NUTRITIONAL COMPOSITION OF SOME INSECTS CONSUMED IN DELTA STATE, NIGERIA

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Abstract: African palm weevil (*Rhynchophorus phoenicus*), termite (*Macrotermes bellicosus*) and cricket (*Brachytrypes spp*) are common palatable species consumed in Delta state and various parts of Africa. This study determined the nutritional composition of these insects. Fresh insects for the experiment were obtained from farms and markets in Abraka, Sapele and Ughelli towns in Delta State. Samples were used both fresh and oven dried at 45^{0}C for 10 min. Crude proteins and fats, Ash, fibre, Carbohydrates, Vitamins C and A, moisture content and gross energy values were determined using standard methods. Results revealed that crude protein (31.2%) was highest in dried African Palm Weevils, while moisture content and crude fat were highest (9.2 and 49.8%) in fresh weevils respectively compared to the other insect forms. Carbohydrate (31.1%) and crude fibre (5.2%) were higher in dried crickets and ash content (7.8%) in dried termites compared to their fresh forms and palm weevils. Vitamin C and A were highest (2.34 and 2.21%) in fresh samples of African palm weevils and, the differences were significant ($p<0.05$) when compared to the dried species and other species. The differences between the proximate composition of edible insects in their fresh and dried forms were significant ($p< 0.05$). Fresh and dried African Palm weevils both had higher caloric content (852.33 and 733.05 Kcal/100g) compared to crickets and termites (fresh and dried). Therefore, insects especially Palm weevils in any form can be adopted as delicacies considering their high protein and fat profiles to serve as cheap, available and alternative sources of proteins for human consumption . This will aid in solving malnutrition issues and in turn boost food security.

Keywords: *Brachytrypes spp.*, Edible insect consumption, *Macrotermes bellicosus*, *Rhynchophorus phoenicus*

Introduction

Insects are well-known and diverse group of animals on the planet earth, having representatives in all environments including the oceans (Premalatha, 2011). Their existence has been dated 400 million years ago with the species rapidly evolving than any other group and classified under the largest subphyla of the arthropods (Gaunt and Miles, 2002). The beneficial roles of insect to man and its environment are encompassing of which some create products valuable to man and his livestock (Omotoso, 2006; Omotoso and Adesola, 2008). However, others cause destruction to his valuable resources (Ojianwuna and Enwemiwe, 2020). The bridge between these two odds is the function of insects in great numbers considered as pests of field crops yet serving as food to man and its livestock. Over the years, insects have served as traditional foods among indigenous people, especially in Africa, Asia and Latin America but they have reduced drastically due to colonization and globalization of Africa, Asia and America (Heinrich and Prieto, 2008; Kagezi *et al.*, 2010; Oibiokpa *et al.*, 2017). According to van Huis *et al.* (2013), an estimated 1900 insect species are considered edible in over 300 ethnics groups in 113 countries worldwide and over 246 species are edible insects in 27 countries in Africa. Ramos-Elorduy (2005) further confirmed Africa as the “hot spot” of edible insects, affirming above 524 edible species from 34 African countries. Studies of Ramos-Elorduy (2005), Alamu *et al.* (2013), and Bernard and Womeni (2017) opined that insects of the order Orthoptera, Lepidoptera, Coleoptera, Hymenoptera, and Isoptera are amongst the highly consumed. In Nigeria, notable studies such as those of Banjo *et al.* (2006), Ntukoyoh *et al.* (2012), Solomon and Prisca (2012), Adeboye *et al.* (2016), and Omotoso and Adesola (2008) have suggested that insects of the order Isoptera, Orthoptera, Coleoptera, Hymenoptera, Hemiptera and Lepidoptera are the major insects consumed. The insects under study including: *Rhynchophorus phoenicus* (Coleoptera: Curculionidae), *Macrotermes bellicosus* (Isoptera: Termitidae) and *Brachytrypes spp.* (Orthoptera: Gryllidae) are variously known as *Odon*, *Ewowor* and *Oror*, *Eruru*, *Atankwoye* and *Ebuzu*, *Doorn*, *Poru*, and *Ikirikri*, *Ikolo*, *Arira*, and *Otete*by the Urhobo, Ibo, Ijaw, and Itsekiri, respectively. These Orders according to Alamu *et al.* (2013) account for 22 identified insect species.

