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Amino Acids Profile of Bee Brood, Soldier Termite, Snout Beetle Larva, Silkworm Larva and Pupa: Nutritional Implications

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Abstract The amino acid (AA) componentst of five insect sample: bee brood (*Apis mellifera*, BB), soldier termite (*Macrotermes bellicosus*, ST), snout beetle larva (*Rhynchophorus phoenicis*, SB), silkworm larva (SWL) and silkworm pupa (SWP) (*Anaphe infracta*) were reported. Among the amino acid investigated, glutamic acid was most abundant in all the five samples with values ranging from 12.5-15.6g/100g crude protein, cp. The most concentrated essential amino acid (EAA) was leucine (7.68-8.04g/100g cp) across board whereas tryptophan (1.15-1.38g/100g cp) was the least concentrated EAA and also recorded the least values among the amino acids in all the samples. The total acidic amino acids in all the samples (20.1-49.7g/100g cp) were greater than the total basic amino acids (12.2-17.3g/100g cp). The leucine (Leu)/isoleucine (Ile) ratio values (1.04-1.54) showed that Leu > Ile across board. The predicted protein efficiency ratio (P-PER$_1$ and P-PER$_2$) ranges were 2.68-2.81 and 2.63-2.77 respectively. The isoelectric point (pI) range was 5.13-5.81, showing the samples to be in acidic medium of the pH range. In the amino acid scores based on whole hen's egg glutamic acid (Glu), proline (Pro) and glycine (Gly) had scores greater than 100% in all the samples; arginine (Arg) was limiting in soldier termite whilst serine (Ser) had the least scores in others. On provisional amino acid scoring pattern, the limiting AAs were valine (Val) in ST (0.909), SWL (0.884) and SWP (0.875); Threonine (Thr) in bee brood (0.940) and Lysine (Lys) in SB (0.909). EAA scores based on pattern for pre-school child (2-5 years) showed that the samples would supply the required EAAs for this category. Generally, statistical calculations showed that no significant difference existed among the samples in most of the parameters determined.

Keywords Edible insects, Essential amino acids, Isoelectric point

1. Introduction

Insects are among the most diversed groups of animals that may be found in nearly all environments including the oceans. They form a class of animals within the arthropod group that have a chitinous exoskeleton, a three-part body (i.e. head, thorax and abdomen), three pairs of disjointed legs, compound eyes and a pair of antennae. There are over one thousand four hundred recorded edible insects [1]. Insects are the only winged invertebrates; cold-blooded, produced quickly and often do not have parental care [2]. A number of insects or their products were used in the past and are to a certain extent still eaten by some West African tribes, as tit-bits, or exclusively by children. Such insects are mostly those which can be collected in large numbers, e.g. locust in the gregarious phase, emerging alate termites, caterpillars and the large African cricket *Brachytrypes* [3]. Some insects such as enormously distended queen termite and the larvae and pupae of scarab beetles and the African silkworm, *Anaphe sp.* are eaten occasionally and sometimes regarded as delicacies [4]. Such consumption, besides Africa, has been practiced throughout the course of history and in all past culture including those of ancient China, Mexico, Egypt, Israel and Greece [5]. The Yukpa people of Colombia and Venezuela preferred their traditional insect foods meat as do the pedi of South Africa [6].

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 [7]. 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) [8]. Along with wasps, honey bees are the most important food insects in northern Thailand

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[9]. Soldier termites are defensive specialists. They have anatomical and behavioural specialisations and their sole purpose is to defend the colony. Among certain termites, soldiers may use their globular heads to block their narrow tunnels [10]. Some unique ones can spray noxious, sticky secretions containing diterpenes at their enemies [11]. Soldiers of larger termite species are consumed in the Central African Republic, the Democratic Republic of Congo, the Bolivian Republic of Venezuela and Zimbabwe [12]. They are often fried or pounded into cakes. Sometimes, for example, in Uganda, only the heads are eaten [13].

Silkworm is the caterpillar of the domesticated silkmoth, *Bombyx mori*. It is an economically important insect, being a primary producer of silk. Silk production is an ancient practice in many parts of Asia and Europe. The worm is considered a commercially viable product. They are considered delicacies and are traditionally eaten and sold in many markets in North Eastern China. Palm weevils especially snoult weevils are highly valued as human food by people of Manipur State of North Eastern India who see insects as cheapest sources of animal protein. They are typically collected, washed and fried for consumption [14]. It is unusual to add oil because the larva exude enough oil during the frying process. Their delicious flavor is credited to their elevated fat content [14].

