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Nutrient Content of Five Species of Edible Insects Consumed in South-West Nigeria

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Abstract

Proximate composition, proportions of energy contribution and utilizable energy due to protein from proximate composition, total energy determination, mineral composition and their calculated ratios and mineral safety index were determined in five edible insects. The insects were bee brood, snoult beetle, termite soldier, silkworm larva and silkworm pupa. The following values were relatively high among the samples (g/100g dry weight): total ash, 4.06 - 8.78; crude protein, 18.2 - 20.3; crude fat, 11.8 - 49.0; carbohydrate, 14.0 - 50.6; also, energy ranged from 1567-2369 kJ/100g with significant differences occurring in crude fat, carbohydrate and energy. Proportion of total energy due to fat was highest in bee brood (B_2) (76.5 %), silkworm larva (SWL) (50.3 %) and silkworm pupa (SWP) (53.3 %) but carbohydrate predominated in snout beetle (P_2) (51.2 %) and termite soldier (T_2) (53.5 %). The utilizable energy due to protein values were close at values of 8.05 - 11.8 with a mean value of 10.8 ± 1.58. Bomb calorimeter energy determination was better than the calculated energy in 80.0 % of the samples. The samples were high sources of Na, K, Mg, Zn, Fe, Mn, Co, P but low in Ca, Cu, Pb and Cd. Some mineral ratios were high: Zn/Cd, 22 - 323; Fe/Cu, - to 128; Zn/Cu, - to 323 but low in Ca/Mg, Na/K, Na/Mg and [K/ (Ca + Mg)]. All the mineral safety index values were within the non-deleterious levels except for Zn in all the samples, Fe and P in sample P_2.

Keywords: *Chemical Composition; Edible Insects; Deleterious*

Abbreviations

B_2: Bee Brood; P_2: Snout Beetle; T_2: Termite Soldier; SWL: Silkworm Larva; SWP: Silkworm Pupa; Na: Sodium; K: Potassium; Mg: Magnesium; Zn: Zinc; Fe: Iron; Mn: Manganese; Co: Cobalt; P: Phosphorus; Ca: Calcium; Cu: Copper; Pb: Lead; Cd: Cadmium; [K/(Ca + Mg)]: Milliequivalent; MSI: Mineral Safety Index; Phy: Phytate; Pp: Phytin Phosphorus; Id: Ideal; TV: Table Value; CV: Calculated Value; D: Difference; RAI: Recommended Adult Intake; RDA: Recommended Daily Average; MTD: Minimum Toxic Dose; USRDA: United States Recommended Daily Average; SD: Standard Deviation; CV %: Coefficient Of Variation Percent.

Introduction

Insects 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. They are among the most diverse group of animals. Insects may be found in nearly all environments including the oceans and there are over one thousand and 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]. Also, eaten occasionally and sometimes regarded as delicacies are fatty grubs such as enormously distended queen termite and the larvae and pupae of scarab beetles and the African silkworm, *Anaphe* sp. [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 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, honeybees are the most important food insects in northern Thailand [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 (phragmotic) 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].

Mopane worm (*Imbrasia belina*) is arguably the most popular among the moths. About 9.5 billion mopane caterpillars are harvested annually in Southern Africa [14]. 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 [15]. Though the caterpillars are important sources of nutrition in lean times, they also form a regular part of the diet [16].

Scarab beetles larvae (*Oryctes boas*) are widely distributed throughout Africa and south America. They are typically collected, washed and fried for consumption [17]. 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 [17].

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 [18].

Maize weevil (*Sitophilus zeamais*) is found in all warm and tropical parts of the world. It is a pest in stored maize, dried cassava, yam, common sorghum and wheat. Both adults and larvae feed on maize grains. Egg, larval and pupal stages are all found within tunnels and chambers bored in the grains and thus not normally seen. Adults emerge from the grains and can be seen walking over the grain surfaces [19].

Silkworm is the caterpillar of the domesticated silk moth, *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 [20]. In the Republic of Korea, silkworm powder is being produced as a medicine for diabetics because of its blood glucose lowering effects [21].

People need to consume adequate calories and nutrients to overcome the problem of protein-energy malnutrition (PEM), [22]. Most of these insects are readily available especially in the rural areas but they are underutilized. The objective of this study therefore is to reveal the proximate and mineral composition of the commonly eaten insects and provide useful information that can further suggest their consideration as alternative sources of nutrients particularly protein.

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. 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. The number of each insect sample used varied between eight and fifty depending on the size of the insect sample.

Sample Analysis

The proximate analysis of each of the five insect samples for moisture, crude fibre and total ash were carried out following the methods described by AOAC [23]. The weight of samples used ranged between 1.00g and 3.00g. The crude fat was extracted with a chloroform / methanol (2:1v/v) mixture using Soxhlet extraction apparatus as described by the AOAC methods. The micro-Kjeldahl method as described by Pearson [24] was followed to determine the crude protein while carbohydrate was determined by difference. The calorific values in kilojoules (kJ) were calculated by multiplying the crude fat, protein and carbohydrate by Atwater factor of 37, 17 and 17 respectively. Proportions of total energy due to fat (PEF), protein (PEP), carbohydrate (PEC) and the utilizable energy due to protein (UEDP) were also calculated. Determinations were in duplicate.

