CHEMICAL COMPOSITION AND MINERAL SAFETY INDEX OF FIVE INSECTS COMMONLY EATEN IN SOUTH WEST NIGERIA

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Abstract: The proximate and mineral composition of *Apis mellifera*, *Macrotermes belliccosus*, *Imbrasia belina*, *Oryctes boas and Sitophilus zeamais* were determined. The protein and carbohydrate contents varied from at 14.0 – 17.2 g/100g and 60.5 – 71.8 g/100g, respectively. Crude fat content was low (2.98 g/100g) in *Oryctes boas*. Total energy (1505-1569 kJ/100g) and protein energy contribution (PEC %) (67.6-77.8) were generally low. Among the minerals (mg/100 g) evaluated, Na (140 – 402), K (198 – 2515) and P (618 – 1443) were the most concentrated; Ca was low at 9.28 – 22.8 mg/100g. Zn was high at 15.3 – 45.2 mg/100g; Fe (9.48 – 13.7 mg/100g) was low except in *Sitophylus zeamais* (22.5 mg/100g) whereas Mn (1.08 – 4.25 mg/100 g) was low in all the samples. Pb recorded 0.00 mg/100g in *Apis mellifera*, *Macrotermes belliccosus*, and *Imbrasia belina* but not detected in *Oryctes boas* and *Sitophylus zeamais*. Cu (0.097 – 0.196 mg/100g) and Cd (0.09 – 0.39 mg/100g) were generally low in the samples. In the mineral ratios, all the samples were less than 0.5 in Ca/P and 1.0 in Ca/Mg. In Na/K, only *Apis mellifera*, and *Macrotermes belliccosus*, had values above the recommended 0.6. The mineral safety index showed that Na, Ca, Mg and Cu were all lower than the standards whereas Zn was higher in all the samples. Fe was outside the index in *Sitophylus zeamais* and P in *Oryctes boas* whereas the two minerals were within the standard in the remaining insect samples. Standard mineral safety index values are Na (4.80), Ca (10.0), Mg (15.0), Zn (33.0), Fe (6.70), Cu (33.0) and P (10.0).
Keywords: Energy contribution, insects, mineral safety index, proximate composition.

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 diversed groups of animals. Insects may be found in nearly all environments including the oceans and there are over one thousand four hundred recorded edible insects (FAO, 2008). Insects are the only winged invertebrates, cold-blooded, produced quickly and often do not have parental care (Delong, 1960). 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* (Adeyeye, 2008). 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.* (Ene, 1963). 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 (Bodenheimer, 1951). The Yukpa people of Colombia and Venezuela preferred their traditional insect foods meat as do the pedi of South Africa (Quinn, 1959).

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 & Walter, 2005). Along with wasps, honey bees are the most important food insects in northern Thailand (Chen *et al.*, 1998).

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.

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 & 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).

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 & 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 & Ajiboye, 1993).

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).

People need to consume adequate calories and nutrients to overcome the problem of protein-energy malnutrition (PEM), (WHO, 2001). 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.

The common and scientific names of the five species of edible insects collected in southwestern Nigeria for this study are depicted in Table 1. Among the insects analysed were one specie of hymenoptera (*Apis melliferaiIii*), one specie of isoptera (*Macrtermes bellicosus),* one specie of lepidoptera (*Imbrasia belina*) and two species of coleoptera (*Oryctes boas and Silophilus zeamais*).

Table 1: Common and scientific names of the insect species

Sample symbol	Insect order	Family	Local name	English name	Scientific name
B_1	Hymenoptera	Apidae	*Oyin*	Honeybee	*Apis mellifera*
T_1	Isoptera	Termitidae	*Esunsun*	Winged termite	*Macrotermes bellicosus*
E_2	Lepidoptera	Notodontidae	*Kanyin*	Mopane worm	*Imbrasia belina*
G_2	Coleoptera	Scarabaeidae	*Ogongo*	Scarab beetle	*Oryctes boas*
KW	Coleoptera	Scarabaeidae	*Kokoro agbado*	Maize weevil	*Sitophilus zeamais*

Materials and Methods

Sample collection and preparation

The insect samples were obtained from farms and markets around Ekiti and neighbouring states and were identified in the Zoology Department of Ekiti State University, Ado-Ekiti. They were sorted to eliminate the defective ones, washed and rinsed with distilled water. The samples were then dried in an oven at 45^{o}C and dry milled separately to fine powder, stored in a dry, cool place prior to use the various analyses.

