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Vitamin Contents of Ten Species of Edible Insects Commonly Found in Southwest Nigeria: Nutritional Implications

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ABSTRACT

Insects are among the most diverse types of animals within the arthropod group that are usually collected for food and feed. The vitamin profile of ten insect samples: adult bee, bee brood, winged termite, termite soldier, mopane worm, scarab beetle, snout beetle, maize weevil, silkworm larva and silkworm pupa were investigated using standard analytical methods. Among the water-soluble vitamins investigated, vitamin B_3 (niacin) had the highest concentration in each of the samples with values 4.57-7.33mg/100g whilst vitamin C (9.27e-5-1.34e-4) recorded the lowest concentration. Other water-soluble vitamins (mg/100g) determined were B_1: 0.050-0.096, B_2: 0.261-0.387, B_5: 1.48e-3-4.14e-3, B_6: 0.124-0.156 and B_9: 6.55e-3-8.58e-3. Vitamin E (1.50-2.48mg/100g) was most concentrated among the fat-soluble vitamins investigated followed by vitamin A (0.021-0.110mg/100g) whilst vitamin K (6.63e-4-1.04e-3mg/100g) had the least concentration. The statistical analysis using Chi-square at α = 0.05 showed that no significant differences existed among the samples in the parameters determined. This research work has therefore provided more useful and reliable information on the vitamins composition of the analyzed ten insect samples that could enhance their usefulness and applications in Food industry.

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 groups of animals that may be found in nearly all environments including the oceans. 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). 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 (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).

Winged termites (*Macrotermes bellicosus*) are the commonly eaten termites specie especially in south western Nigeria. They are usually collected while on their nuptial flight or picked from the ground after they have shed their wings.

A honey bee (*Apis mellifera*) is any member of the genus *Apis*, primarily distinguished by the production and storage of honey and the construction of perennial, colonial nest from wax. Currently, only seven species of honey bee are recognized with a total of forty-four subspecies (Michael, 1999). Today's honey bees constitute three clades: drones (males) produced from unfertilized eggs, i.e. have only a mother; workers and queens (both females) result from fertilized eggs (i.e. have both a father and a mother) (Maria and Walter, 2005). Along with wasps, honey bees are the most important food insects in northern Thailand (Chen et al., 1998).

Mopane worm (*Imbrasia belina*) is arguably the most popular among the moths. About 9.5 billion mopane caterpillars are harvested annually in southern Africa (Ghazoul, 2006). Vast number of people partakes in the mopane harvest and are willing to travel hundreds of kilometers across the mopane woodlands in search of the insects (Kozanayi and Frost, 2002). Though the caterpillars are important sources of nutrition in lean times, they also form a regular part of the diet (Stack et al., 2003).

Maize weevil (*Sitophilus zeamais*) is found in all warm and tropical parts of the word. It is a pest in stored maize, dried cassava, yam, common sorghum and wheat. Both adults and larvae feed on maize grains. Eggs, larval and pupal stages are all found within tunnels and chambers bored in the grains and are thus not normally seen. Adults emerge from the grain and can be seen walking over the grain surfaces (CABI, 2010). Scarab beetles larvae (*Oryctes boas*) are widely distributed throughout Africa, southern Asia and south America.

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They are typically collected, washed and fried for consumption (Fasoranti and Ajiboye, 1993). It is unusual to add oil because the larvae exude enough oil during the frying process. Their delicious flavour is credited to their elevated fat content (Fasoranti and Ajiboye, 1993).

The fact remains that people need to consume adequate calories and nutrients. The wide spread malnutrition prevalent among the rural communities in Africa is typically due 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. 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 food composition tables and promote their consumption.

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^{o}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

The vitamin content of the insect samples was analyzed by following the modified methods of AOAC (2005) [MTHD 992.03, 992.04 and 992.26]. The sample was made to attain laboratory atmospheric condition on the bench after being removed from the storage chamber at less than 4^{o}C. The sample was pressed and completely homogenized in the mortar carefully with pestle to avoid forming balls. 0.1 g of each insect sample was weighed into 10 ml beaker capacity. The sample was extracted in the container by the above methods. The extracted sample was concentrated to 1.0 ml for the chromatographic analysis.

