normally seen. Adults emerge from the grain and can be seen walking over the grain surfaces (CABI, 2010). Scarab beetles larvae (*Oryctes boas)* are widely distributed throughout Africa, southern Asia and south America. They are typically collected, washed and fried for consumption (Fasoranti and Ajiboye, 1993). It is unusual to add oil because the larvae exude enough oil during the frying process. Their delicious flavour is credited to their elevated fat content (Fasoranti and Ajiboye, 1993).

There is need for people to consume adequate calories and nutrients to overcome the problem of protein-energy malnutrition. There is a link between malnutrition in Africa and inadequate and poor quality food supply (Kent, 2002). Most of these insects are nutritionally underutilized. Many developing regions consume insects as protein supplement in their diets. The objective of this study is to determine the amino acids composition and calculate the nutritional quality parameters of commonly consumed insects in southwestern Nigeria.

2. Materials and methods

2.1. Materials

2.1.1. Sample collection and preparation

Insect samples were obtained from farms and markets around Ekiti and neighbouring states and were later identified in the Zoology Department of Ekiti State University, Ado-Ekiti. Samples were screened, washed and rinsed with distilled water. Samples were then dried at 45°C, dry milled to fine powder, stored dried prior to use for various analyses.

2.2. Methods

2.2.1. Extraction and analysis

Extraction and the instrumentation analysis were carried out by following AOAC method (AOAC, 2005). The samples were dried to constant weigh. Ten grams was weighed into 250ml conical flask. Samples were defatted with 30ml of petroleum spirit (3x) using Soxhlet extractor. Samples were hydrolyzed thrice for complete hydrolysis. The defatted samples were soaked in 30ml of 1M potassium hydroxide solution, incubated for 48 hours at 110°C in hermetically closed borosilicate glass. After the alkaline hydrolysis, the hydrolysate was neutralized to get pH in the range of 2.5–5.0. The solution was purified by cation – exchange solid-phase extraction. The amino acids from the purified solutions were derivatised using ethylchloroformate (fig. 1).

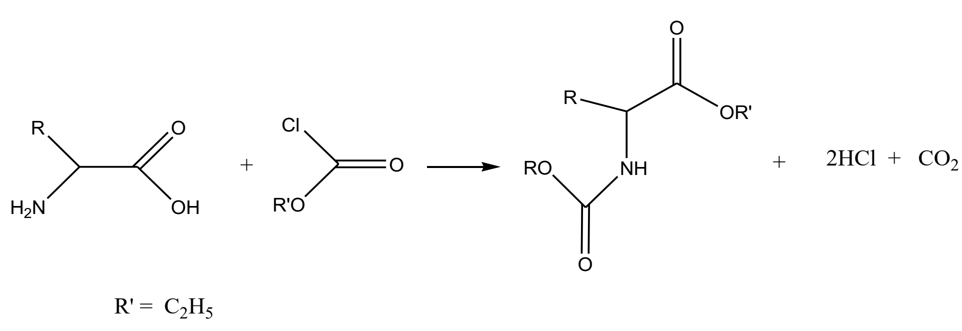

Figure 1. Derivatization process of amino acid

The derivatising reagent was removed by scavenge with nitrogen. The derivatized amino acid was made up to 1ml in a vial for gas chromatography analysis. The gas chromatographic conditions for the amino acids analysis were as follows: GC : HP6890 powered with HP Chemstation rev. A09.01 [1206] software; injection temperature: split injection; split ratio: 20:1; carrier gas: hydrogen; flow rate: 1.0ml/min; inlet temperature: 250°C; column type: EZ; column dimensions: 10m x 0.2mm x 0.25µm; oven programme: initial @ 110°C, first ramp @ 27°C/min to 320°C, second, constant for 5 mins at 320°C; detector: PFPD; detector temperature: 320°C; hydrogen pressure: 20 psi; compressed air: 35 psi.

2.3. Determination of Amino Acid Quality Parameters

2.3.1. Amino acid scores

Amino acid scores determination was first based on whole chicken's egg (Paul *et al.*, 1976); the scoring included both essential and nonessential amino acids. The second determination was based on the provisional essential amino acid scoring pattern (FAO/WHO, 1973). The last score was based on pre-school child essential amino acid requirement for ages 2-5 years (FAO/WHO/UNU, 1985).