Total Energy Determination Using Bomb Calorimeter

Between 0.1 and 0.2g of the sample was ignited electrically in a Ballistic Bomb Calorimeter (Gallenkamp, CBB-330 - 010L) and burned in an excess of oxygen (with the recommended oxygen pressure of 25 atmospheres) in the bomb. The maximum temperature rise of the bomb was measured with the thermocouple and galvanometer system. The rise in temperature obtained was compared with that of benzoic acid to determine the calorific value of the sample using the following formula:

Calorific value of sample = (Q2-Q1) Y/Z kcal/g.

(where Q2 - Q1 = galvanometer deflection due to sample, Z = mass of sample in gramme and Y = calibration constant).

Determination of Phytic Acid and Phytin Phosphorus

4g of the sample was soaked in 100 ml 2% HCl for 3 hours and then filtered. 25 ml of the filtrate was placed in a 100 ml conical flask and 5 ml of 0.03% NH_4SCN solution was added as indicator. 50 ml of distilled water was added to give it the proper acidity (pH 4.5). This was titrated with ferric chloride solution which contained 0.005 mg of Fe per ml of $FeCl_3$ until a brownish yellow colour persisted for 5 minutes. Phytin phosphorus (Pp) was determined and the phytic acid content was calculated by multiplying the value of Pp by 3.55. Each milligram (mg) of Fe is equivalent to 1.19 mg of Pp.

Iron equivalence = titre value x 1.95

Pp = titre value × 1.95 × 1.19

Therefore, phytic acid = titre value x 1.95 x 1.19 x 3.55 mg

% Phytic acid = titre value x 8.24/1000 x 100/weight of sample

Phytin phosphorus as percentage of phosphorus (Pp % P) = Pp/P × 100

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The minerals were analyzed from the solutions obtained after dry ashing the samples at 550˚C to constant weight. Sodium and potassium were determined using flame photometer (model 405, Corning, UK) and phosphorus was determined colorimetrically using a Spectronic 20 (Gallenkamp, UK) using the phosphovanadomolybdate method as described by AOAC [23]. All other metals were determined by means of atomic absorption spectrophotometer (Buck Scientific model 200 A/210, Norwalk, Connecticut 06855). All chemicals used were of analytical grade from British Drug Houses (BDH, London, UK). Ca/P, Na/K, Ca/Mg, K/Na and the milliequivalent ratio [K/(Ca+Mg)] [25] as well as the mineral safety index (MSI) of Na, Ca, Mg, Zn, Fe, Cu and P [26] were calculated. The differences between the standard MSI and the samples MSI were also calculated. Mean, standard deviation and coefficients of variation percent were calculated where necessary [27]. The calculated chi-square was compared with Table value setting the level of confidence at α = 0.05 [28].

Results and Discussion

Results

In Table 1, we have the proximate composition of the five insects on dry weight basis. The moisture content was low (4.32g/100g) in bee brood but high in other samples with value range of 9.56 - 11.3g/100g. The total ash was low to high with values of 4.06 - 8.78 g/100g showing that they might be good sources of minerals. The crude fat of 11.8 - 49.0g/100g showed the samples to be good sources of high dietary energy. Close values were observed in the crude fibre values having levels of 4.22 - 5.87 g/100g with mean value of 5.04 ± 0.63g/100g and coefficient of variation percent (CV%) of 12.5. Carbohydrate content was low in bee brood (14.0 g/100g) but high in other samples with values of 31.4 - 50.6 g/100g with high variation of 42.1 %. The energy values were high at 1567 - 2369 kJ/100g and they were reflections of the values of crude fat and carbohydrate in particular in the samples. The Chi-square analysis showed that significant differences occurred in the crude fat, carbohydrate and energy values at α = 0.05 among the samples.

Parameter	B_2	P_2	T_2	SWL	SWP	Mean	SD	CV%	χ^2	Remarks
Moisture	4.32	9.56	11.1	11.3	10.4	9.34	2.89	30.9	3.57	NS
Total ash	8.78	6.81	4.06	8.29	6.92	6.97	1.84	26.4	1.94	NS
Crude fat	49.0	12.3	11.8	24.0	26.7	24.8	15.1	60.9	37.0	S
Crude protein	18.7	18.2	18.3	20.3	19.4	19.0	0.876	4.61	0.162	NS
Crude fibre	5.21	5.87	4.22	4.64	5.24	5.04	0.630	12.5	0.316	NS
Carbohydrate	14.0	47.2	50.6	31.4	31.4	34.9	14.7	42.1	24.6	S
Energy(kJ/100g)	2369	1567	1608	1767	1852	1833	321	17.5	226	S
Energy(kcal/100g)	566	375	384	422	443	438	76.7	17.5	53.8	S

Table 1: *Proximate Composition [g/100g] of the insect samples.*

B_2 = Bee brood; P_2 = snout beetle; T_2 = termite soldier; SWL = silkworm larva; SWP = silkworm pupa; SD = standard deviation; CV% = coefficient of variation percent

The proportion of energy distribution due to fat, protein, carbohydrate and utilizable energy due to protein are depicted in Table 2. The contribution (in percentages) due to crude fat ranged from 27.2 - 76.5; for carbohydrate, range was 10.0 - 53.5; for protein, it was 13.4 - 19.7. The energies due to crude fat and carbohydrate contributions were each significantly different among the samples at α = 0.05. The utilizable energy due to protein appeared low at 8.05 - 11.8 %. The CV % for the parameters in Table 2 was low to high with values of 4.61 - 61.1.