The fact remains that people need to consume adequate calories and nutrients to overcome the problem of protein-energy malnutrition (PEM) [15]. Kent [16] attributed the wide spread malnutrition prevalent among the rural communities in Africa to inadequate and poor quality food supply. A greater number of people in such areas, due to their poverty level commonly depend on one stable food usually of carbohydrate source. Most of these insects are readily available especially in the rural areas but they are underutilized. However, many developing regions of Africa (including Nigeria), Asia, Central and South America consume many of the insects especially termites based on seasonal ubiquity either as dessert, appetizer or as protein supplement in their diet. For instance, DeFoliart, [17] stated that ‘‘the Yukpa people of Colombia and Venezuela and the Pedi people of South Africa prefer termite foods to fresh meat in some of their traditional diets. The objective of this study therefore is to reveal the amino acids composition of the commonly eaten insects and provide useful information that can further suggest their consideration as alternative sources of nutrients particularly protein.

2. Materials and Methods

Sample collection and preparation

The 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. They were screened to eliminate the defective ones, washed and rinsed with distilled water. The samples were then dried in an oven at 45°C and dry milled separately to fine powder, stored in a dry, cool place prior to use for various analyses as described below.

Sample analysis

About 1g of each sample was weighed into the extraction thimble and the fat extracted with chloroform/methanol mixture (2:1v/v) using a Soxhlet apparatus [18]. The extraction lasted 5-6 h. About 30mg of the defatted sample was weighed into glass ampoules. 7ml of 6M HCl were added and oxygen expelled by passing nitrogen gas into the sample. The glass ampoules were sealed with a Bunsen flame and put into an oven at 105 ± 5°C for 22 h. The ampoule was allowed to cool; the content was filtered to remove the humins. The filtrate was evaporated to dryness at 40°C under vacuum in a rotary evaporator. Each residue was dissolved with 5ml acetate buffer (pH 2.0) and stored in a plastic specimen bottle and kept in a deep freezer. Amino acid analysis was by ion exchange chromatography (IEC) using the Technicon Sequential Multisample (TSM) Amino Acid Analyzer (Technicon Instruments Corporation, New York). The period of analysis was 76 minutes for each sample. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated.

Determination of amino acid quality parameters

Determination of amino acid scores: Determination of the amino acid scores was first, based on whole hen’s egg [19]. In this method, both essential and nonessential amino acids were scored. The essential amino acid score was calculated using the provisional essential amino acid scoring pattern [20]. Amino acid score based on pre-school child essential amino acid requirement for ages 2-5 years was also calculated [21].

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 (TEAlAA), e.t.c. and their percentages were made. Total sulphur amino acid (TSAA) and percentage cystine in TSAA (% Cys in TSAA) were also calculated. The Leu/Ile, Lys/Trp and Met/Trp ratios were computed.

The predicted protein efficiency ratio (P-PER) was calculated using one of the equations derived by Alsmeyer *et al*. [22], i.e.

$$\text{P-PER}_1 = -0.468 + 0.454\ (\text{Leu}) - 0.105\ (\text{Tyr}).$$
$$\text{P-PER}_2 = -0.684 + 0.456\ (\text{Lue}) - 0.047\ (\text{Pro})$$

The isoelectric point (pI) was calculated using the equation of the form Olaofe and Akintayo [23]:

$$\text{pIm} = \sum_{i=1}^{n} \text{IPiXi}$$

Where pIm 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 [24].

The essential amino acid index (EAAI) and biological value (BV) were calculated by the method of Oser [25]. BV = 1.09 (EAAI) – 11.73.

The various amino acid groups into classes I-VII [26] were also calculated.

Thirty (30) insects each of bee brood and soldier termite; ten insects each of snout beetle, silkworm larva and silkworm pupa were blended together for the analyses and each analysis was carried out in duplicate.