Analytical methods

The moisture, crude fibre and total ash contents were determined following the methods described by AOAC (2010). The crude fat was extracted with a chloroform / methanol (2:1) mixture using Soxhlet extraction apparatus as described by the AOAC (2010) methods. The micro-Kjeldahl method as described by Pearson (1976) was followed to determine the crude protein. 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 by means of their percentage composition. Determinations were made in duplicate.

The minerals were analysed from the solutions obtained after dry ashing the samples at 550^{o}C to constant weight. Sodium and potassium were determined using flame photometer (Type model 405, Corning, UK) and phosphorus was determined colorimetrically using a Spectronic 20 (Gallenkamp, UK) by the phosphovanadomolybdate method as described by AOAC (2010). All other metals were determined using atomic absorption spectrophotometer (Buck Scientific model – 200 A/210, Norwalk, Connedicut 06855). All chemicals used were from British Drug House (BDH, London, UK) analytical grade. Ca/P, Na/K, Ca/Mg, K/Na and the milliequivalent ratio [K/(Ca+Mg)] (Nieman *et al.*, 1992); the mineral safety index (MSI) of Na, Ca, Mg, Zn, Fe, Cu and P (Hathcock, 1985) 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 (Steel & Torrie, 1960). The calculated chi-square was compared with Table value setting the level of confidence at $\propto = 0.05$ (Oloyo, 2001).

Results and Discussion

Table 2 shows the proximate composition of the insect samples. The low moisture content (5.04 – 6.64 g /100 g) would ensure a fairly long keeping quality of the samples especially where there is frequent electricity failure. The ash contents (4.41 – 7.62 g/100 g) with the exception of *Oryctes boas* (2.65 g/100g) were higher than the value reported for grasshopper (*Zonocerus variegatus)* whose value was 3.1 g/100g (Olaofe *et al.,* 1998) but compared with 4.9-6.6 g/100g for African giant cricket varieties (Adeyeye & Awokunmi, 2010). However, the ash content of *Oryctes boas* (2.65 g/100g) compared favourably with the value of 2.77 g/100 g reported for *Anaphe infracta* larvae (Adeyeye, 2008). Ash is a rough estimate of the mineral content of a sample. The crude fat contents of the samples ranged between 2.98 – 6.26 g/100g. These values were comparable with 3.2 g/100 g and 5.3 g/100g in male and female giant African crickets respectively (Adeyeye & Awokunmi, 2010) but lower than 9.16 g/100 g reported for *Anaphe infracta* (Adeyeye, 2008). The values of crude protein in this report were in the range 14.0 – 17.2 g/100g. These protein values were lower than those reported for raw groundnut seeds: 29.0 g/100g (Adeyeye, 2011), *Prosopis africana:* 23.6 g/100g (Aremu *et al.*, 2006) and *A. infracta*: 27.8 g/100g (Adeyeye, 2008). Though the protein contents in this study were moderately high, they generally fell below the recommended 23-56 g/100 g human daily protein requirement (NRC, 1989). The crude fibre contents ranged from 3.48-5.31 g/100 g. Crude fibre is important in facilitating feacal elimination (Olaleye *et al.*, 2013). The carbohydrate levels (60.5 – 71.8 g/100g) were higher than 47.2 g/100g reported by Adeyeye (2008) for *A. infracta*.They were also higher than 60.8 g/100 g reported by Olaleye *et al*., 2013 for *Vigna subterranea* whole seed flour except maize weevil (KW) (60.5 g/100g) which was comparable. The concentration of carbohydrate (60.5-71.8 g/ 100g) in this study was above 53.7 g/100 g reported by Afiukwa *et al.* (2013) for similar insects. Generally, maize weevil (*Sitophilus zeamais*) had the highest concentration in (g/100g dry weight) of moisture (6.64), total ash (7.62) and crude fat (6.26): *Macrotermes sp.* in crude protein (17.2) and crude fibre (5.31) and *Oryctes boas* in carbohydrate (71.8). The coefficient of variation percent (CV %) was low for all the parameters determined. The chi-square (χ^2) results at $\alpha = 0.05$ showed that no significant difference existed in all the samples.