2.3.2 Other determinations

Other determinations such as total amino acid (TAA), total essential amino acid (TEAA), total non-essential amino acid (TNEAA), total acidic amino acid (TAAA), total basic amino acid (TBAA), total aromatic amino acid (TArAA), e.t.c. and their percentages were carried out. Total sulphur amino acid (TSAA) and percentage cystine in TSAA (% Cys in TSAA) were also calculated. Leu/Ile, Lys/Trp and Met/Trp ratios were computed.

Predicted protein efficiency ratio (P-PER) was calculated using equations derived by Alsmeyer*et al*. (1974), i.e.

$$P\text{-}PER_1 = -0.468 + 0.454\,(Leu) - 0.105\,(Tyr). \quad (1)$$

$$P\text{-}PER_2 = -0.684 + 0.456\,(Leu) - 0.047\,(Pro) \quad (2)$$

The isoelectric point (p*I*) was calculated using the equation of the form (Olaofe and Akintayo, 2000):

$$IPm = \sum_{i=1}^{n} IPiXi \quad (3)$$

Where IP_m 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 (Fiar, 1975).

The essential amino acid index (EAAI) and biological value (BV) were calculated by the method of Oser (1959).

$$BV = 1.09\,(EAAI) - 11.73 \quad (4)$$

Various amino acid groups into classes I-VII (Nieman *et al*., 1992) were also calculated. Data obtained were subjected to simple descriptive statistics and Chi-square analyses (Oloyo, 2001).

3. Results and discussions

3.1. Common and scientific names

The common and scientific names of five edible insects commonly found in southwestern Nigeria used for this study are shown in Table 1. The insects analysed were one specie of hymenoptera (*Apismellifera*), one specie of isoptera (*Macrotermesbellicosus*), one specie of lepidoptera (*Imbrasiabelina*) and two species of coleoptera (*Oryctesboas*larva and *Sitophilus zeamais*).

3.2. Amino acid composition

Amino acids composition of the insect samples is presented in Table 2. Among the amino acids analyzed, Glu had the highest concentration in the samples having values ranging between 12.3 g/100g cp in *M. bellicosus* and 15.0 g/100g cp in *O.boas* larva. Tryptophan (Trp) recorded the lowest concentration (1.22-1.33g/100g cp) among the amino acids in each sample. Leucine (Leu) was the most concentrated essential amino acid in four out of the five samples (g/100g cp): *A. mellifera* (8.28), *M. bellicosus* (8.11), *I. belina* (8.22) and *S. zeamais* (8.42). In *O. boas* larva, Lys (8.28g/100g) recorded the highest EAA. Other EAAs of high concentrations were (g/100gcp): arginine (Arg) (5.26-6.06), valine (Val) (4.24-5.76), isoleucine (Ile) (5.27-7.54) and phenylalanine (Phe) (4.11-4.71)). Valine daily requirement is 23 mg/kg and its deficiency leads to locomotor dysfunction in young rats (Adeyeye, 2009). The presence of substantial amount of arginine in diets enhances Ca^{2+} absorption, but under most physiological circumstances, this is of little consequence (White *et al*., 1973). Threonine (Thr) in the insect samples ranged between 3.28-4.34 g/100g cp with the highest concentration recorded in *O. boas* (4.34 g/100g cp). The concentration of methionine (Met) ranged between 2.02-2.51 g/100g cp. Met contains sulphur in the thioether linkage. Administration of Met prevents fatty liver and causes resumption of growth (Adeyeye, 2009). Histidine (His) ranged between 1.92-2.22 g/100g cp. His is a precursor of histamine, a substance normally present in small amounts in cells (Ogungbenle *et al*., 2013).

Table 1. Common and scientific names of the insect species

Symbol	Order	Family	Local name	English name	Scientific name
AB	Hymenoptera	Apidae	Oyin	Honeybee	*Apis mellifera*
WT	Isoptera	Termitidae	Esunsun	Winged termite	*Macrotermesbellicosus*
MOW	Lepidoptera	Notodontidae	Kanyin	Mopane worm	*Imbrasia belina*
SB	Coleoptera	Scarabaeidae	Gongo	Scarab beetle	*Oryctes boas*
MaW	Coleoptera	Scarabaeidae	Kokoroagb ado	Maize weevil	*Sitophilus zeamais*

Table 2. Amino acid content of the insect samples (g/100g)