3. Results and Discussion

The amino acids composition of the five insect samples (dry weight): bee brood (*Apis mellifera*), soldier termite (*Macrotermes bellicosus*), snout beetle larva (*Rhynchophorus phoenicis*), silkworm larva and pupa (*Anaphe infracta*) was presented in Table 1. Among the amino acids analyzed, Glu had the highest concentration in all the samples with the values ranging between 12.5 g/100g cp in snout beetle larva and 15.6 g/100g cp in soldier termite. Tryptophan (Trp) recorded the lowest concentration (1.15-1.38g/100g cp) among the amino acids in all the samples. The most concentrated essential amino acid was lysine in soldier termite (8.70g/100g cp), silkworm larva and pupa (8.67g/100g cp and8.55g/100g cp respectively). The highest EAA was leucine (Leu) in bee brood (7.99g/100g cp) and snout beetle larva (8.04g/100g cp). Arg (5.20-6.40g/100g cp) and Ile (5.00-7.65g/100g cp) were also high in abundance. The presence of substantial amount of arginine in diets enhances Ca^{2+} absorption, but under most physiological circumstances, this is of little consequence [27]. Histidine (His) ranged between 2.00-2.218 g/100g cp. His is a precursor of histamine, a substance normally present in small amounts in cells [28]. Children do not grow if His is absent from their diet, but adults can probably synthesize enough for their daily needs. Threonine (Thr) in the insect samples ranged between 3.68-4.71 g/100g cp with the highest concentration recorded in silkworm pupa (4.71g/100g cp). The concentration of methionine (Met) ranged between 2.00-2.57 g/100g cp. Met contains sulphur in the thioether linkage. Met is needed for the synthesis of other important substances, including choline. It is worthy of note that the FAO/WHO/UNU [21] standards for pre-school children (2-5 years) are (g/100g cp): Leu (6.6), Ile (2.8), Lys (5.8), Met + Cys (2.5) and His (1.9). Hence, the insects in this study would be able to provide the required or even more than the required Leu, Ile, Met + Cys and His. Three samples (g/100g cp): soldier termite (8.70), silkworm larva (8.67) and silkworm pupa (8.55) would provide more than the requirements. Generally, comparison of results among the samples showed no significant variation as it was evident in the levels of coefficient of variation percent (CV%).

Table 1. Amino acid content of the insect samples (g/100g)

Amino acid	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
Lysine	5.41	8.70	5.00	8.67	8.55	7.27	1.89	26.0	1.96	9.49	NS
Histidine	2.18	2.15	2.00	2.16	2.10	2.12	0.072	3.40	0.010	9.49	NS
Arginine	5.24	6.40	5.20	6.28	6.28	5.88	0.605	10.3	6.80	9.49	NS
Threonine	3.76	3.92	3.68	4.03	4.71	4.02	0.409	10.2	0.167	9.49	NS
Valine	5.49	4.04	5.58	4.42	4.37	4.78	0.705	14.7	0.416	9.49	NS
Methionine	2.22	2.48	2.00	2.51	2.57	3.36	0.240	7.14	1.57	9.49	NS
Tryptophan	1.30	1.30	1.38	1.24	1.15	1.27	0.085	6.69	0.023	9.49	NS
Leucine	7.99	7.68	8.04	7.88	7.77	7.87	0.150	1.91	0.011	9.49	NS
Isoleucine	7.65	5.00	7.47	5.37	5.20	6.14	1.31	21.3	1.11	9.49	NS
Phenylalanine	4.28	3.65	3.86	3.69	4.04	3.90	0.261	6.69	0.070	9.49	NS
Aspartic acid	7.24	8.54	7.57	8.65	8.66	8.13	0.675	8.30	0.225	9.49	NS
Glutamic acid	12.8	15.6	12.5	14.9	15.3	14.2	1.46	10.3	0.599	9.49	NS
Serine	4.61	4.06	4.61	3.79	4.35	4.28	0.357	8.34	0.119	9.49	NS
Proline	4.17	3.94	4.46	4.13	4.06	4.15	0.193	4.65	0.036	9.49	NS
Glycine	5.05	5.68	5.61	5.71	5.38	5.49	0.276	5.03	0.055	9.49	NS
Alanine	4.70	7.63	4.88	7.57	7.39	6.43	1.50	23.3	1.41	9.49	NS
Cystine	1.50	1.85	1.70	2.12	1.90	1.81	0.231	12.8	0.118	9.49	NS
Tyrosine	3.71	3.23	3.73	2.85	2.74	3.25	0.464	14.3	0.265	9.49	NS
Totals	89.3	95.8	89.3	96.0	96.5	93.4	3.73	3.99	0.597	9.49	NS

SD = standard variation, CV% = coefficient of variation percent, χ^2 = Chi-square, α = 0.05, df = k–1, NS = not significant at α = 0.05 and df = k-1, TV = table value.