Recently, there has been a clamour for insect inclusion in the processed form of human diets and also as alternative feed sources, and attentions has been ongoing to establish the nutritional content of common edible species to inform entrepreneur on the road map (Adalla and Cervancia, 2010; FAO, 2015; Durst and Hanboonsong, 2015; Caparros *et al.*, 2016). It is a very difficult hurdle to secure highly nutritious food for a growing population especially as situation report of food security has worsened. Insects are promising considering the fact that they predominates more than half of the planet. Studying the proximate composition of edible insect species is the first step to realizing sustainable production of insect. Edible insects are not only found encompassing in nature but are retailed by families from a number of areas in Africa, predominantly Zimbabwe, South Africa, Ivory Coast, Zambia and Nigeria where households make good living from sales. According to Balinga *et al.* (2004) and Agbidye *et al.* (2009) insects are harvested from the wild, processed by women and children, and sold in school premises or alongside vehicular paths. In Delta State, processed insects and their products are particularly sold along the Sapele/Benin road. Among the notable edible species, Ebenebe and Okpoko (2015) reported that the African palm weevil is the majorly vended species along the Onitsha-Owerri expressway in Anambra State. Considering the global growth in human population and the protein deficiencies implicated in the increasing numbers of child and maternal mortality, FAO (2015) has reported that 11% of the world’s population comprising 795 million of humans is undernourished and about 98% of them reside in developing regions. This has prompted search for sustainable nutritional materials to balance up deficiencies. It is imperative to note that malnutrition adversely affects the economy of any nation owing to infuriating poverty, poor growth among children, depreciating future earnings of individuals and decreased growth of a country (FAO, 2008).

Most under-developed or developing nations are faced with the problems of food scarcity and thus importing expensive food as a means to ameliorate hunger among the populace. Thus, recent studies are being diverted from ecological perspective of insects to their application in real life situations (Bernard and Womeni, 2017). The estimation of insect abundance, biomass determination, and their high protein content would not make sense if their historic practice amidst the diverse culture of Africa and Latin America, and their culinary processes are not modernized for future consumptions (Wang *et al.,* 2004). Defoliart (2002) reported that several levels of protein and fat in some insects are generally higher than animal protein sources; considering them as Insects are considered cheapest representatives of animal protein as compared to the expensive, orthodox and conventional sources of animal protein (Jacob *et al.*, 2013) in the world especially Nigeria. Irrespective of the high level of insect consumption and retailing in Delta State, detailed information on their nutritional and essential vitamin composition is scanty hence the need for this study to explore the nutritional composition of the common insects sold and consumed in Delta State.

Materials and Methods

Sample collection and preparation

Samples were collected from farms and markets in Abraka, Sapele/Benin road and Ughelli towns. Samples were collected in zip lock bags, labelled and transported to the Animal and Environmental Biology Laboratory where they were identified by an Entomologist using standard manuals in the Insectary. Insects sampled were maintained in laboratory condition with temperature of 28±2°C and relative humidity of 78±3%, and then sorted to remove the defected ones, rinsed with distilled water, degutted. They were split into two, one part was dried in the oven at 45°C for 10 min and grounded to fine powder using kitchen blender while the other part (fresh) was milled into paste. Experiment was carried out in triplicate in separate airtight containers and analyzed immediately to avoid deterioration. This method was adopted from (Adeyeye and Olaleye, 2016).