Amino acid	AB	WT	MoW	SB	MaW	Mean	SD	CV%
Lysine	5.42	5.40	5.24	8.28	5.46	5.96	1.30	21.8
Histidine	2.22	2.15	1.92	2.18	2.02	2.10	0.125	5.95
Arginine	5.46	5.26	5.34	6.06	5.32	5.49	0.328	5.97
Threonine	3.45	3.28	3.88	4.34	3.68	3.73	0.412	11.0
Valine	5.55	5.76	5.12	4.24	4.80	5.09	0.606	11.9
Methionine	2.10	2.17	2.02	2.51	2.25	2.21	0.188	8.51
Tryptophan	1.22	1.27	1.28	1.24	1.33	1.27	0.042	3.31
Leucine	8.28	8.11	8.22	7.74	8.42	8.15	0.257	3.15
Isoleucine	7.13	7.26	7.54	5.27	7.03	6.85	0.902	13.2
Phenylalanine	4.12	4.36	4.35	4.11	4.71	4.33	0.244	5.64
Aspartic acid	7.70	7.35	7.55	8.53	7.47	7.72	0.470	6.09
Glutamic acid	12.9	12.3	12.8	15.0	12.4	13.1	1.10	8.40
Serine	4.67	4.84	4.38	3.95	4.64	4.50	0.347	7.71
Proline	4.61	4.55	4.44	4.13	4.27	4.40	0.199	4.52
Glycine	5.37	5.45	5.49	5.52	5.41	5.45	0.060	1.10
Alanine	4.68	4.51	4.86	7.35	4.73	5.23	1.16	22.8
Cystine	1.70	1.86	1.63	2.12	1.59	1.78	0.216	12.1
Tyrosine	3.03	3.43	3.66	3.04	3.47	3.33	0.280	8.41
Totals	89.6	89.3	89.7	95.6	89.0	90.6	2.79	3.08

SD = standard variation, CV% = coefficient of variation percent, χ^2 = Chi-square, α = 0.05,

df= k–1, NS = not significant at $\alpha = 0.05$ and df = k-1,TV = table value

It is worthy of note that the FAO/WHO/UNU (1985) standards for pre-school children (2-5 years) are (g/100gcp): Leu (6.6), Ile (2.8), Lys (5.8), Met + Cys (2.5) and His (1.9). Hence, the insects would be able to provide the required or even more than the required Leu, Ile, Met + Cys and His. In Lys, results of four out the five samples (5.40-5.46 g/100g cp) representing 80% were comparable with the standard while *O. boas* (8.28 g/100g cp) would provide more than the required 5.8 g/100g cp. Generally, comparison of results among the samples showed no significant variation as observed in coefficient of variation percent (CV %) levels.

3.2.1. Amino acid categories

Table 3 depicts concentrations of total amino acid (TAA), total essential amino acid (TEAA), total non-essential amino acid (TNEAA), total acidic amino acid (TAAA), total basic amino acid (TBAA), total neutral amino acid (TNAA), total essential aliphatic amino acid (TEAlAA) and their percentage values. Some other parameters such as Leu/Ile ratios, Lys/Trp, Met/Trp ratios, predicted protein efficiency ratio 1 and 2 (P-PER_1 and P-PER_2), isoelectric point (pI), essential amino acid index (EAAI) and biological value (BV) are also depicted in Table 3. The TAA values of the present study ranged between 89.0-95.6 g/100g cp. The TEAA values (g/100g cp) in this study fell within 44.9-46.0 (with His); 42.7-43.8 (no His). These values were much higher than the 33.9 g/100g cp FAO/WHO/UNU (1985) standard for pre-school children (2-5 years). The EAA requirements are (g/100g, with His): infant (46.0), pre-school (2-5 years) (33.9), school child (10-12 years) (24.1) and adult (12.7); (without His): infant (43.4), pre-school (32.0), school child (22.2) and adult (11.1). It also revealed TEAA as (g/100g cp, with His): egg (51.2), cow's milk (50.4) and beef (47.9); (without His): egg (49.0), cow's milk (47.7) and beef (44.5). The values in this report were comparable to the afore-mentioned standards. Values of %TEAA in this report (48.1-50.7%) compare well with that of egg (50%) (FAO/WHO, 1990). In all the samples, the TAAA (19.7-44.0 g/100g cp) were higher than the TBAA (12.5-16.5 g/100gcp). The %TNAA in the samples [except in *S. zeamais* (36.2)] ranged between 58.2-63.6. This indicates that the neutral amino acids formed the bulk of the amino acids.