Table 2 depicts the 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 ($P\text{-}PER_1$ and $P\text{-}PER_2$), isoelectric point (pI), essential amino acid index (EAAI) and biological value (BV) are also contained in Table 2. The TAA values of the present study ranged between 89.3-96.5 g/100g cp. The concentration of TEAA (g/100g cp) in this study ranged between 44.2-46.8 (with His); 42.2-44.6 (no His). The EAA requirements according to FAO/WHO/UNU [21] 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). FAO/WHO/UNU [21] also revealed the 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 compared well with the above standards. The values of %TEAA in this study (47.3-51.0%) were comparable with that of egg (50%) [29] and some other animal protein sources: 45.9-47.1% in meat organs of turkey hen [30], 46.2% in *Zonocerus variegates* [31] and 48.1-49.5% in brain and eyes of African giant pouch rat [32]. In all the samples, the TAAA (20.1-49.7 g/100g cp) were higher than the TBAA (12.2-17.3 g/100g cp). The results of %TNAA in bee brood (56.4%) and soldier termite (54.4%) indicated that neutral amino acids formed the bulk of the amino acids. The percentage cystine in total sulphur containing amino acid (% Cys inTSAA) varied between 40.6-45.9%. Most animal proteins are low in Cys. Some of the literature reports on Cys/TSAA% are: male fresh water crab body parts (13.3-15.9) [33]; female fresh water crab body parts (27.3-32.8) [34]; three different Nigerian fishes (23.8-30.1) [35]. In contrast, many vegetable proteins contain substantial amounts of Cys than Met; examples (% Cys/Met): 50.5 in *Anacardium occidentale*) [36]; 62.9 in coconut endosperm [37]; raw, steeped, germinated sorghum (58.9-72.0) [38]. The present values for % Cys in TSAA were close to those of vegetable proteins. This might be due to plants being their major dietary source. The values of Leu/Ile ratios (1.04-1.54) in the insects were good as they were all lower than the required 2.36 [39]. Leu/Ile imbalance from excess leucine might be a risk factor in the development of pellagra particularly in maize eaters [40]. The present study revealed Lys/Trp as 3.63-7.41 and Met/Trp as 1.45-2.33. Mammalian tissue pattern have Lys/Trp: muscle (6.3), viscera (2.0), plasma protein (1.1) [41]. 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 [42]. Lys supplementation of wheat gluten increases the nutritive values of that of milk protein product. In this study, Lys/Trp from termite soldier (6.71), silkworm larva (6.97) and silkworm pupa (7.41) meet the muscle and plasma protein standards whilst all the samples recorded lower Met/Trp values (1.45-2.23) as compared with muscle value of 2.5 but approached the plasma proteins of 1.1. The predicted protein efficiency ratio (P-PER) in this study are $P\text{-}PER_1$ (2.68-2.81) and $P\text{-}PER_2$ (2.63-2.77). These values were higher than the levels of 2.16-2.42 in domestic duck [43]; favourably compared with 2.6-3.4 in fresh water female crab [34]. This means, the samples proteins would be physiologically utilized effectively as much as the cited literatures. The values of P-PER in this study fell within 0.00 and 4.00 margins for poor and good protein foods. The isoelectric point (pI) in this study varied between 5.13-5.81. This showed that the samples were in the acidic medium of the pH range. The calculation of pI from AA will assist in the quick production of certain isolate of organic products without going through the protein solubility determination to get to the pI. The range of essential amino acid index (EAAI) and the corresponding biological value (BV) were 36.9-37.9 and 28.5-29.6 respectively. This revealed to a reasonable extent the quality of protein in the insect samples. EAAI is useful in evaluating food formulation for protein quality, although, it does not account for difference in protein quality due to processing methods or certain chemical reactions [44]. BV is a scale of measurement used to determine what percentage of a given nutrient source is utilized by the body. It shows how well and quickly our body can actually use the proteins we consume. Both EAAI and BV values were generally low in this report.

Table 3 depicts the amino acid scores (AAS) based on whole hen's egg amino acid. Glutamic acid (Glu), proline (Pro) and glycine (Gly) had scores greater than 1.00 in each sample: Glu (1.04-1.30), Pro (1.04-1.20) and Gly (1.68-1.90). Serine (Ser) had the lowest scores in bee brood (0.584), snout beetle (0.514), silkworm larva (0.480) and silkworm pupa (0.551); Arginine (Arg) (0.353) was limiting in soldier termite.