Proximate analysis

Crude protein

The Kjeldahl method described by Chang (2003) and adopted from Oibiokpa *et al.* (2017) was used to determine the protein content of the samples. The total nitrogen was determined and multiplied with factor 6.25 to obtain protein content.

Carbohydrate

The carbohydrate content of each sample was calculated by difference as adopted from the AOAC (2000). Thus using the formula described by Ajifolokan and Adeniran, (2016);

% carbohydrate = 100% – (% moisture + % crude protein + % crude fat + % crude fibre + % ash)

Crude fibre

The method of James (1995) was used to determine crude fibre content. Actual weight of the fibre was obtained and calculated as a percentage of the weight of sample analyzed as adopted from Chang (2003);

$$\text{\% Crude Fiber} = \frac{\text{weight of residue} - \text{weight of ash}}{\text{weight of sample}} \times 100$$

Ash content

Ash content of the insect samples was determined by the method of AOAC (2000). Five gram (g) of homogenized samples were weighed into a crucible. Drops of glycerol were then added and mixed thoroughly. The sample was left to scorch slowly over a Bunsen burner. The crucible was transferred into a muffle furnace (Model SX-5-12, Trademark Wincom, China) at about 550°C till a white grey ash was obtained. The crucible was cooled in a desiccator, reweighed and the percentage ash content calculated as:

$$\text{\% Ash} = \frac{\text{weight of ash}}{\text{original weight of sample}} \times 100$$

Moisture content

The moisture content was determined by gravimetric method according to AOAC (2000) using an electro-thermal oven model DHG-9030A. The moisture content was determined using the formula:

$$\text{\% moisture content} = \frac{loss\ in\ weight\ of\ sample}{original\ weight} \times 100$$

Crude fat

5 g of the sample was weighed into a fat free extraction thimble and plugged lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 mL soxhlet flask which has been previously dried in the oven, cooled in a desiccator and weighed. The soxhlet flask was then filled to two-thirds of its capacity with n-hexane and boiled on a heating mantle. The heater was put on for 6 hours with constant running water from the tap for condensation of hexane vapour. The n-hexane was left to siphon over several times and thereafter drained into a stock bottle. The thimble containing the sample was removed and dried. The extractor, flask and condenser were replaced and the distillation continued until the flask was practically dry. The flask containing the oil was detached, its exterior cleaned and dried to weights of the distillation flask represented the oil extracted from the sample and the percentage ether extract was calculated as shown below as adopted from Chang, 2003;

$$\text{\% Ether} = \frac{\text{Extract final weight of flask} - \text{initial weight of flask}}{\text{Sample weight}} \times 100$$

Metabolisable energy

Metabolisable energy of the sample was calculated using Atwater factors as described by Oibiokpa *et al.* (2017).

$$\text{Metabolisable energy} = (\text{protein x 4}) + (\text{lipid x 9}) + (\text{carbohydrate x 4})$$

The sum of these values was expressed in Kcal/100g.

Vitamin analysis

The vitamin A and C contents of the insect samples were determined using various standard analytical procedures.

Vitamin C

Vitamin C content was determined using the method described by Onwuka (2005). 5 g of the sample was homogenised in 45 mL of distilled water and the suspension filtered. 5 mL aliquot of the filtrate was measured into a 250 mL conical flask and 0.1 mL of glacial acetic acid was added. Dichlorophenol indophenol was titrated against the filtrate in the flask until the solution became pale pink. The titre value was taken and then used for the calculation of vitamin C content.