Parameter	B_2	P_2	T_2	SWL	SWP	Mean	SD	CV%	χ^2	Remarks
Total energy [kJ/100g]	2369	1567	1608	1767	1852	1833	321	17.5	3.57	NS
Energy[kJ/100g] [PEF%]	1813(76.5)	455(29.0)	437(27.2)	888(50.3)	988(53.3)	916	560	61.1	1368	S
E in kJ/100g [PEP %]	318(13.4)	309(19.7)	311(19.3)	345(19.5)	330(17.8)	323	15.0	4.64	2.75	NS
E in kJ/100g [PEC %]	238(10.0)	802(51.2)	860(53.5)	534(30.3)	534(28.8)	594	249	42.0	418	S
UEDP [%]	8.05	11.8	11.6	11.7	10.7	10.8	1.58	14.6	0.930	NS

Table 2: *Proportions of energy contribution due to fat, protein, carbohydrate and utilizable energy due to protein. PEF = Proportion of total energy due to fat; PEP = Proportion of total energy due to protein; PEC = Proportion of total energy due to carbohydrate; UEDP = Utilizable energy due to protein;* χ^2 *= Chi-square;* $\alpha = 0.05$ *df @ k-1; S = Significant; NS = not significant*

The variation between machine (bomb calorimeter) total energy and calculated total energy of the insect samples and their corresponding percentage differences could be seen in Table 3. The results showed that 4/5 or 80 % of the samples had higher values as determined by the bomb calorimeter than by the calculation. However, the differences were low with the exception of snout beetle with value difference of 38.5% whilst others ranged from 0.216 - 1.04%. The only sample (silkworm larva) that had a negative difference of -8.0 kJ/100g (-0.50 %) also had the least values under both parameters: 1600 kJ/100g (bomb calorimeter) and 1608 kJ/100g (calculated).

Samples	Energy (Bomb cal)	Calculated energy kJ/100g	Difference	% difference
B_2	2394	2369	25.0	1.04
P_2	2549	1567	982	38.5
T_2	1600	1608	-8.00	-0.500
SWL	1772	1767	5.00	0.282
SWP	1856	1852	4.00	0.216

Table 3: *Variation between machine total energy and calculated total energy of the insect samples and their corresponding percentage differences.*

The various mineral components of the samples have been depicted in Table 4. High mineral values were observed in the samples as shown (mg/100g): Na (193 - 266), K (89.3 - 890), Mg (39.4 - 64.0) and P (618 - 1732) but low in Ca (7.26 - 13.0), all for the major minerals; high values in trace minerals were: Zn (24.5 - 38.1), Fe (9.26 - 31.2), Mn (1.26 - 9.09), Co (0.907- 4.76) but low in Cu (0.00 - 0.433), Pb (0.00 - 0.09) and Cd (0.090 - 1.73). Whilst Phy was high at 16.1 - 98.8 mg/g, both Pp (4.53 - 27.8 mg/100g) and Pp % of P (0.262 - 4.47) were low. The CV % ranged from 15.4 - 222 coming from Na and Pb respectively. These minerals were significantly different among the samples at $\alpha = 0.05$: Na, K, Mg, Fe, Mn and P.

In Table 5, we have the calculated mineral ratios of the insect samples. The following ratios did not have full complement because some of the original concentration results had 0.00 mg/100g values. Such ratios were Zn/Cu (four samples), Fe/Cu (four samples), Ca/Pb (one sample) and Fe/Pb (one sample). The mineral ratios involving the trace minerals were high (for available results) in Zn/Cu (88 - 323), Fe/Cu (51.2 - 128), Ca/Pb (116), Fe/Pb (128) and Zn/Cd (22 - 323). The ratios were low in the major minerals: Ca/Mg (0.148 - 0.330), Na/K (0.299 - 2.12), Ca/K (0.015 - 0.114), Na/Mg (3.02 - 6.75), Ca/P (0.008 - 0.018) and [K/(Ca + Mg)] (1.31 - 1.68). except in snout beetle where the ratio was 17.0. In the Chi-square analysis, only Zn/Cd and [K/(Ca + Mg)] had significant values at $\alpha = 0.05$.