Table 2: Proximate composition (g/100g) of five insect species

Parameters	B_1	T_1	E_2	G_2	KW	Mean	SD	CV%	χ^2	TV	Remark
Moisture	6.29	5.81	5.41	5.04	6.64	5.84	0.646	11.1	0.286	9.49	NS
Total ash	5.71	4.72	4.41	2.65	7.62	5.02	1.82	36.3	2.65	9.49	NS
Crude fat	5.35	3.74	3.53	2.98	6.26	4.37	1.38	31.6	1.73	9.49	NS
Crude protein	15.8	17.2	16.9	14.0	15.4	15.9	1.28	8.05	0.413	9.49	NS
Crude fibre	3.66	5.31	3.48	3.49	3.62	3.91	0.785	20.1	0.63	9.49	NS
Carbohydrate	63.2	63.2	66.3	71.8	60.5	65.0	4.32	6.65	1.15	9.49	NS

B_1 = Adult bee, T_1 = Winged termite, E_2 = Mopane worm, G_2 = scarab beetle larva, KW = maize weevil, SD = Standard deviation, CV% = coefficient of variation percent, χ^2 = Chi square, α0.05 df n–1, S= significant, NS = not significant

Table 3: Proportions of energy contribution due fat, protein, carbohydrate and utilizable energy due to protein

Parameters	B_1	T_1	E_2	G_2	KW	Mean	SD	CV%	χ^2	TV	Remark
PEF (%)	12.8	9.19	8.45	7.03	15.2	10.5	3.37	32.1	4.30	9.49	NS
PEP (%)	17.4	19.4	18.6	15.2	17.2	17.6	1.60	9.09	0.584	9.49	NS
PEC (%)	69.7	71.4	73.0	77.8	67.6	71.9	3.86	5.37	0.829	9.49	NS
UEDP (%)	10.5	11.7	11.2	9.10	10.3	10.6	0.989	9.33	0.365	9.49	NS
$\sum$E (kJ/100g)	1541	1505	1545	1569	1522	1536	24.2	1.58	1.53	9.49	NS

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 = Utilized energy due to protein

The proportions of total energy due to fat (PEF %), protein (PEP %) and carbohydrate rate (PEC %); utilizable energy due to protein (UEDP %) and total energy in kg/100 g (ΣE) are presented in Table 3. The contribution to the total energy was 67.6 – 77.8 %,15.2 – 19.4 %, 7.03 – 15.2 % by carbohydrate, protein and fat, respectively. The contribution to the total energy by fat was highest in maize weevil (15.2 %). The contribution by protein was highest in *Macrotermes sp*. (19.4 %) whereas *O. boas* had the highest contribution by carbohydrate (77.8 %). The highest of UEDP was in *Macrotermes sp.* (11.7%) and that of total energy (ΣE) was in *O. boas* (1569 kJ/100 g). The results of the parameters determined were close with the low values of coefficient of variation percent (1.58 – 32.1%). The calculated chi-square analysis showed that no significant difference ($p > 0.05$) existed among the insect samples.

Water is indispensable for the efficient utilization and conservation of food within the body (Snively & Wessner, 1954). There is a link between the water content of the body and the type of diet taken (White House Conferences, 1932). For example, water deficit created by protein metabolism is about seven times that for equivalent calories of carbohydrate or fat. Studies conducted on animals and children showed that an increase in calories from carbohydrate causes hydration; whereas an increase in calories from proteins causes dehydration (Pratt & Snyderman, 1953). Albanese (1959) had given values of grammes of water needed for complete metabolism of 100 calories of some food substances: food material: protein, starch and fat (preformed water=0.00); gained by oxidation: protein (10.3), starch (13.9) and fat (11.9); lost in dissipating heat: 60 for all (protein, fat and starch); lost in excreting end products: protein (300), both starch and fat (0.00); deficit, protein (350), starch (46) and fat (48). One Calorie of protein requires 3.0 ml of water for excretion of the urea and sulphate formed from it; 1 g of ash requires 65ml of water for its excretion (Albanese, 1959). The calculated kcal values for each sample protein as well as their water values for the elimination of urea and sulphate by-products of metabolism are: B_1=142.2 kcal/100 g (need 426.6ml water); T_I=154.8 kcal/100 g (need 464.4ml water); E_2=152.1 kcal/100 g (need 456.3ml water); G_2=126 kcal/100 g (need 378.0ml water) and KW=138.6 kcal/100 g (need 415.8ml water). The water deficit could be made up for by the high carbohydrate level of the samples or from water intake.