Vitamin A

Vitamin A content was determined by the method described in the Marck Index (2001). 2 g of grounded insect sample was weighed into a flat bottom flask, and 10 mL of distilled water added to the sample and then 25 mL of 0.5 M of alcoholic KOH solution. The mixture was heated on a water bath for an hour and allowed to cool and 30 mL of distilled water was added. The hydrolysate obtained was transferred into a separatory funnel. The solution was extracted three times with 250 mL of chloroform. Two grams (2 g) of anhydrous Na_2SO_4 was added to the extract to remove any trace of water. The mixture was then filtered into 100 mL volumetric flask and made up to mark with chloroform. Standard solution of Vitamin A of range 0 – 50 µg/mL was prepared by dissolving 0.003 g of standard Vitamin A in 100 mL of chloroform. Absorbance of sample and standards were read on the Spectrophotometer (MetrohmSpectronic 21D Model) at a wavelength of 328 nm and vitamin A content was calculated. All reagents used in this study are of analytical grade.

Data analysis

Data obtained were statistically analyzed using analysis of variance (ANOVA) using SPSS version 21. Means were separated using Turkey's test and significant difference was accepted at 5% level of probability ($p < 0.05$).

Results and Discussion

This present study reported the nutritional content of fresh and dried insects commonly consumed in Delta State (Table 1). Crude protein content ranged from 24.7 to 31.2% irrespective of forms. Protein content was observably highest in dried African palm weevils (31%) compared to termites and crickets. The differences between crude proteins were significant ($p < 0.05$) in palm weevils and crickets, but not in termites ($p > 0.05$). Though, the protein content recorded in termites and crickets was low, they can be combined or integrated with other formsof protein to measure up deficiencies. On a general note, the protein contents recorded in fresh and dried insects in this study is lower than the reports of Oibiokpa *et al*. (2017) which recorded protein values of 43.8 and 71.0% for termites and crickets respectively. Similar trend was observed in the protein content reported for seven insect species by Bednavora (2013), of which protein content was relatively same insects except in the wax moth (*G. mellonella*) where protein content was reportedly 38.4% while other species ranged from 50.7% in yellow mealworm beetle (*T. molitor*) to 62.2% for the African migratory locust (*L. migratoria*). The intake of some insects especially termites was linked to nutrient supplement and requirements (Sogbesan and Ugwumba, 2008). On the basis of comparison, the insect proteins reported in this study is considerably higher than those reported in conventional meat, dairy products, fish and plants (Defoliart, 2002; Jacob *et al.,* 2013). This implies the importance of insects in combating malnutrition, should the world adopt their proteins as alternatives. Crude fat was equally highest (49.8%) in the fresh form of African palm weevil compared to other insect species and this was closely followed by the dried forms. Crude fat was low in dried and fresh termites, and crickets. Xiaoming *et al.* (2010) reported average fat in dry samples of insects to be between 10 to 60%, and higher in larval stages compared to adult species. The fat content reported in this study is higher than those reported by Ekpo *et al*. (2009), which found that cholesterol in the termites *Macrotermes bellicosus* and the caterpillar of *Imbrasia belina* average 3.6%.

Carbohydrate and crude fibre recorded in this study was between 5 to 31% and 1.9 to 5.2% respectively irrespective of the form. Carbohydrate and crude fibre was highest in the dried form of cricket (31 and 5.2%), respectively compared to other insect species understudy. However, the fresh forms followed accordingly (26 and 4.7%). Carbohydrate and crude fibre contents were higher in crickets and termites than in African palm weevil. This can be attributed to the chitin nature of the insect exoskeleton compared to those of African palm weevil which has only the anterior part of the body with chitin. Omotoso and Adesola (2018), Bukken (2005) confirmed that the presence of chitin in exoskeleton of insects contribute to the high crude fibre contents. Chitin digestibility has raised some questions and insects endowed with chitin may imply low digestibility considering their complexity but according to Paoletti *et al*. (2007), the enzyme chitinase has been discovered in the human gastric juice to aid the digestion of chitin. Though, chitin has not been confirmed as dietary fibre, but the study of Muzzarrelli *et al*. (2001) affirmed it as good substitute for dietary fibre. Fibre-rich diets according to Oibiokpa *et al.* (2017), Omotoso and Adeola (2018) have been known to slow down the rate of carbohydrate absorption, oblige decreases in the rise of blood sugar and insulin levels. Carbohydrate and fibre contents reported in this present study corroborates with the study of Ntukoyoh *et al*. (2012) that reported the nutritional composition of different stages of termites. Crude fat ranged between 30.2 to 49.8% irrespective of forms. This was reportedly higher in African palm weevil compared to crickets and termites. This substantiates previous findings of Womeni *et al.* (2009) and further supports the findings of Banjo *et al.* (2006) and Alamu *et al.* (2013) that found out that African palm weevil had more crude fat than any other insect.