3.2.2. Quality parameter ratios

The values of Leu/Ile ratios (1.09-1.47) in the insects were good as they were all lower than the required 2.36 (FAO/WHO, 1991) since it will not lead to concentration antagonism. Leu/Ile imbalance from excess leucine may lead to developing pellagra (FAO, 1995). Present study revealed Lys/Trp as 4.09-6.66 and Met/Trp as 1.70-2.02. Mammalian tissue pattern have Lys/Trp: muscle (6.3), viscera (5.3), plasma protein (6.2) (Mitchell, 1950). The utilization of dietary proteins increases as their Lys and Trp contents approach that of muscle tissues. The nutritional values of some protein products with low Lys/Trp values can be enhanced by small additions of Lys (Adeyeye, 2015). Lys supplementation of wheat gluten increases the nutritive values of that of milk protein product. In the present results, *O. boas* larva Lys/Trp (6.66) meet the muscle, viscera and plasma protein standards while others were lower. All the Met/Trp values (1.70-2.02) were lower than the muscle value of 2.5 but approached the plasma proteins of 1.1 (Adeyeye, 2015). The predicted protein efficiency ratios, P-PER_1 (2.73-2.99) andP-PER_2 (2.65-2.96) vary between 0.00 for a very poor protein food and a maximum possible of just above 4.00 for good protein food. In general, the better the protein, the lower the level the diet required to produce the highest protein efficiency ratio. This reflects the importance of nutritive balance of all the amino acids for metabolic efficiency.

Table 3. Classification of amino acids (g/100g crude protein) of the insect samples

Amino acid	AB	WT	MoW	SB	MaW	Mean	SD	CV%	χ^2	TV	Remark
TAA	89.6	89.3	89.7	95.6	89.0	90.6	2.79	3.08	0.343	9.49	NS
TEAA + His	44.9	45.0	44.9	46.0	45.0	45.2	0.472	1.04	0.020	9.49	NS
TEAA – His	42.7	42.9	43.0	43.8	43.0	43.1	0.421	0.977	0.016	9.49	NS
% TEAA+His	50.7	50.4	50.1	48.1	50.6	50.0	1.08	2.16	0.093	9.49	NS
%TEAA–His	47.7	48.0	47.9	45.8	48.3	47.5	0.996	2.10	0.084	9.49	NS
TNEAA	44.7	44.3	44.8	49.6	44.0	45.5	2.33	5.12	0.475	9.49	NS
%TNEAA	49.9	49.6	49.9	51.9	49.4	50.1	1.01	2.02	0.081	9.49	NS
TAAA	20.6	19.7	20.4	23.5	44.0	25.6	10.4	14.6	16.8	9.49	S
%TAAA	23.0	22.1	22.7	24.6	49.4	28.4	11.8	41.5	19.6	9.49	S
TBAA	13.1	12.8	12.5	16.5	12.8	13.5	1.67	12.4	0.825	9.49	NS
%TBAA	14.6	14.3	13.9	17.3	14.4	14.9	1.37	9.19	0.501	9.49	NS
TNAA	55.9	56.8	56.8	55.6	32.2	51.5	10.8	21.0	9.03	9.49	NS
%TNAA	62.4	63.6	63.3	68.2	36.2	56.7	11.7	20.6	9.63	9.49	S
TEAlAA	21.0	21.2	20.9	17.2	20.3	20.1	1.67	8.31	0.553	9.49	NS
%TEAlAA	23.4	23.6	23.3	18.0	22.8	22.2	2.38	10.7	1.02	9.49	NS
TSAA	3.80	4.03	3.65	4.63	3.84	3.99	0.383	9.60	0.147	9.49	NS
%Cys in TSAA	44.9	46.2	44.8	49.9	41.3	45.4	3.09	6.81	0.844	9.49	NS
Leu/Ile ratio	1.16	1.12	1.09	1.47	1.20	1.21	0.152	12.6	0.077	9.49	NS
Leu – Ile	1.15	0.849	0.685	2.47	1.39	1.31	0.704	53.7	1.51	9.49	NS
%(Leu –Ile)/TAA	1.28	0.951	0.764	2.59	1.56	1.43	0.717	50.1	1.44	9.49	NS
%(Leu –Ile)/Leu	13.9	10.5	8.33	31.9	16.5	16.2	9.30	57.4	21.4	9.49	S
Lys/Trp	4.45	4.26	4.09	6.66	4.12	4.72	1.10	23.3	1.02	9.49	NS
Met/Trp	1.72	1.71	1.58	2.02	1.70	1.75	0.163	9.31	0.061	9.49	NS
P-PER1[a]	2.97	2.86	2.88	2.73	2.99	2.89	0.100	3.46	0.015	9.49	NS
P-PER1[a]	2.87	2.80	2.86	2.65	2.96	2.83	0.115	4.06	0.019	9.49	NS
pI[b]	5.16	5.15	5.16	5.54	5.15	5.23	0.172	3.29	0.023	9.49	NS
EAAI[c]	97.5	93.3	87.8	92.0	92.4	92.6	3.46	3.74	0.518	9.49	NS
BV[d]	94.5	90.0	83.9	88.6	89.0	89.0	3.80	4.26	0.647	9.49	NS

[a] Predicted protein efficiency ratio, [b] Isoelectric point, [c] Essential amino acid index, [d] Biological value, S = significant at $\alpha = 0.05$ and df = k-1.