Table 4 shows the mineral composition (mg / 100 g) and the calculated mineral ratios of the various insect samples. Lead had zero concentration in B_1, T_1, and E_2 and was not detected in G_2 and KW. Lead (Pb) was not detected in the sample and this is desirable as this Pb in not needed in the body for any biochemical process (Adeyeye & Faleye, 2004). The absence of lead showed that the environments where the insects lived were contaminated by lead. Both copper (0.097 – 0.196 mg/100 g) and cadmium (0.09 – 0.39 mg/100 g) had low concentrations. While Cd like Pb is not required in the body for any biochemical process, Cu is needed in the diet. Copper and iron are present in the enzyme cytochrome oxidase involved in energy metabolism (Li & Vallee, 1973). It is also needed to form red blood cells (with vitamin C) (FAO, 1997). Among the minor minerals, maize weevil was highest in zinc (45.2 mg / 100 g), iron (22.5 mg / 100g) and manganese (4.25 mg/100 g). The Zn levels (27.3 – 45. 2 mg/100 g) in the samples and even G_2 (15.3 mg/100 g) were higher than the Zn allowance of about 15 – 20 mg per day (Fleck, 1976). Zinc is present in all tissues of the body and is a component of more than 50 enzymes. High level of zinc in the insect samples contrasted literatures that Zn is one of the several trace minerals that are deficient in the diets, especially where meat is not consumed (Pew Initiative on Food and Biotechnology, 2007). Zinc deficiency is associated with impaired growth and reproduction, anorexia, immune disorders and a variety of other symptoms (Adeyeye *et al.*, 2014). Zinc dietary deficiency had been found in adolescent boys (Bender, 1992). People using vegetable and cereal sources of protein because of their low income may not be able to meet the zinc allowance (about 15 – 20 mg) per day. This is because the zinc in these sources is not as available as animals sources (NAS, 1971). The iron contents (9.48 – 22.5 mg/100 g) were higher than those in various West African edible snails (4.6 – 9.3 mg/100 g) (Adeyeye, 1996), freshwater fish (0.2 – 0.5 mg/100 g) (Adeyeye, 1994) and *Zonocerus variegatus* (3.7 mg/100 g) (Olaofe *et al.*, 1998). Fe requirement by human is 10 – 15 mg for children, 18 mg for women and 12 mg for men (Fleck, 1976). Lack of adequate iron in the diet had been associated with poorer learning and decreased cognitive development (FAO, 1997). Iron also facilitates the oxidation of carbohydrates, protein and fats (Adeyeye *et al.*, 2014). Literature revealed that addition of meat to legume / cereal diet can double the amount of iron absorbed and so contribute significantly to the prevention of anaemia, which is so widespread in developing countries such as Nigeria (Wheby, 1974). High Fe contents in the insect would make them good substitutes for conventional meat sources as they are capable of providing Fe to meet human requirement for iron. The low values of manganese (1.08 – 4.25 mg/100 g) in this study agreed with the literature reports for Mn in most of the foods consumed in Nigeria which include 2.8 $\pm$ 0.01 mg/100 kg (cake) and 2.9 $\pm$ 0.01 mg/kg (*moin – moin*) (Adeyeye *et al.*, 2012). Manganese functions as an essential constituent for bone structure, for reproduction and for normal functioning of the nervous system; it is also part of the nervous system (Fleck, 1976).

The major minerals obtained in this study were Na, K, Ca, Mg and P. *Macrotermes bellicosus* had the highest concentration of Na (402 mg/100g) and Ca (22.8 mg/100g); *Imbrasi betina* had 2515 mg / 100 g K. The *Oryctes boas* was highest in P (1443 mg/100 g) and *Sitophilus seamais* in Mg (105 mg/100 g). Both Na (140 – 402 mg/100 g) and K (198 – 2515 mg/100 g) were high in the samples. Sodium is widely distributed in foods; animals containing more than plant sources (Fleck, 1976). Both Na and K contents were higher than those: 12.5 – 63.1 mg / 100 g, Na; 12.5 – 16.9 mg / 100 g, K reported for Nigeria fresh water fishes (Adeyeye *et al.*, 1996). Sodium and potassium are required to maintain osmotic balance of the body fluid, the pH of the body, regulate muscle and nerve irritability, control glucose absorption and enhance normal retention of protein during growth (NRC, 1989). Potassium is primarily an intracellular cation. In large part, K is bound to protein (Sandstead, 1967).

The calcium levels of the samples (9.39 – 22.8 mg/100g) were far below the recommended daily allowance (RDA) level of 800 mg (Adeyeye, 2011). There is more calcium in the body than any other mineral element. It is a major component of bones and teeth and an important constituent of body fluid. It tends to co-ordinate other inorganic elements. Ca corrects excessive amounts of Na, Mg or K present in the body. If Ca is adequately enough in the diet, Fe is utilized to better advantage. This is an instance of 'sparing action' (Fleck, 1976). A relatively constant rate of bone loss occurs after the ages of 20 -30 years (Rose, 1967; Newton – John & Morgan, 1968). Also, osteoporosis (bone thinning) is more common among older people, females and whites than younger people, males and non-whites (Moldswer *et al.*, 1968). Ca, P and vitamin D (which produces a hormone called 1, 25 – dihydroxycholecalciferol, DHCC (Chesworth, 1992) combine together to prevent rickets in children and osteomalacia (adult rickets).