For EAA scores based on provisional essential amino acid scoring pattern [20] (Table 4), the following had scores greater than 1.00 in all the samples: Leu (1.10-1.15), Ile (1.30-1.91), Met + Cys (1.06 -1.32) and Phe + Tyr (1.09-1.33). Lys had scores >1.00 in soldier termite (1.58), silkworm larva (1.58) and silkworm pupa (1.55). Thr > 1.00 in silkworm larva (1.01), and silkworm pupa (1.18). Val had values greater than 1.00 in bee brood (1.10) and snout beetle (1.12). The limiting amino acids were recorded as: Val in soldier termite (0.809), silkworm larva (0.884) and silkworm pupa (0.875); Thr in bee brood (0.940); Lys in snout beetle larva (0.909). Therefore, to correct for the limiting amino acid (LAA) needs from the samples, it will be 100/80.9 (or 1.24) × protein of soldier termite, 100/88.4 (or 1.13) × protein of silkworm larva, and 100/87.5 (or 1.14) × protein of silkworm pupa, 100/94.0 (or 1.06) × protein of bee brood and 100/90.9 (or 1.10) × protein of snout beetle larva has to be consumed if they are sole protein sources in the diets [45].

Table 2. Classification of amino acids (g/100g crude protein) of the insect samples

Amino acid	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
TAA	89.3	95.8	89.3	96.0	96.5	93.4	3.73	3.99	0.597	9.49	NS
TEAA											
(With His)	45.5	45.3	44.2	46.3	46.8	45.6	0.998	2.19	0.088	9.49	NS
(No His)	43.3	43.2	42.2	44.1	44.6	43.5	0.920	2.11	0.078	9.49	NS
% TEAA											
(With HiS)	51.0	47.3	49.5	48.2	48.2	48.8	1.44	2.95	0.170	9.49	NS
(No His)	48.5	45.1	47.3	45.9	47.6	46.9	1.36	2.90	0.159	9.49	NS
TNEAA	43.8	50.5	45.1	49.7	49.7	47.8	3.07	6.42	0.791	9.49	NS
%TNEAA	49.0	52.7	50.5	51.8	51.5	51.1	1.41	2.76	0.156	9.49	NS
TAAA	20.1	24.1	45.1	49.7	49.7	37.7	14.5	38.5	22.2	9.49	S
%TAAA	22.5	25.2	50.5	51.8	51.5	40.3	15.1	37.5	22.5	9.49	S
TBAA	12.8	17.3	12.2	17.1	16.9	15.3	2.53	16.5	1.68	9.49	NS
%TBAA	14.3	18.1	13.7	17.8	17.5	16.3	2.10	12.9	1.09	9.49	NS
TNAA	56.4	54.4	32.0	29.2	29.9	40.4	13.8	34.2	18.8	9.49	S
%TNAA	63.2	56.8	35.8	30.4	31.0	43.4	15.4	35.5	21.9	9.49	S
TEAlAA	21.1	16.7	21.1	17.7	17.3	18.8	2.15	11.4	0.981	9.49	NS
%TEAlAA	23.6	17.4	23.6	18.4	17.9	20.2	3.14	15.5	1.95	9.49	NS
TSAA	3.73	4.33	3.70	4.63	4.47	4.17	0.431	10.3	0.178	9.49	NS
% Cys/TSAA	40.6	42.7	45.9	45.9	42.4	43.5	2.33	5.36	0.501	9.49	NS
Leu/Ile ratio	1.04	1.54	1.08	1.45	1.50	1.33	0.244	10.3	0.180	9.49	NS
Lys/Trp	4.16	6.71	3.63	6.97	7.41	5.78	1.75	30.3	2.11	9.49	NS
Met/Trp	1.71	1.91	1.45	2.02	2.23	1.86	0.298	16.0	0.191	9.49	NS
$P\text{-}PER_1$[a]	2.77	2.68	2.79	2.81	2.77	2.76	0.050	1.81	0.004	9.49	NS
$P\text{-}PER_2$[a]	2.76	2.63	2.77	2.72	2.67	2.71	0.060	2.21	0.005	9.49	NS
pI[b]	5.13	5.81	5.22	5.56	5.63	5.47	0.286	5.23	0.060	9.49	NS
EAAI[c]	37.2	37.4	37.9	36.9	36.9	37.3	0.416	1.12	0.019	9.49	NS
BV[d]	28.8	29.0	29.6	28.5	28.5	28.9	0.455	1.57	0.029	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 3. Amino acid scores of the insect samples based on whole hen's egg amino acid