GC conditions for the analysis of vitamins

GC: HP5890 powered with HP ChemStation rev. A 09.01(1206) software

Injection Type:	Split injection
Split Ratio:	20:1
Carrier Gas:	Nitrogen, Flow rate- 30 ml/min
Inlet Temperature:	250°C
Column Type:	HP 5
Column Dimensio	30m x 0.25mm x 0.25µm
Oven Programme:	Initial temperature at 50°C
	First ramping at 10°C/min for 20min, maintained for 4min
	Second ramping at 15°C/min for 4min, maintained for 5min
Detector:	PFPD
Detector Temperature:	320°C
Hydrogen Pressure:	20psi
Compressed Air:	30 psi

Results and discussion

The common and scientific names of ten edible insects commonly found in southwest Nigeria used for this study are shown in Table 1. The insects analysed were two species of hymenoptera (*Apis mellifera*), two species of isoptera (*Macrotermes bellicosus*), three species of lepidoptera (*Imbrasia belina* and *Bombyx mori*) and three species of coleoptera (*Oryctes boas* larva and *Sitophilus zeamais*).

Table 2 depicts the levels of various vitamins contents (both water and fat-soluble) of the insect samples. The vitamins determined were (water-soluble): thiamin (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxamine (B_6), folic acid (B_9) and ascorbic acid (Vit C); (fat soluble): retinol (vitamin A), tocopherol (vitamin E) and phylloquinone (vitamin K).

The levels of vitamin B_1 in the samples were 0.050-0.096mg/100g. Thiamin (B_1) functions in the body in the form of thiamin pyrophosphate (TPP), the co-enzyme for the transfer of active aldehyde in carbohydrate metabolism and decarboxylation of α-keto acids such as pyruvate (NRC, 1989). The requirements of vitamin B_1 is directly correlated with carbohydrate intake and increases as the metabolic rate increases due to pregnancy, lactation or increased physical exercise (NRC, 1989). For those whose total caloric intake is less than 2000kcal, at least 1.0mg/day is recommended, men and women (19-50years) in the 1985 survey averaged 0.7mg/1000kcal whereas children (1-5years) averaged 0.79mg/100kcal (USDA, 1987). Severe thiamin (B_1) deficiency was observed in patients with tumors of the lymphoid-hematopietic system (De Reuck *et al*., 1980). Since all the patients had gastrointestinal bleeding, hepatic failure and sepsis, the authors suggested that malabsorption was a probable cause of the thiamin deficiency. Therefore there may be no direct relationship between vitamin B_1 and tumorigenisis; rather, thiamin deficiency may be a secondary effect of malnutrition. The levels of thiamin in this study were fairly higher than 0.021-0.022mg/100g in cosmas variety seeds and 0.016-0.017mg/100g in sassako variety seeds (Gwana *et al*., 2014), but they were comparatively lower than the recommended daily allowance (RDA). Hence foods rich in thiamin have to be taken alongside the insect samples in order to meet the RDA.

Vitamin B_2 (riboflavin) in the present study ranged between 0.261-0.387mg/100g. The accumulation of fat in the liver in riboflavin deficient person resembles changes observed in the liver of chronic alcoholics. In humans with liver cirrhosis, decreased concentration of vitamin B_2 is found mostly in necrotic regions (Chen and Liano, 1960). Diets lack in riboflavin can lead to the development of cuteneous lesions, which includes hyperkeratosis, gross derangement of