Ash content was highest in dried termites and this was closely followed by the fresh form (Table 1). The moisture content was high in fresh palm weevils and followed by fresh termites. The ash and moisture content of freshly sampled insects are within the range of 1.7 to 7.8, and 5.3 to 9.2%, respectively. Ash and moisture content was lowest in fresh African palm weevils and dried cricket respectively. This is remarkably higher than those reported in the study of Sani *et al*. (2014) and falls within the study of Ntukoyoh *et al.* (2012). In this present study, the differences recorded in fresh and dried forms of insects implies that drying influenced moisture and ash content of the insect species understudy. The moisture contents reported in this study is not agreement with the study of Ntukoyoh *et al*. (2012) carried out in the Niger Delta region and Sani *et al.* (2014) in Northwestern part of Nigeria. However, the moisture content of insects reported was in accordance with Banjo *et al.* (2006) and Sani *et al*. (2014).Though, variations in moisture content may occur as a result of differences in geographical regions and, this justifies the longevity and shelf life of these insects when processed for incorporations. The differences between the proximate composition of edible insects in their fresh and dried form were significant ($p < 0.05$) (Table 1). The nutritional composition of termites compared favorably to crickets irrespective of forms.

Metabolic energy is represented in terms of calories/gram. The highest metabolisable energy was recorded in the fresh and dried form of African palm weevil representing 852 and 733 kcal/100g, respectively compared to termite and cricket and, this was lowest in the fresh and dried forms of crickets. This can easily be attributed to their high crude fat content of African palm weevil compared to the other insects. High metabolisable energy of insect species can contribute to the daily energy requirements when adopted and incorporated in human diets. The metabolisable energy obtained from our study is in agreement with that of Ramos-Elorduy (2005) which recorded 293 to 762 Kcal/100g, Siulapwa *et al.* (2014) which recorded 385 to 810 kcal/100g and Oibiokpa *et al.* (2017) which recorded 554 to 392 kcal/100g. Food consumables with insect formulations can ameliorate the clamour for alternate protein sources considering the rapid growth of human population.

Table 1: Proximate composition (%) of fresh and dried insects consumed in Delta State

Proximate (%)	Form	Edible Insect Species		
		African Palm Weevil	Termite	Cricket
Crude protein	Fresh	28.42 ± 0.17^{b}	24.71 ± 0.21^{c}	26.31 ± 0.22^{bc}
	Dried	31.23 ± 0.18^{a}	24.96 ± 0.16^{c}	28.47 ± 0.38^{b}
Carbohydrate	Fresh	5.94 ± 0.05^{d}	20.21 ± 0.21^{bc}	26.08 ± 0.02^{b}
	Dried	11.67 ± 0.19^{c}	24.57 ± 0.29^{b}	31.13 ± 0.15^{a}
Crude fibre	Fresh	1.86 ± 0.27^{b}	4.43 ± 1.14^{a}	4.71 ± 1.26^{a}
	Dried	2.13 ± 0.06^{b}	4.56 ± 0.20^{a}	5.15 ± 1.21^{a}
Ash content	Fresh	1.68 ± 0.07^{c}	5.93 ± 1.10^{ab}	2.40 ± 0.22^{bc}
	Dried	4.69 ± 0.06^{b}	7.83 ± 0.04^{a}	2.47 ± 0.03^{bc}
Moisture content	Fresh	9.22 ± 0.11^{a}	8.35 ± 0.14^{a}	6.82 ± 0.12^{b}
	Dried	8.16 ± 0.08^{ab}	6.35 ± 0.13^{b}	5.30 ± 0.25^{b}
Crude fat	Fresh	49.80 ± 0.21^{a}	34.09 ± 0.13^{b}	31.01 ± 0.18^{c}
	Dried	45.20 ± 0.67^{ab}	34.10 ± 0.01^{b}	30.15 ± 1.88^{c}
Energy (Kcal/100g)	Fresh	852.33	477.13	232.97
	Dried	733.05	330.05	175.79