Amino acid	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.872	1.40	0.806	1.40	1.38	1.17	0.305	26.1	0.317	9.49	NS
His	0.909	0.897	0.834	0.899	0.877	0.883	0.030	3.40	0.004	9.49	NS
Arg	0.858	0.353	0.853	1.03	1.03	0.825	0.278	33.7	0.374	9.49	NS
Thr	0.737	0.768	0.721	0.791	0.923	0.788	0.080	10.2	0.033	9.49	NS
Val	0.732	0.539	0.744	0.589	0.583	0.637	0.094	14.8	0.055	9.49	NS
Met	0.693	0.774	0.625	0.784	0.803	0.736	0.075	10.2	0.030	9.49	NS
Trp	0.722	0.720	0.764	0.691	0.641	0.708	0.045	6.36	0.012	9.49	NS
Leu	0.962	0.926	0.968	0.950	0.937	0.949	0.017	1.79	0.001	9.49	NS
Ile	1.37	0.893	1.33	0.959	0.928	1.10	0.233	21.2	0.198	9.49	NS
Phe	0.840	0.715	0.757	0.723	0.793	0.766	0.052	6.79	0.014	9.49	NS
Asp	0.677	0.799	0.707	0.809	0.809	0.760	0.063	8.29	0.021	9.49	NS
Glu	1.07	1.30	1.04	1.24	1.27	1.18	0.120	10.2	0.049	9.49	NS
Ser	0.584	0.514	0.584	0.480	0.551	0.543	0.045	8.29	0.015	9.49	NS
Pro	1.20	1.04	1.17	1.09	1.07	1.11	0.068	6.13	0.017	9.49	NS
Gly	1.68	1.89	1.87	1.90	1.79	1.83	0.092	5.03	0.019	9.49	NS
Ala	0.870	1.41	0.903	1.40	1.37	1.08	0.221	20.5	0.343	9.49	NS
Cys	0.841	1.03	0.943	1.18	1.05	1.01	0.126	12.5	0.063	9.49	NS
Tyr	0.928	0.806	0.932	0.714	0.686	0.813	0.116	14.3	0.066	9.49	NS
Totals	0.894	0.959	0.894	0.961	0.966	0.935	0.037	3.96	0.006	9.49	NS

Table 4. Essential amino acid scores of the insect samples based on FAO/WHO (1973) standards

Amino acid	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.983	1.58	0.909	1.58	1.55	1.32	0.343	26.0	0.357	9.49	NS
Thr	0.940	0.979	0.919	1.01	1.18	1.01	0.104	10.3	0.043	9.49	NS
Val	1.10	0.809	1.12	0.884	0.875	0.958	0.142	14.8	0.066	9.49	NS
Leu	1.14	1.10	1.15	1.13	1.11	1.13	0.021	1.86	0.002	9.49	NS
Ile	1.91	1.25	1.87	1.34	1.30	1.53	0.327	21.4	0.279	9.49	NS
Trp	1.30	1.30	1.38	1.24	1.15	1.27	0.085	6.69	0.023	9.49	NS
Met + Cys	1.07	1.24	1.06	1.32	1.13	1.16	0.113	9.74	0.027	9.49	NS
Phe + Tyr	1.33	1.15	1.26	1.09	1.13	1.19	0.100	84.0	0.033	9.49	NS
Totals	1.20	1.16	1.18	1.19	1.19	1.18	0.015	1.27	0.001	9.49	NS