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*
B_2	Hymenoptera Apidae	Oyin	Bee brood	*Apis mellifera*
T_1	Isoptera Termitidae	Esunsun	Winged termite	*Macrotermes bellicosus*
T_2	Isoptera Termitidae	Ikan	Termite soldier	*Macrotermes bellicosus*
E_2	Lepidoptera Notodontidae	Kanyin	Mopane worm	*Imbrasia belina*
G_2	Coleoptera Scarabaeidae	Gongo	Scarab	*Oryctes boas*
P_2	Coleoptera Curculionidae	Itun	Snout beetle	*Rhynchophorus phoenicis*
KW	Coleoptera Scarabaeidae	Kokoro agbado	Maize weevil	*Sitophilus zeamais*
SWL	Lepidoptera Bombycidae	Eruku	Silkwom larva	*Bombyx mori*
SWP	Lepidoptera Bombycidae	Eruku	Silkwom pupa	*Bombyx mori*

keratonisation with acathosis and impressive pseudocarcinomatous hyperplasia (Foy and Kondi, 1984). Deficiency of riboflavin in mice have been reported to alter hepatic architecture, including enlargement and distortion of mitochondria, possibly due to defects in oxidative phosphorylation resulting from lack of flavoproteins (Tandler *et al*., 1968). It has also been reported that consumption of alcohol can reduce intestinal bioavailability of riboflavin, particularly flavin adenine dinucleotide (FAD) (Pinto *et al*., 1984). The 1980 recommended daily allowance is 0.6mg/1000kcal; a minimum of 1.2mg/day had been recommended for those whose caloric intake is less than 2000kcal/day. The 1985 mean intake of riboflavin for men and women, 19-50years was 0.82mg/1000kcal and 0.88mg/1000kcal respectively; for children 1-5years, it was 1.12mg/1000kcal (USDA, 1987). The values of vitamin B_2 in the present report were generally low and would require supplementation with riboflavin-rich foods.

The niacin (vitamin B_3) levels in the insect samples were 4.57-7.33mg/100g. The term niacin has been used generally to encompass the active forms of this vitamin, nicotinic acid and nicotinamide; however, estimates of niacin requirements take into account preformed niacin as well as that obtained as niacin equivalent in the body from tryptophan (Trp) metabolism. Hence, it was estimated that when 60mg of Trp is consumed by an adult, enough of Trp is oxidized to produce 1.0mg of niacin (NRC, 1980). In 1980, RDA of niacin was 6.6 niacin equivalent (NE) per 1000kcal and intake not less than basic NE had been recommended when the caloric intake is less than 2000kcal; one NE is equivalent to 1.0mg niacin (or 60mg Trp) (NRC, 1989).

The levels of pantothenic acid (vitamin B_5) in the samples ranged between 0.00148-0.00414mg/100g. It has been reported that vitamin B_5 are often more concentrated in the liver than other tissues (NRC, 1989) and symptoms such as malaise and abdominal distress may be related to deficiency of pantothenic acid (Olson, 1984). Human and animal studies have shown that some Japanese populations with endemic vitamin B_5 deficiency also had an increased prevalence of hypertension (Koyanagi *et al*., 1966). The values of pantothenic acid were generally low in the present study.

The concentrations of vitamin B_6 (folic acid) were in the range 0.124-0.156mg/100g. The highest and lowest concentrations were observed in bee brood and maize weevil respectively. Vitamin B_6 is a generic name used for pyridoxine, pyridoxal and pyridoxamine, the co-enzyme forms of which are pyrodixal phosphate and pyridoxamine phosphate (NRC, 1989). Vitamin B_6 is needed in the synthesis of DNA bases; it is a co-enzyme in the biosynthesis of thymedine. A dietary vitamin B_6 deficiency or an increase in the thymedine requirement at a critical time during cell division could result in initial cell mutations that develop into a tumor (Prior, 1985). The 1980 recommended daily allowance for adult females was 2.0mg/day, assuming a protein intake of 100g/day; for adult males, it was 2.2mg/day, assuming a protein intake of 110g/day; a lower allowance would be appropriate for those with lower protein intakes (Lee, 2000). The RDAs were based on a ratio of 0.02mg of vitamin B_6 per gram of protein consumed. The present levels generally fell below the RDA standards but higher than the levels reported for rosmas variety seeds (0.046-0.049mg/100g) and sassako variety seeds (0.044-0.045mg/100g) (Gwana *et al*., 2014).