Parameter	B_2	P_2	T_2	SWL	SWP	Mean	SD	CV%	χ^2	Remarks
Sodium	193	266	199	197	189	209	32.2	15.4	19.9	S
Potassium	97.8	890	106	115	89.3	260	353	136	1915	S
Calcium	10.4	13.0	12.1	11.4	7.26	10.8	2.21	20.5	1.86	NS
Magnesium	64.0	39.4	61.4	57.2	49.0	54.2	10.0	18.5	7.43	S
Zinc	29.1	38.1	30.5	27.2	24.5	29.9	5.12	17.1	3.50	NS
Iron	11.5	31.2	10.0	12.0	9.26	14.8	9.24	62.4	23.1	S
Copper	0.090	0.433	0.000	0.182	0.181	0.177	0.162	91.5	0.590	NS
Lead	0.090	0.000	0.000	0.000	0.000	0.018	0.040	222	0.360	NS
Cadmium	0.090	1.73	0.152	0.182	0.091	0.449	0.717	160	4.58	NS
Manganese	1.26	9.09	2.12	1.82	2.09	3.28	3.27	99.7	13.0	S
Cobalt	1.80	4.76	1.74	0.727	0.907	1.99	1.62	81.4	5.30	NS
Phosphorus	622	1732	720	645	618	867	485	55.9	1085	S
Phy (mg/100g)	98.8	16.1	25.5	33.0	22.3	39.1	33.9	86.7	118	S
Pp (mg/100g)	27.8	4.53	7.20	9.31	6.28	11.0	9.54	86.7	33.1	S

Table 4: *Mineral content of the insect samples.*

Phy = phytate; Pp = phytin phosphorus

Parameter	B_2	P_2	T_2	SWL	SWP	Mean	SD	CV%	χ^2	Remarks
Ca / Mg	0.163	0.330	0.197	0.199	0.148	0.207	0.072	34.8	0.100	NS
Na / K	1.97	0.299	1.88	1.71	2.12	1.60	0.740	46.3	1.37	NS
Ca / K	0.106	0.015	0.114	0.099	0.081	0.083	0.040	48.2	0.077	NS
Na /Mg	3.02	6.75	3.24	3.44	3.86	4.06	1.53	37.7	2.32	NS
Zn / Cu	323	88.0	-	149	135	-	-	-	-	-
Ca /P	0.017	0.008	0.017	0.018	0.012	0.014	0.004	28.6	0.00001	NS
Fe / Cu	128	72.1	-	65.9	51.2	-	-	-	-	-
Ca / Pb	116	-	-	-	-	-	-	-	-	-
Fe / Pb	128	-	-	-	-	-	-	-	-	-
Zn / Cd	323	22.0	201	149	269	193	116	60.1	280	S
[K / (Ca + Mg)]	1.31	17.0	1.44	1.68	1.59	4.60	6.93	151	41.7	S

Table 5: *Calculated mineral ratios of the insect samples.*

The mineral safety index (MSI) values of the samples can be seen in Table 6. The following minerals were within their standard levels: mineral (standard level): Na (4.80), Ca (10.0), Mg (15.0) and Cu (33.0) whilst Zn (33.0) had all the calculated values greater than 33.0; also, Fe (6.70) was higher in snoult beetle (13.9) and P (10.0) was also higher in snoult beetle (14.4).

In Table 7, the concentration of Zn, Ca, Phy and calculated values of Phy:Zn, Ca:Phy and [Ca][Phy]/[Zn] molar ratios of the insect are shown. The various parameters determined were highly varied except in Zn and Ca where respective CV % values were 17.1 and 20.5 whereas other parameters have CV % range of 63.2 - 86.6.

Minerals	B_2			P_2			T_2			SWL			SWP		
	TV	CV	D	TV	CV	D	TV	CV	D	TV	CV	D	TV	CV	D
Sodium	4.80	1.85	2.95	4.80	2.55	2.25	4.80	1.91	2.89	4.80	1.89	2.91	4.80	1.81	2.99
Calcium	10.0	0.087	9.91	10.0	0.108	9.89	10.0	0.101	9.90	10.0	0.095	9.91	10.0	0.061	9.94
Magnesium	15.0	2.40	12.6	15.0	1.48	13.5	15.0	2.30	12.7	15.0	2.15	12.9	15.0	1.84	13.2
Zinc	33.0	64.0	-31.0	33.0	83.2	-50.2	33.0	67.1	-34.1	33.0	59.8	-26.8	33.0	53.9	-20.9
Iron	6.70	5.14	1.56	6.70	13.9	-7.20	6.70	4.47	2.23	6.70	5.36	1.34	6.70	4.14	2.56
Copper	33.0	0.99	32.0	33.0	4.76	28.2	33.0	0.000	33.0	33.0	2.00	31.0	33.0	1.99	31.0
Phosphorus	10.0	5.18	4.82	10.0	14.4	-4.40	10.0	6.00	4.00	10.0	5.38	4.62	10.0	5.15	4.85

Table 6: *Mineral safety index (MSI) of the insect samples.*

TV = Table Value; CV = Calculated Value; D = Difference

Parameter	B_2	P_2	T_2	SWL	SWP	Mean	SD	CV%	χ^2	Remarks
Ca : Phy[1]	1.73	13.3	7.81	5.69	5.36	6.78	4.25	62.7	10.6	S
Phy : Zn[2]	0.337	0.042	0.083	0.120	0.090	0.134	0.117	87.3	0.406	NS
[Ca][Phy]/[Zn][3]	0.0009	0.0001	0.0003	0.0003	0.0002	0.0004	0.0003	75.0	0.001	NS

Table 7: *Ca : Phy, Phy:Zn and [Ca][Phy]/[Zn] molar ratios of the insect samples.*

[1] *mg of Ca/MW (molecular weight) of Ca:mg of Phy/MW of Phy*

[2] *mg of Phy/MW of Phy:mg of Zn/MW of Zn*

[3] *[mol/kg Ca] × [mol/kg Phy]/[mol/kg Zn]*

The statistical analysis showed that only Ca:Phy was significant at α = 0.05 in the samples.