Table 4. Amino acid scores of the samples based on whole hen's egg amino acid profile

Amino acid	AB	WT	MoW	SB	MaW	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.874	0.870	0.845	1.33	0.880	0.960	0.207	21.6	0.179	9.49	NS
His	0.935	0.898	0.980	0.908	0.842	0.911	0.050	5.49	0.011	9.49	NS
Arg	0.894	0.863	0.875	0.994	0.871	0.899	0.054	6.01	0.013	9.49	NS
Thr	0.677	0.643	0.761	0.851	0.721	0.731	0.081	11.1	0.036	9.49	NS
Val	0.740	0.769	0.683	0.565	0.640	0.679	0.081	11.9	0.039	9.49	NS
Met	0.655	0.768	0.631	0.784	0.703	0.708	0.067	9.46	0.026	9.49	NS
Trp	0.676	0.704	0.711	0.691	0.736	0.704	0.023	3.27	0.003	9.49	NS
Leu	0.997	0.997	0.991	0.932	1.01	0.985	0.031	3.15	0.004	9.49	NS
Ile	1.27	1.30	1.35	0.940	1.26	1.22	0.163	13.4	0.087	9.49	NS
Phe	0.808	0.854	0.852	0.805	0.923	0.848	0.048	5.66	0.011	9.49	NS
Asp	0.719	0.687	0.706	0.798	0.698	0.722	0.044	6.09	0.011	9.49	NS
Glu	1.07	1.03	1.07	1.25	1.03	1.09	0.092	8.44	0.031	9.49	NS
Ser	0.592	0.613	0.554	0.500	0.588	0.569	0.044	7.73	0.014	9.49	NS
Pro	1.21	1.20	1.17	1.09	1.12	1.16	0.052	4.48	0.009	9.49	NS
Gly	1.79	1.82	1.83	1.84	1.80	1.82	0.021	1.15	0.001	9.49	NS
Ala	0.866	0.835	0.900	1.36	0.877	0.968	0.221	22.8	0.201	9.49	NS
Cys	0.946	1.03	0.908	1.18	0.881	0.989	0.121	12.2	0.059	9.49	NS
Tyr	0.758	0.856	0.915	0.759	0.866	0.831	0.070	8.42	0.023	9.49	NS
Totals	0.897	0.894	0.898	0.957	0.891	0.907	0.028	3.09	0.003	9.49	NS

Table 5. Essential amino acid scores of the insect samples based on FAO/WHO (1973) standards

Amino acid	AB	WT	MoW	SB	MaW	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.985	0.981	0.952	1.50	0.993	1.08	0.234	21.7	0.203	9.49	NS
Thr	0.864	0.820	0.970	1.08	0.920	0.931	0.100	10.7	0.044	9.49	NS
Val	1.11	1.15	1.02	0.848	0.960	1.02	0.121	11.9	0.057	9.49	NS
Leu	1.18	1.16	1.17	1.11	1.20	1.16	0.034	2.93	0.004	9.49	NS
Ile	1.78	1.82	1.88	1.32	1.76	1.71	0.224	13.1	0.117	9.49	NS
Trp	1.22	1.27	1.28	1.24	1.33	1.27	0.042	3.31	0.006	9.49	NS
Met+ Cys	1.09	1.15	1.04	1.32	1.10	1.14	0.108	9.47	0.041	9.49	NS
Phe + Tyr	1.19	1.30	1.33	1.19	1.36	1.27	0.080	6.30	0.020	9.49	NS
Totals	1.13	1.19	1.19	1.19	1.19	1.18	0.027	2.29	0.002	9.49	NS

For EAA scores based on provisional essential amino acid scoring pattern (FAO/WHO, 1973) (Table 5), the following had scores greater than 1.00 in all the samples: Leu (1.11-1.20), Ile (1.32-1.88), Trp (1.22-1.33), Met + Cys (1.04 -1.32) and Phe + Tyr (1.19-1.36).