Folic acid (vitamin B_9) has been reported to inhibit growth of tumors (Prentice *et al*., 1985; Lee, 2000).

Folacin, the co-enzyme of vitamin B_9 (folic acid) is needed for the synthesis of purine and methionine, for the catabolism of histidine, and for the conversion of serine to glycine (NRC, 1989). The levels of folic acid in the present report (0.00655-0.00858mg/100g) were comparatively lower than the RDA: 400mg/day (person $\geq$ 11years), 189mg/day (women of 19-50years) and 305mg/day (men of 19-50years) (USDA, 1986). Among the water-soluble vitamins, vitamin C (ascorbic acid) had the least concentrations (mg/100g) with values ranging between 9.27e-5 to 1.34e-4.

Vitamin C is active in the body either as ascorbic acid or as dehydro ascorbic acid. There is a clear link between the functions of vitamin C and its reversible oxidation and reduction properties. It plays important roles in many biochemical reactions, such as mixed-function oxidation involving incorporation of oxygen into the substrate (Lee, 2000). Also, tissue defence mechanisms against free radical damage generally involve vitamin C, vitamin E and B-carotene as the major vitamin anti-oxidants in extracellular fluids (Stocker and Frei, 1991). Vitamin C can also help in the metabolic oxidation of certain amino acids, including tyrosine and appears to prevent the inhibition of the enzyme P-hydroxyphenyl pyruvic acid in tyrosine metabolism sequence (Lee, 2000). The RDA of vitamin C for adults (60mg/day) maintains a body pool of 1.5g and 10mg/day is sufficient to prevent orcure scurvy (NRC, 1980). The present vitamin C levels were lower than those in (mg/100g): grape fruits (34.0-45.0), melons (25.0), spinach (10.0-60.0), lemons (80.0) and blackberries (20.0) (Nobile and Woodhill, 1981; Lee, 2000).

Fat-soluble vitamins are so called because they are not soluble in water but soluble in fat and organic solvents and are absorbed and transported in a manner similar to that of fats (Lee, 2000). Vitamin A in the present report ranged between 0.021-0.110mg/100g. Vitamin A is needed for the maintenance of normal mucous membranes and for normal vision. Nutrition surveys in the United States indicated that serious vitamin A deficiency does not occur frequently, however, borderline serum concentrations of vitamin A and reduced liver stores of vitamin A have been observed at autopsy (Underwood, 1984; Goodman, 1984). The values of tocopherols (vitamin E) in this study ranged between 1.50-2.48mg/100g. Although, these levels are moderately high, they may not be able to meet the RDAs for vitamin E: 10mg α–tocopherol equivalents (α-TE) (15 IU) for males aged 15years or older and 8mg of α-TE (12 IU) for females aged 11 and older (NRC, 1989). The need for vitamin E is increased if the polyunsaturated fat intake is high, but in the United States food supply, foods with high levels of polyunsaturated fatty acids also have high vitamin E content (NRC, 1989). Vitamin E is an important antioxidant that protect against free radicals implicated in cell damage leading to abnormal ageing and to the development of neoplasia, but few reports of vitamin E deficiency in humans have been shown except in premature baby (Oski and Barness, 1967).

Vitamin K (mg/100g) values ranged between 6.63e-4 to 1.04e-3 and had the least concentrations among the fat-soluble vitamins determined.Vitamin K is needed in the liver for the formation of several blood clotting factors. Food and Nutrition Board Committee had estimated the safe and adequate intake range of vitamin K for adults as 70-140µg/day (NRC, 1989); this range is above the range of values in the present report.

Table 2. Levels of vitamins content (mg/100g) in the insect samples.