Discussion

In Table 1, the moisture content showed that most of the samples had low keeping quality particularly where electricity is epileptic. Calculation due to the proximity of moisture levels among samples showed the following: (i) 4.32; (ii) 9.56, 11.1, 11.3, 10.4 (mean = 10.6 ± 0.788 and 7.44 %) showing two major groups giving the total mean value of 9.34 ± 2.89 and 30.9%. The ash content is a reflection of the mineral content of the samples. The ash results compared well with the values of 4.9-6.6 g/100g in the heterosexual samples of African giant cricket [29]. The total ash content could be grouped into two due to their proximity values: (i) 8.78, 6.81, 8.29, 6.92 (mean = 7.70 ± 0.986 and 12.8 %); (ii) 4.06. The crude fat content of 11.8-49.0 g/100 g was higher than the value of 9.16 g/100g reported for *Anaphe infracta* [3]. The fat values were in three groups as shown: (i) 49.0; (ii) 12.3, 11.8 (mean = 12.1 ± 0. 354 and 2.93 %); (iii) 24.0, 26.7 (mean = 25.4 ± 1.91 and 7.53 %).

The crude protein values of 18.2 - 20.3 g/100g were all lower than in *A. infracta* (27.8 g/100g) [3]. They also fell below the recommended levels of 23 - 56 g/100g human daily requirement [30]. The proximity levels of the protein concentration could be seen in two groups: (i) 18.7, 18.2, 18.3 (mean = 18.4 ± 0.265 and 1.44 %); (ii) 20.3, 19.4 (mean = 19.9 ± 0.636 and 3.21 %). The crude fibre is important in facilitating faecal elimination [31]. In the present sample, the fibre levels of 4.22-5.87 g/100g would contribute reasonably to this fibre function. The fibre content could have come from vegetables (plants) consumed by the insects and the exoskeleton. The values of the crude fibre could be divided into two major proximity levels: (i) 5.21, 5.87; 5.24 (mean = 5.44 ± 0.373 and 6.85 %); (ii) 4.22, 4.64 (mean = 4.43± 0.297 and 6.70 %). The carbohydrate levels of 14.0 - 50.6 g/100g could be put into three groups thus: (i) 14.0; (ii) 47.2, 50.6 (mean

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= 48.9 ± 2.40 and 4.92 %); (iii) 31.4, 31.4 (mean = 31.4 ± 0.00 and 0.00 %). The value of 47.2 g/100g (carbohydrate) was exactly similar to the value of 47.2 g/100g reported for *A. infracta* [3]. The value of 47.2 g/100g in the present samples came from snout beetle. The metabolisable energy values were high at 1576 - 2369 kJ/ 100g (375-566 kcal/100g) showing the samples to be concentrated sources of energy. The energy values could be seen proximally in two main groups: (i) 2369; (ii) 1567, 1608, 1767, 1852 (mean = 1699 ± 134 and 7.88 %).

The energy contributions in the samples by crude fat, crude protein and carbohydrate gave the total energy of each sample at 100g level.

The samples with the highest crude fat content were also the samples with the highest total energy followed by the samples with the highest carbohydrate content. The observation goes thus: bee brood (PEF% = 76.5) > silkworm pupa (PEF % = 53.3) > silkworm larva (PEF % = 50.3) > termite soldier (PEC % 53.5) > snoult beetle (PEC % = 51.2). In Table 2, the PEF % values would be seen to be in three groups: (i) 1813; (ii) 888, 988 (mean = 938 ± 70.6 and 7.53 %); (iii) 455, 437 (mean = 446 ± 12.7 and 2.85%). For PEP % values, we have just one group because the variation was low (in fact the lowest) as shown: mean = 323 ± 14.9 and 4.61 %. For PEC %, we have three groups in values of proximity: (i) 238; (ii) 802, 860 (mean = 831 ± 40.9 and 4.92 %; (iii) 534, 534 (mean = 534 ± 0.00 and 0.00 %). In the UEDP %, we have just two groups as follows: (i) 8.05; (ii) 11.8, 11.6,11.7, 10.7 (mean = 11.5 ± 0.507 and 4.42 %).

The energy provided to living cells by energy-providing nutrients can differ from the heat of combustion in the same nutrients. This may be caused by losses arising from incomplete digestion when some nutrients are lost in the faeces.

Metabolisable or available energy = Heat of combustion – Digestive losses.