Table 6. Essential amino acid scores based on requirements of pre-school child (2-5 years)

Amino acid	AB	WT	MoW	SB	MaW	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.934	0.931	0.903	1.43	0.941	1.03	0.225	21.8	0.197	9.49	NS
His	1.17	1.20	1.07	1.21	1.12	1.15	0.059	5.13	0.012	9.49	NS
Thr	1.02	0.965	1.02	1.14	0.968	1.02	0.071	6.96	0.020	9.49	NS
Val	1.59	1.65	1.46	1.25	1.37	1.46	0.162	11.1	0.072	9.49	NS
Trp	1.11	1.11	1.16	1.13	1.20	1.14	0.038	3.33	0.005	9.49	NS
Leu	1.25	1.23	1.25	1.17	1.28	1.24	0.041	3.31	0.005	9.49	NS
Ile	2.55	2.59	2.69	1.88	2.51	2.44	0.322	13.2	0.170	9.49	NS
Met + Cys	1.52	1.61	1.46	1.85	1.53	1.59	0.153	9.62	0.059	9.49	NS
Met + Tyr	1.14	1.24	1.27	1.13	1.30	1.22	0.077	6.31	0.020	9.49	NS
Totals	1.27	1.33	1.32	1.33	1.32	1.31	0.025	1.91	0.002	9.49	NS

3.2.3. Other quality parameters

The p*I* in this study ranged between 5.15-5.54. The calculation of p*I* from AA enhances production of certain isolate of organic products. The EAAI of 87.8-97.5 and their corresponding BV of 83.9-94.5 revealed to a reasonable extent the quality of protein in the insect samples. The insect values are better than in poultry (chicken, muscle without skin, duck, muscle without skin) (Finar, 1975). EAAI is essential in evaluating food for protein quality (Nielson, 2002). BV is a scale used to evaluate what proportion of a given nutrient source is utilized by the body. It shows how fast and efficiently our body utilizes proteins we consume. Both EAAI and BV values were generally high in this report.

3.3. Amino acid scores

In the amino acid scores based on whole chicken's egg amino acid (Table 4), Glu, Pro and Gly had scores greater than 1.00 in each sample: Glu (1.03-1.25), Pro (1.09-1.21) and Gly (1.79-1.84). Ile had scores greater than 1.00 in *A. mellifera* (1.27), *M. bellicosus* (1.30), *I. belina* (1.35) and *S. zeamais* (1.26). Ser had the lowest scores (0.500-0.613) in all the samples. Val had scores >1.00 in *A. mellifera* (1.11), *M. bellicosus* (1.15) and *I.belina*(1.02). Thr had the least EAA scores in *A. mellifera* (0.864), *M. bellicosus* (0.820) and *S. zeamais* (0.920) and therefore, to correct for the limiting amino acid (LAA) of the samples if they serve as sole source of protein food, it will be 100/86.4 (or 1.16) × protein of *A. mellifera*, 100/82.0 (or 1.22) × protein of *M. bellicosus* and 100/92.0 (or 1.09) × protein of *S. zeamais* (Bingham, 1977). Lys (0.952) and Val (0.848) were the LAAs for *I.belina* and *O. boas* respectively and would require corresponding 100/95.2 (or 1.05) and 100/84.8 (1.18) correction factors. Table 6 depicts the essential amino acid scores on the suggested requirements for pre-school children (2-5 years). The insect samples would supply virtually all the required EAAs for the pre-school children as most of the EAA scores were above 1.00 (i.e. 100%) except Lys (0.934) in *A. mellifera*, Lys (0.931) and Thr (0.965) in *M. bellicosus*, Lys (0.903) in *I. belina* and Lys (0.941) and Thr (0.968) in *S. zeamais*. Generally, the EAAs most often acting in a limiting capacity are (a) Lys, (b) Met + Cys, (c) Thr, and (d) Trp (Bingham, 1977).

4. Conclusions

The results of the study showed that the insects investigated are moderately rich in amino acids especially essential amino acids. Concentrations of Leu, Ile, Asp and Glu were high in the samples. Percentage essential amino acids in the samples were comparable with the percentage of non-essential amino acids. Total EAAs met the FAO/WHO/UNU standards for all categories of human beings: infant, pre-school, school child and adult. The samples' proteins were within range of conventional animal proteins. Generally, the insect samples are good sources of amino acids and would be useful as food supplements and in food fortification particularly because the EAAI and BV are even much better in values than most conventional meat protein sources.

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