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

Amino acid	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
Lys	0.932	1.50	0.862	1.50	1.47	1.25	0.326	26.1	0.340	9.49	NS
His	1.15	1.20	1.11	1.20	1.17	1.17	0.038	3.25	0.005	9.49	NS
Thr	1.11	1.15	0.968	1.06	1.24	1.11	0.101	9.10	0.038	9.49	NS
Val	1.57	1.16	1.59	1.26	1.25	1.37	0.199	14.5	0.116	9.49	NS
Trp	1.18	1.18	1.25	1.13	1.05	1.16	0.074	6.38	0.019	9.49	NS
Leu	1.21	1.16	1.22	1.19	1.18	1.19	0.024	2.02	0.002	9.49	NS
Ile	2.73	1.79	2.67	1.92	1.86	2.19	0.465	21.2	0.394	9.49	NS
Met + Cys	1.49	1.73	1.48	1.85	1.79	1.67	0.172	10.3	0.071	9.49	NS
Phe + Tyr	1.27	1.09	1.20	1.04	1.08	1.14	0.095	8.33	0.052	9.49	NS
Totals	1.34	1.30	1.31	1.33	1.33	1.32	0.016	1.21	0.001	9.49	NS

Table 6. Amino acid groups of the insect samples

Groups	BB	ST	SB	SWL	SWP	Mean	SD	CV%	χ^2	TV	Remark
I	30.9	30.0	31.6	30.9	30.1	30.7	0.660	2.15	0.057	9.49	NS
II	8.37	7.98	8.29	7.83	9.06	8.31	0.476	5.73	0.109	9.49	NS
III	3.73	4.33	3.70	4.63	4.47	4.17	0.431	10.3	0.178	9.49	NS
IV	20.1	24.1	45.1	49.7	49.7	37.7	14.5	38.5	22.2	9.49	S
V	12.8	17.3	12.2	17.1	16.9	15.3	2.53	16.5	1.68	9.49	NS
VI	9.29	8.18	8.97	7.78	7.93	8.43	0.664	7.88	0.210	9.49	NS
VII	4.17	3.94	4.46	4.13	4.06	4.15	0.193	4.65	0.036	9.49	NS

Group I = amino acids with aliphatic side chains (Gly, Ala, Val, Leu and Ile), group II = amino acids with side chains containing OH group (Ser and Thr), group III = amino acids with side chains containing sulphur atom (Cys and Met), group IV = amino acids with side chains containing acidic groups or their amides (Asp and Glu), group V = amino acids with side chains containing basic groups (Lys, His and Arg), group VI = amino acids with side chains containing aromatic rings (His, Phe, Tyr and Trp), group VII = imino acids (Pro).

Table 7. Summary of the amino acid profiles into factors A and B

	Insect samples (Factor A means)					
Amino acid composition	BB	ST	SB	SWL	SWP	Factor B means
Total essential amino acids	45.5	45.3	44.2	46.3	46.8	45.6
Total non-essential amino acids	43.8	50.5	45.1	49.7	49.7	47.8
Factor A means	44.7	47.9	44.7	48.0	48.3	46.7

The essential amino acid scores on the suggested requirements for pre-school children (2-5 years) were depicted in Table 5. Only Lys in bee brood (0.932); Lys (0.862) and Thr (0.968) in snout beetle larva had scores less than 1.00 (i.e. 100%). The Table showed that the insect samples would be able to supply the required EAAs for the pre-school children as almost all the EAA scores were above 100% requirements. Bingham [45] reported that the EAAs most often acting in limiting capacity were (a) Lys; (b) Met + Cys; (c) Thr; (d) Trp.

The distribution of various amino acids into groups is depicted in Table 6. The concentrations are given as (g/100g cp): group I (30.0-31.6), group II (7.83-9.06), group III (3.70-4.63), group IV (20.1-49.7), group V (12.2-17.3), group VI (9.94-11.5) and group VII (3.94-4.46).

Table 7 summarizes the amino acids into two factors A and B. Factor A means are the means of amino acid values of the samples along the vertical axis and factor B means are the means along the horizontal axis. Here, the mean of factor A means gave the same value of 46.7 g/100g cp as in factor B means as a total summary.

4. Conclusions

The results of the study showed that the insects samples investigated are rich in amino acids especially Leu, Ile, Asp and Glu. The concentrations total non-essential amino acids were fairly above those of essential amino acids. The concentrations of leucine were generally higher than those of isoleucine. Dietary excess of leucine could be counteracted by increasing the intake of niacin or tryptophan or by supplementation with isoleucine [40]. The P-PER values in the samples were low and therefore should be supplemented with foods of considerably high P-PER values. The amino acid scores based on whole hen's egg amino acid, FAO/WHO [20] standard and pre-school child requirements showed Ser, Arg, Val, Thr and Lys as being limiting. Summarily, the samples are good sources of amino acids and would be useful in food fortification.

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