Kilgour [32] had given the metabolisable or available energy of different nutrients compared with their heat of combustion. In carbohydrate, digestion loss (%) = 1, in lipid, it is 5, it is nil in ethanol and it is 29 in protein; heat of combustion (kJ/g): carbohydrate (17.2), lipid (39.4), ethanol (29.0) and protein (24.0); for metabolisable or available energy to cells (kJ/g), we have 17.0 (carbohydrate), 37.0 (lipid), 29.0 (ethanol) and 17.0 (protein). Thus, the available energy values become important factors, in calculating the energy of a foodstuff; the factors being 17 for carbohydrate and protein, 37 for lipid and 29 for ethanol. The available energy values shown in Table 3 (column 3) were calculated from the lipid, carbohydrate and protein content of the samples using the factors enumerated earlier. The energy values determined by the bomb calorimeter (column 2) provided heat of combustion values, hence the differences as seen in columns 4 and 5 of Table 3. Energies from calculated values ranged from 1.61 - 2.37 MJ/100g which were better than in cereals (1.1 - 1.6), sugar and confectionery (1.1 - 2.3), legumes, nuts and seeds (1.3 - 2.5), meat, poultry, fish (0.4-1.2) and dairy products: cheeses (0.4 - 1.7) and milk fresh/dried (0.25 - 2.0) [32]. The energies (calculated and from bomb calorimeter) could each be divided into two groups: bomb (i) 2394, 2549 (mean = 2472 ± 110 and4.43 %); (ii) 1600, 1772, 1856 (mean = 1743 ± 130 and 7.49 %). For calculated, we have: (i) 2369; (ii) 1567, 1608, 1767, 1852 (mean = 1699 ± 134 and 7.88 %).

The results of the mineral content of the samples could be seen in Table 4. Both Cd and Pb were relatively low and with highest levels of CV % with values of 222 (Pb) and 160 (Cd). Both Cd and Pb are not useful to human beings biochemically and their presence could be due to the onset of pollution. Copper level was low whereas Co was much higher; whilst Cu is a constituent of enzyme cytochrome oxidase involved in energy metabolism, Co is a constituent of cobalamin. Iron content of 9.26 - 31.2 mg/100g would be able to satisfy the following conditions: Fe requirement by human being is 10 - 15 mg for children, 18 mg for women and 12 mg for men [33]. Lack of adequate Fe in the diet had been attributed with learning and decreased cognitive development [34]; Fe also facilitate the oxidation of carbohydrates, protein and fats. The high Fe levels in the samples would make the insects good substitutes for conventional meat sources and would prevent anaemia. The values of Mn (1.26 - 9.09 mg/100g) were characteristically low in 80 % of the samples (1.26 - 2.09) as earlier observed in some foods consumed in Nigeria: 2.8 ± 0.01 mg/100g (cake) and 2.9 ± 0.01 mg/100g (moin-moin) [35]. Manganese functions as an essential constituent for bone structure, for reproduction and for normal functioning of the nervous system [33]. The Zn values of 24.5 - 38.1 mg/100g in the samples were all higher than the Zn allowance of about 15 - 20 mg per day [33]. This meant that Zn could not be said to be a trace mineral in the insects just as we have in the Fe values. Zinc is present in all tissues of the body and is a component of more than 50 enzymes. Zinc deficiency is associated with impaired growth and reproduction, anorexia, immune disorders and a variety of other symptoms [36]. Zinc dietary deficiency had been found in adolescent boys [37]. The major minerals recorded in the samples were Na, K, Mg, Ca and P. Out of the five samples, 4/5 or 80.0 % of the samples contained more Na than K with the exception being snout beetle (890 K versus 266 Na mg/100g); more Na than K is a characteristic of animal mineral content. Sodium and potassium are required to maintain osmotic balance of the body fluid, the pH of the body, regulation of muscle and nerve irritability, control of glucose absorption and enhancement of normal retention of protein stability during growth [30]. The Ca level was low at 7.26 - 13.0 mg/100g and much lower than the recommended daily allowance (RDA) level of 800 mg. Ca corrects excessive amounts of Na, Mg or K present in the body and its adequacy in the diet leads to better utilization of Fe; this is an instance of 'sparing action' [33]. Ca, P and vitamin D combine together to prevent rickets in children and osteomalacia (adult rickets). Magnesium was of moderate concentration (39.4 - 64.0 mg/100g). Mg is an activator of many enzyme systems and maintains the electrical potential in nerves [33]. The P levels in this report (618-1732 mg/ 100g) compared favourably with the RDA level of 800 mg. Phosphorus is an essential component in nucleic acids and the nucleoproteins responsible for cell division, reproduction and the transmission of hereditary traits [33]. The Pp (mg/100g) ranged from 7.2-27.8 with corresponding Pp % of P of being 1.00 - 4.47 respectively. The implication of the Pp % of P showed that the P of the samples was only linked to Pp to the tune of 1.00 - 4.47 which would not affect the utilization of divalent minerals and also would not render unavailable some essential amino acids.