The values of Mg were much lower than 962 mg/100g dry weight (dw) reported for *Callinectes latimanus* (Adeyeye *et al.*, 2014). Magnasium is an activator of many enzyme systems and maintains the electrical potential in nerves (Shils, 1973). The samples were good sources of phosphorus. The P levels in this study (618-1443 mg/100 g) compared favourably with the RDA level of 800 mg and were higher than 10.0 -80.5 mg/100 g reported for *Vigna subterranean* seed parts (Olaleye *et al.*, 2013). Phosphorus is an essential component in nucleic acids and the nucleoproteins responsible for cell division, reproduction and the transmission of hereditary traits (Hegsted, 1973). The calculated mineral ratios are also shown in Table 4. The Na / K ratios (0.147 – 0.349) in E_2, G_2 and KW were good as they were lower than 0.6: a ratio that favours non enhancement of high blood pressure disease in man (Nieman *et al.*, 1992). Those in B_1, and T_1 were higher, which means, to bring the ratio low, B_1 and T_1 should be complemented with food rich in potassium. Ca/P levels ranged between 0.007-0.032 mg/100 g. These values were much lower than 0.5 which is the minimum requirement for favourable Ca absorption in the intestine and for bone formation (Nieman *et al.*, 1992). Food is considered 'good' if the Ca/P ratio is above 1.0 and 'poor' if the ratio is less than 0.5 (Aremu *et al.*, 2006). The Ca/Mg ratios ranged between 0.168 – 0.540 mg / 100g whereas the recommended value is 1.0. This means more Ca would have to be supplied from other sources when the samples are sources of food in the diet. The milliequivalent ratios of [K/(Ca + Mg)] in the samples (5.29 – 62.3) were much higher than the recommended 2.2 (Hathcock, 1985). These abnormal high levels were contributed by the relatively high values of K compared to low levels of Ca. Both elements would need adjustment in order to avoid the risk of hypomagnesaemia in man (NRC, 1989).

Table 4: Mineral and calculated mineral ratios (mg/100g) of five insect samples

Parameters	B1	T1	E2	G2	KW	Mean	SD	CV%	χ^2	TV	Rrk
Sodium	369	402	370	273	140	311	107	34.4	147	9.49	S
Potassium	198	209	2515	782	710	883	952	108	4109	9.49	S
Calcium	18.0	22.8	19.5	9.39	17.6	17.5	4.95	28.3	5.62	9.49	NS
Magnesium	56.8	54.9	61.2	17.4	105	59.1	31.1	52.3	65.6	9.49	S
Zinc	30.0	27.3	34.6	15.3	45.2	30.5	10.9	35.7	15.6	9.49	S
Iron	11.2	9.48	12.7	13.7	22.5	13.9	5.06	36.4	7.35	9.49	NS
Copper	0.180	ND	0.097	0.196	0.177	–	–	–	–	9.49	–
Lead	0.00	0.00	0.00	ND	ND	–	–	–	–	9.49	–
Cadmium	0.090	0.228	0.390	0.196	0.355	0.252	0.122	48.4	0.237	9.49	NS
Manganese	1.08	2.35	2.35	2.94	4.25	2.59	1.15	44.4	2.03	9.49	NS
Phosphorus	618	710	864	1443	1198	967	346	35.8	480	9.49	S
Cobalt	1.89	1.59	2.14	3.13	3.55	2.46	0.840	34.1	0.844	9.49	NS
Ca/P	0.029	0.032	0.023	0.007	0.015	0.021	0.010	47.6	0.020	9.49	NS
Na/K	1.86	1.92	0.147	0.349	0.197	0.895	0.912	102	3.72	9.49	NS
Ca/Mg	0.317	0.415	0.319	0.540	0.168	0.352	0.137	38.9	0.215	9.49	NS
K/Na	0.537	0.520	6.80	2.86	5.07	3.16	2.78	88.0	9.77	9.49	S
K/(Ca + Mg)	5.29	5.38	62.3	58.4	11.6	28.6	29.1	102	119	9.49	S