Vitamins	B_1	B_2	T_1	T_2	E_2	G_2	P_2	KW	SWL	SWP	Mean	SD	CV%	χ^2	R
B_1	0.086	0.087	0.078	0.050	0.087	0.070	0.086	0.096	0.068	0.070	0.078	0.013	16.7	0.021	NS
B_2	0.338	0.379	0.315	0.261	0.377	0.301	0.338	0.387	0.294	0.298	0.329	0.042	12.8	0.405	NS
B_3	6.72	6.76	7.33	4.57	6.68	5.02	6.95	6.25	4.60	4.70	5.96	1.10	18.5	1.83	NS
B_5	$4.14e^{-3}$	$3.89e^{-3}$	$3.62e^{-3}$	$1.48e^{-3}$	$3.95e^{-3}$	$1.84e^{-3}$	$4.10e^{-3}$	$3.21e^{-3}$	$1.82e^{-3}$	$1.84\ e^{-3}$	$2.99e^{-3}$	$1.11e^{-3}$	37.1	0.004	NS
B_6	0.152	0.156	0.127	0.134	0.154	0.145	0.142	0.124	0.142	0.148	0.142	0.011	7.75	0.008	NS
B_9	$7.10e^{-3}$	$8.58e^{-3}$	$6.55e^{-3}$	$7.09e^{-3}$	$8.54e^{-3}$	$7.09e^{-3}$	$7.02e^{-3}$	$7.21e^{-3}$	$7.07e^{-3}$	$6.91e^{-3}$	$7.32e^{-3}$	$6.80e^{-4}$	9.29	$5.86e^{-4}$	NS
C	$1.31e^{-4}$	$1.22e^{-4}$	$1.34e^{-4}$	$9.27e^{-5}$	$1.21e^{-4}$	$9.53e^{-5}$	$1.31e^{-4}$	$1.30e^{-4}$	$1.03e^{-4}$	$1.02e^{-4}$	$1.16e^{-4}$	$1.62e^{-5}$	14.0	$2.04e^{-5}$	NS
Total WSV	7.31	7.39	7.86	4.71	7.31	5.55	7.53	6.87	5.11	5.22	6.49	1.19	18.3	1.98	NS
A	0.085	0.097	0.078	0.024	0.097	0.022	0.110	0.085	0.022	0.021	0.064	0.037	57.8	0.193	NS
E	1.55	1.69	1.56	2.14	1.68	2.48	1.54	1.50	2.19	2.17	1.85	0.357	19.3	0.620	NS
K	$7.90e^{-4}$	$1.03e^{-3}$	$6.63e^{-4}$	$9.78e^{-4}$	$1.02e^{-3}$	$1.04e^{-3}$	$7.86e^{-4}$	$7.40e^{-4}$	$9.80e^{-4}$	$1.01e^{-3}$	$9.04e^{-3}$	$1.42e^{-4}$	1.57	0.073	NS
Total FSV	1.64	1.79	1.64	2.16	1.78	2.50	1.65	1.59	2.21	2.19	1.92	0.321	16.7	0.482	NS
Grand total	8.95	9.18	9.50	6.87	9.09	8.05	9.18	8.46	7.32	7.41	8.40	0.932	11.1	0.931	NS

WSV = water-soluble vitamin, FSV = fat-soluble vitamin, R = remark, NS = not significant

Conclusion

Among the vitamins determined, vitamin B_3 (niacin) was the major water-soluble vitamin in all the samples; vitamin E (tocopherol) was most abundant among the fat-soluble vitamins. High contents of these vitamins in the samples would promote blood circulation, maintain normal functioning of the brain and protect cell membranes from oxidative stress. Statistical information from the results showed that no significant variation or difference existed among the samples in the parameters determined with the low levels of coefficient of variation percent (CV %) and chi-square (χ^2) results at α = 0.05. This work has therefore given additional information on vitamins in each of the insect samples investigated. The research has also provided useful information on the dietary and health importance of the insects for food industry.

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