Explained next would be the proximity of the minerals within the samples. Sodium would be in two groups as shown: (i) 193, 199, 197, 189 (mean = 195 ± 4.43 and 2.28 %); (ii) 266; for K, we have two groups also: (i) 97.8, 106, 115, 89.3 (mean = 102 ± 11.0 and 10.8 %); (ii) 890; in Ca, we have two as well: (i) 10.4, 13, 12.1, 11.4 (mean = 11.7± 1.10 and 9.38 %); (ii) 7.26; for Mg, we have two groups: (i) 64, 61.4, 57.2 (mean = 60.9 ± 3.43 and 5.64 %); (ii) 39.4, 49.0 (mean = 44.2 ± 6.79 and 15.4 %) and P has three groups: (i) 622, 645, 618 (mean = 628 ± 14.6 and 2.32 %); (ii) 1732; (iii) 720. In Zn, we have two groups: (i) 29.1, 30.5, 27.2, 24.5 (mean = 27.8 ± 2.60 and 9.33 %); 38.1; Fe also has two groups: (i) 11.5, 10, 12, 9.26 (mean = 10.7 ± 1.28 and 11.9 %); (ii) 31.2; in Cu, we have four groups: (i) 0.00; (ii) 0.09; (iii) 0.433; (iv) 0.182, 0.181, 0.177 (mean = 0.18 ± 0.001 and 0.39 %); Pb has two groups: (i) 0.00; (ii) 0.09; in Cd, we have two groups: (i) 0.09, 0.091 (mean = 0.0905 ± 0.0007 and 0.78 %); (ii) 1.73, 0.152, 0.182 (mean = 0.167 ± 0.021 and 12.7 %); Mn has three: (i) 1.26; (ii) 2.12, 1.82, 2.09 (mean = 2.01 ± 0.165 and 8.22 %); (iii) 9.09 and in Co, we have three groups: (i) 1.80, 1.74 (mean = 1.77 ± 0.042 and 2.40 %); 4.76; (iii) 0.727, 0.907 (mean = 0.817 ± 0.127 and 15.7 %). In Phy results, we have four groups: (i) 988; (ii) 16.1; (iii)25.5, 22.3 (mean = 23.9 ± 2.26 and 9.47 %); (iv) 33.0 and in Pp % of P, we have five proximity groups: (i) 4.47; (ii) 0.262; (iii) 1.0 (iv) 1.44; (v) 1.02.

The various calculated mineral ratios of the insect samples could be seen in Table 5. The following ratios were less than the ideal ratios: Na/K [ideal (id) = 2.50, values = 0.299 - 2.12], Na/Mg [id = 4.17, values = 3.02 - 3.86; except in snout beetle = 6.75], [K/(Ca + Mg)] [id = 2.2, values = 1.31 - 1.68; except in snout beetle = 17.0], Ca/Mg [id = 6.67, values = 0.163 - 0.330], Ca/P [id = 2.5, values = 0.008 - 0.018] and Ca/K [id = 4.00, values = 0.015 - 0.114]. The following mineral ratios: Zn/Cu, Fe/Cu (except in four samples), Ca/Pb and Fe/Pb have ratio values much higher than the ideal. Ideal [id = 500, values = 22 - 232] in Zn/Cd ratio. Toxic ratios are usually depicted by Ca/Pb, Fe/Pb and Zn/Pb. Balance in all phases of life is critically important to maintain health and this principle applies to mineral levels in animal analyses. The importance of ratios had been enumerated [38]: ratios are often more important than levels; ratios represent homeostatic balances; ratios are indicative of disease trends; ratios are frequently predicative of future metabolic dysfunction or hidden metabolic dysfunctions. Most of the insect mineral ratios were far from the ideal for human beings.

The proximity groups in the calculated mineral ratios from Table 5 are as follows: Ca/Mg were within two groups: (i) 0.163, 0.197, 0.199, 0.148 (mean = 0.177 ± 0.025 and 14.3 %); (ii) 33; Na/K formed three groups: (i) 1.97, 1.88, 1.71 (mean = 1.85 ± 0.132 and 7.12 %); (ii) 0.299; (iii) 2.12; Ca/K could be found within three groups: (i) 0.106, 0.114 (mean = 0.11 ± 0.006 and 5.14 %); (ii) 0.015; (iii) 0.099, 0.081 (mean = 0.090 ± 0.013 and 14.1 %); In Na/Mg, we have three groups: (i) 3.02; (ii) 6.75; (iii) 3.24, 3.44, 3.86 (mean = 3.51 ± 0.320 and 9.01 %); Zn/Cu has three groups: (i) 323; (ii) 88; (iii) 149, 135 (mean = 142 ± 9.90 and 6.97 %); For Ca/P, we have two groups: (i) 0.017, 0.017, 0.018, 0.012 (mean = 0.016 ± 0.003 and 16.9 %); (ii) 0.008; two groups were observed in Fe/Cu: (i) 12.8; (ii)72.1, 65.9, 51.2

(mean = 63.1 ± 10.7 and 17.0 %); Ca/Pb has one group (i) 116; Fe/Pb also had one group: (i) 128; in Zn/Cd, five groups were identified: (i) 323; (ii) 22.0; (iii) 201; (iv) 149; (v) 269 and in [K/(Ca + Mg)], two groups were identified: (i) 1.31, 1.44, 1.68, 1.59 (mean = 1.51 ± 0.163 and 10.9 %); (ii) 17.0.

In getting the values of the MSI in Table 6, the recommended adult intake (RAI) and the minimum toxic dose (MTD) were involved in their calculations. For example, the RAI of Na is 560 mg and the MTD is 2,400 mg or 4.8 times the recommended daily average (RDA), this is equivalent to the standard MSI of Na. This explanation goes for other MSI determined. The MSI ranges for the minerals were: Na (1.81 - 2.55), Ca (0.061 - 0.108), Mg (1.48 - 2.40), Zn (53.9 - 83.2), Fe (4.14 - 13.9), Cu (0.00 - 4.76) and P (5.15 - 14.4). All the MSI values in Na, Ca, Mg and Cu were all within the USRDA [26] whereas all the MSI values in Zn, Fe (in snout beetle only) and P (also in snout beetle only) were outside (higher) than the USRDA.