ND = Not detected; **–** = Not determined

Table 5: Mineral safety index (MSI) of the insect samples

Minerals	B_1			T_1			E_2			G_2			KW		
	TV	CV	D	TV	CV	D	TV	CV	D	TV	CV	D	TV	CV	D
Sodium	4.80	3.54	1.26	4.80	3.86	0.941	4.80	3.55	1.25	4.80	2.62	2.18	4.80	1.34	3.46
Calcium	10.0	0.150	9.85	10.0	0.190	9.81	10.0	0.163	9.84	10.0	0.078	9.92	10.0	0.147	9.85
Magnesium	15.0	2.13	12.9	15.0	2.06	12.9	15.0	2.30	12.7	15.0	0.653	14.3	15.0	3.94	11.1
Zinc	33.0	66.0	-33	33.0	60.1	-27.1	33.0	76.1	-43.1	33.0	33.7	-0.660	33.0	99.4	-66.4
Iron	6.70	5.0	1.70	6.70	4.23	2.47	6.70	5.67	1.03	6.70	6.12	0.581	6.70	10.1	-3.35
Copper	33.0	1.98	31.0	33.0	-	-	33.0	1.07	31.9	33.0	2.16	30.8	33.0	1.95	31.1
Phosphorus	10.0	5.15	4.85	10.0	0.043	9.96	10.0	7.20	2.80	10.0	12.0	-2.03	10.0	9.98	0.017

The mineral safety indexes (MSI) of the insect samples are depicted in Table 5. The standard MSI for the elements are Na (4.8), Mg (15), P (10), Ca (10), Fe (6.7), Cu (33), and Zn (33) (Hathcock, 1985). For example, the recommended adult intake (RAI) of Na is 500 mg and the minimum toxic dose (MTD) is 2 400 mg or 4.8 times the recommended daily average (RDA). This is equivalent to the standard MSI of Na. The same reason applies to other minerals whose MSI are determined. The MSI values for Na ranged from 1.34 KW in to 3.86 in (T_1) with all the differences between the standard and calculated MSI values being positive (19.6 – 72.1). This implied that the body might not be overloaded with Na by any of the insects; therefore the risk of secondary hypertension would be avoided (Nieman *et al.*, 1992).

The calculated MSI for Ca (0.078 – 0.190), Mg (0.653 – 3.94) and Cu (1.07 – 2.16) were lower than those in Table values (10, 15 and 33, respectively). These are within the USRDA (Hathcock, 1985). Minerals whose MSI values were higher than the Table MSI were Zn (all the samples) at - 66.4 to - 0.66, Fe (*Sitophilus zeamais*) at – 3.35 and P (*O. boas*) at -2 .03. Iron and P overload would only come from one out of the five samples where the calculated MSI was higher than the Table MSI by 50% (Fe) and 20.3% (P) (Hathcock, 1985). Iron overload was 75% and 100% for different organs of *Numidia Meleagris* (Adeyeye, 2014) and four samples of fast foods (Adeyeye *et al.*, 2012) respectively. Excess Zn would come from all the samples (100%) as it was also reported for four samples of fast food (Adeyeye *et al.*, 2012). The minimum toxic dose (MTD) for Zn is 500 mg, or 33 times the RDA (Hathcock, 1985). High doses of Zn can decrease the amount of high density lipoprotein (HDL) circulating in the blood hence, increasing the risk of heart disease and excess Zn interacts with other minerals such as Cu and Fe, decreasing their absorption (Adeyeye, 2014). Excess Zn can also decrease the functioning of the immune system and 3.5 mg / day Zn intake above the RDA decreases Cu absorption (Nieman *et al.*, 1992).

Conclusion

The insect samples varied in their proximate and mineral compositions. The insects were good sources of protein and carbohydrate. They were in PEF% (< 30 – 35%) and PEC%. The Ca/P and [K/ (Ca + Mg)] ratios were poor in the insects. All the samples had good levels of Na/K ratios. All the insects samples were overloaded with Zinc but none was overloaded with Na.

References

Adeyeye EI 1994. Determination of trace heavy metals in *Illisha africana* fish and in associated water and soil sediments from some fish ponds. *Int. J. Environ. Studies* 45: 231 – 238.

Adeyeye EI 1996. Waste yield, proximate and mineral composition of three different types of land snails found in Nigerian. *Int. J. Food Sci. Nutr*., 47: 111-116.

Adeyeye EI 2008. Proximate composition, nutritionally valuable minerals and the effects of some salts on the foundational properties of silkworm (*Anaphe infracta)* Larvae. *Pak. J. Sci. Ind . Res*, 51 (2): 77 – 85.