The implications of the MSI results could be that the human body would not be loaded deleteriously with Na, Ca, Mg, Fe (except snout beetle). Excess Zn would come from all the samples. The MTD for Zn is 500 mg or 33 times the RDA [26]. High doses of Zn can decrease the amount of high density lipoprotein (HDL) circulating in the blood, hence, increasing the risk of heart disease; also, excess Zn interacts with other minerals such as Cu and Fe thereby decreasing their absorption. Excess Zn can also decrease the functioning of the immune system and 3.5 mg/day Zn intake above the RDA decreases Cu absorption [25].

The proximity levels into groups of the MSI values are as follows: in Na, we have two groups: (i) 1.85, 1.91, 1.89, 1.81 (mean = 1.87 ± 0.044 and 2.38 %); (ii) 2.55; for Ca, we have two groups: (i) 0.087, 0.095, 0.061 (mean = 0.08 ± 0.018 and 21.9 %); (ii) 0.108, .0101) mean = 0.105 ± 0.005 and 4.74 %); two groups were also observed for Mg: (i) 2.40, 2.30, 2.15 (mean = 2.28 ± 0.126 and 5.51 %); (ii) 1.48, 1.84 (mean = 1.66 ± 0.255 and 15.3 %); Zn exhibited three groups: (i) 64.0, 67.1 (mean = 65.6 ± 2.19 and 3.34 %); (ii) 83.2; (iii) 59.8, 53.9 (mean = 56.9 ± 4.17 and 7.34 %); Fe has two groups: (i) 5.14, 4.47, 5.36, 4.14 (mean = 4.78 ± 0.569 and 11.9 %); (ii) 13.9; four groups were observed for Cu: (i) 0.99; (ii) 4.76; (iii) 0.00; (iv) 2.00, 1.99 (mean = 2.00 ± 0.007 and 0.354 %) and P has two groups: (i) 5.18, 6.00, 5.38, 5.15 (mean = 5.43 ± 0.395 and 7.28 %); (ii) 14.4.

The molar ratios of the samples are shown in Table 7. Oberleas and Hearland [39] showed that foods with a molar ratio of Phy : Zn less than 10 showed adequate availability of zinc and problems were encountered when the value was greater than 15. Only bee brood of Phy : Zn (33.6) will encounter this availability problem under this model as observed by Morris and Ellis [40] who showed that growth of rat was significantly depressed when cereals with Phy : Zn molar ratios of 24 and greater were the Zn source. Also in human studies, Phy : Zn molar ratios of 15:1 have also been associated with reduced Zn bioavailability [41]. In Wise [42] model, phytate precipitation is not complete until dietary Ca : Phy molar ratios attain a value of approximately 6 : 1. At Ca : Phy lower than 6.1, phytate precipitation is incomplete, so that some of the dietary Zn remains in solution. The proportion remaining in solution increases with decreasing Ca : Phy molar ratios [42]. In our samples, no Ca : Phy was up to the critical molar ratio of 6:1. The low levels of the Ca : Phy were due to low levels of Ca in the samples. Ferguson., *et al*. [43] showed that the the molar ratio varies with different foods and recommended that this value be used in conjunction with other data to explain the availability of Zn using the Ca: Phy ratio. Ellis., *et al*. [44] and Davies and Warrington [45] indicated that the ratio of Ca × Phy: Zn is a better predictor of Zn availability of Zn. In the present results, Ca × Phy: Zn values were lower than 0.5 mol/kg in all the samples meaning that all the samples would promote Zn bioavailability.

The explanation on the proximity arrangement of molar ratios into groups now follows. The proximity values of Zn, Ca and Phy had been described under Table 4 discussion. For the molar ratios, we have: in Phy/Zn, we have four groups: (i) 0.337; (ii) 0.042; (iii) 0.083, 0.090 (mean = 0.087 ± 0.005 and 5.75 %); (iv) 0.120; we also have four groups in Ca/Phy: (i) 1.73; (ii) 13.3; (iii) 7.81; (iv) 5.69, 5.36 (mean = 5.53 ± 0.233 and 4.21 %) and finally,in [Ca][Phy]/[Zn], we have two groups: (i) 0.0009; (ii) 0.0001, 0.0003,0.0003, 0.0002 (mean = 2.25 e-4 ± 9.57 e-5 and 42.5 %).

Conclusion

These results show that the five insect samples were good sources of fat, protein and energy whilst they were moderate in their values for utilizable energy due to protein. The samples would supply adequate quantities of Na, K, Zn, Fe, Mn and P but low in Ca: the low level of Pp % of P is a dietary advantage. The mineral safety index values were of the indication that the minerals were not deleterious except in Zn; the [Ca][Phy]/[Zn] molar ratio values show that the minerals would be bioavailable. Work is ongoing to look at other nutrients in the insects under discussion.

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