Adeyeye EI 2011. Effects of processing on the nutritional and anti-nutritional factors of *Arachis hypogaea* Linn (groundnut) seed flour. *Int. J. Chem. Sci*., 4 (1): 131-142.

Adeyeye EI 2014. Proximate, Mineral composition and mineral safety Index of eight organs of Guinea fowl (*Numidia meleagris). Frontiers in food science and technology*, 1 (1): 7 – 13.

Adeyeye EI & Awokunmi EE 2010.Chemical composition of female and male giant African crickets, *Brachytrypes membranaceus* L. *International Journal of Pharma and bio. Sciences*. 5 (4): 125-136.

Adeyeye EI & Faleye FJ 2004. Mineral composition important for health from animal sources. *Pack. J. Sci. Ind. Res*., 47 (6): 471 – 477.

Adeyeye EI, Orisakeye OT & Oyarekua MA 2012. Composition, mineral safety index, calcium, zinc and phytate interrelationships in four fast-foods consumed in Nigeria. *Bull. Chem. Soc. Ethiop*., Vol. 26 (1) pp. 43-54.

Adeyeye EI, Oyarekma MA & Adesina AJ 2014. Proximate, mineral, amino acid composition and mineral safety index of *Callinectes laminates. International Journal of Development Research*, Vol 4, Issue 12, pp. 2641 – 2649.

Afiukwa JN, Okereke C & Odo MO 2013. Evaluation of proximate and mineral contents of termite (*Trinervitermes germinatus)* from Abakaliki and Ndieze izzi, Ebonyi state, Nigeria. *Am. J. Food. Nutr,* 3 (3): 98-104.

Albanese AA 1959. Protein and amino acid nutrition. New York and London. *Academic Press*, pp 297-347.

AOAC 2010. Official Methods of Analysis, 18th ed., AOAC International, Maryland U.S.A.

Aremu MO, Olanisakin A, Atolaya BO & Ogbu CF 2006. Some nutritional and functional studies of *Prosopis africana*. *Electronic Journal of Agricultural and Food Chemistry*, 5 (6): 1640-1648.

Bender A 1992. Meat and meat products in human nutrition in developing countries. FAO Food and Nutrition Paper, 53, FAO, Rome, Italy, pp 46-47.

Bodenheimer FS 1951. Insects as human food; a chapter of the ecology of man.*The Hague, Dr. W. Junk Publishers*, pp. 352.

CABI 2010. *Sitophillus zeamais* (maize weevil) datasheet crop protection compendium, 2010 Edition. CAB international publishing Wallingford, U K. www.cabi.org/cpc. Accessed on 28 Jan., 2010.

Chen PP, Wongsiri S, Jamyanya T, Rinderer, TE Vongsamanode S, Matsuka, M Sylvester HA & Oldroyd BP 1998. Honey bees and other edible insects used as human food in Thailand. *American Entomologist*, 44 (1): 24-28.

Chesworth J 1992. Ruminant Nutrition. London, CTA Macmillan, pp 170.

Delong DM 1960. Man in a world of insects. *The Obio Journal of Science*, 60 (4): 193-206.

ENE JC 1963. Insects and man in West Africa. *Ibadan University Press, Ibadan*.

FAO 1997. Human Nutrition in Development World FAO Food Nutrition Series No. 29, Rome, FAO. ISSN: 1014-3181.

FAO 2008. Forest insects as food: Humans bite back. *Forest News.* Vol. 22, 1. (www.fao.org/world/regional/rap/tigerpaper/Paper/TP35_1_FN.pdf)

Fasoranti JO & Ajiboye DO 1993. Some edible insects of Kwara State, Nigeria.*American Entomologist,* 39 (2): 113-116.

Fleck H 1976. Introduction to Nutrition, 3rd ed. Macmillan, New York, USA, pp. 207-219.

Ghazoul J 2006. Mopane woodlands and the mopane worm: Enhancing rural livelihoods and resource sustainability. *Final technical report. London, DFID.*

Hathcock JN 1985. Quantitative evaluation of vitamin safety. *Pharmacy Times*, 104 – 113.

Hegsted DM 1973. Calcium and phosphorus. In modern nutrition in health and disease, ch. 6, sect. A. Philadelphia, PA, Lea and Febiger.

Kozanayi W & Frost P 2002. Marketing of mopane worm in Southern Zimbabwe. Harare, Institute of Environmental Studies, pp 31.

LI, Ting-KAI & Vallee BL 1973. The biochemical and nutritional role of trace elements. In *Modern Nutrition in health and disease*, eds RS Goodhart and ME Shils, chap. 8, p. 384. Lea and Febigaer: Philadelphia..

Maria CA & Walter SS 2005. Phylogenetic relationships of honey bees (Hymenoptera: Apinae: Apini) inferred from nuclear and mitochnrodrial DNA sequence data. Modecular phytogenetics and evolutions 37 (1): 25 – 35.

Michael SE 1999.The taxanomy of recent and fossil honey bees (Hymenoptera: Apidae; Apis). *Journal of Hymenoptera Research* 8, 165 – 196.

Moldswer M, Zimmerman SJ & Collins LC 1965. Incidence of osteroporosis in elderly whites and elderly Negroes. *J. Am. Med. Assoc*., 194 (8), 859 – 862.

NAS 1971. Food and Nutrition Board: zinc in human nutrition. In *Introduction to nutrition*, Fleck H (ed.), 3rd edn., Macmillan Publishing Co. Inc, New York, pp. 1-552.

National Research Council 1989. Recommended Daily Allowances, 10th edn. National Academic Press, Washington DC, USA. *http://www.nap.edu/books/0309046335/html/*

Newton-John HF & Morgan DB 1968. Osteoporosis: disease or senescence. *Lancet* Vol. 7561 (1) pp. 26 – 28.

Nieman DC, Butterworth DE & Nieman CN 1992. Nutrition., Butterworth DE, Nieman CN 1992. Nutrition, Wm C. Brown Publishers, Dubuque, pp. 1-540.

Olaleye AA, Adeyeye EI & Adesina A J 2013. Chemical composition of bambara groundnut (*V. Subterranean* L. Verdc) seed parts. *Bangladesh J.Sci.Ind.Res.* 48 (3): 167-178.

Olaofe O, Arogundade LA, Adeyeye EI & Falusi AM 1998. Composition and food properties of the variegated grasshopper, *Zonocerus variegatus*. *Tropical Sci*., 38: 233-237.

Oloyo RA 2001. Fundamentals of research methodology for social and applied sciences, ROA educational press, Ilaro, Nigeria, pp. 96-99.

Pearson D 1976. Chemical analysis of foods, 7th ed.*J.A.* Churchill, London, UK, pp 7-11.

Pew Initiative on Food and Biotechnology (2007). Application of Biotechnology for Functional Foods. University of Richmond, USA.

Pratt EL & Snyderman SE 1953. Pediatrics 12:241. In: Albanese A.A. ed. (1959). Protein and amino acid nutrition New York and London, *Acadmic Press*, 300-301.

Quinn PJ 1959. Foods and feeding habits of the Pedi, Wilwatersrand University, Johannesbury Republic of South Africa, pp. 278.

Rose AG 1967. A critique of modern methods of diagnosis and treatment of osteoporosis. *Clin Orthopol* Vol. .55 pp. 17-41.

Sandstead HH 1967. Present knowledge of minerals. In: *Knowledge in nutrition.* Chap 28, Nutrition Foundation New York, USA. In: *Introduction to Nutrition*, 3rd ed. Ed Fleck, H. *Macmillan, New York, USA*, pp 204.

Shils ME 1973. Magnesium In: Introduction to Nutrition Fleck H.(ed) 3rd edn. Macmillan Co. Inc. New York, p. 215.

Snively WD Jr; & Wessner M 1954. The ABC,s of fluid balance. *Journal of Indian Medical Assciation*, 47, 47, 957-972.

Stack J, Dorward A, Gondo T, Frost P, Taylor F & Kurebgaseka N 2003. Mopane worm utilization and rural livelihoods in Southern Africa.*Paper presented at the International Conference on Rural Livelihoods, Forests and Biodiversity, Bonn, Germany*, 19-23.

Steel RGD & Torrie JH 1960. Principles and procedures of statistics. Mc Graw-Hill, London, UK, pp. 7-30.

Wheby CK 1974. Systemic effects or iron deficiency. In Iron, Ed. W.H. Crosby, New York, Medicom, pp. 39-45.

White House Conferences 1932. Growth and development of the child, III. *Nutrition*. New York: Appleton-Century.Crofts: New York. In: Albanese, A.A. ed. Protein and amino acid nutrition, Academic Press New York; 1959; pp. 297-347.

WHO 2001. Water-related diseases: Malnutrition Available at http:/www.who.int/water_sanitation_health/diseases/malnutrition/en/