Values are % means of triplicate determinations ± SEM. Values along column for fresh and dried samples with different superscript are significantly different ($p < 0.05$) by Turkey's test.

Table 2: Vitamins A and C contents of fresh and dried insects consumed in Delta State

Proximate (%)	Form	Edible Insect Species		
		African Palm Weevil	Termite	Cricket
Vitamin A	Fresh	2.21±0.24[a]	1.33±0.12[a]	0.76±0.06[b]
	Dried	2.14±0.03[a]	1.11±0.17[ab]	0.68±0.17[b]
Vitamin C	Fresh	2.34±0.02[a]	1.83±0.17[a]	0.96±0.24[b]
	Dried	1.67±0.21[b]	1.08±0.15[ab]	0.85±0.15[b]

Values are % means of triplicate determinations ± SEM in mg/100g. Values along column for fresh and dried samples with different superscript are significantly different ($p < 0.05$) by Turkey's test

Most insects pieces contain varieties of water soluble or lipophilic vitamins (Xiaoming *et al.,* 2010; Oonincx and Dierenfeld, 2012).The vitamins A and C contents of fresh and dried insects consumed in Delta State is presented in Table 2. Vitamin A and C contents reported in this study were adequate, commensurable and not significantly different except with termites. Vitamin A and C was highest in the fresh form of African palm weevils comparing favourably to dried forms. This was followed by termites and crickets. The differences between vitamin A and C in fresh and dried forms of crickets, and vitamin A of African palm weevil were not significant (p>0.05). However, that of termites and vitamin C content of fresh and dried weevils were significantly different (p< 0.05). Though, vitamin C of fresh and dried palm weevils were significantly different (p <0.05). Similar results of vitamin content by Agbemafle *et al*. (2012), Igwemmar *et al*. (2013) and Sengeung *et al*. (2018) suggested that vitamin A and C are water soluble and temperature sensitive vitamins, hence their tendency of being easily degraded during heating. More so, Sengeung *et al.* (2018) opined that the retention of vitamins is highly associated to the method used and heating. They demonstrated that microwaved vegetables had higher vitamins compared to boiling, blanching and steaming. The high vitamin content recorded in this study may be due to the fact that samples were microwaved rather than solarized. In comparing fresh insect samples to dried forms heated in the oven at 45ºC for 10 min, there was no significant difference (p>0.05); African palm weevil recording the highest value for vitamin C and A. However significant differences (p<0.05) was observed within the three insect species. The vitamin content of the insect species in this present study corroborate those in studies of Banjo *et al.* (2006), Ntukoyoh *et al*. (2012), and Oibiokpa *et al*. (2017). Vitamins are essential micronutrients required for cellular capacities and variations in vitamin A and C content in various insects has equally been reported by Banjo *et al*. (2006), Ntukoyoh *et al*. (2012), van Huis *et al*. (2013) and Oibiokpa *et al*. (2017). Generally, drying influence the nutritional composition of insect samples. However, results from this present study revealed that there was significant difference (p<0.05) between the proximate composition of dried and fresh insect species.

Conclusion

This study show that the nutritional content of African Palm Weevil was highest compared to termites and crickets. The insects under study have shown to be good sources of proteins, fat and considerable amount of vitamins. Calories value of palm weevils was higher compared to other insects. Their consumption in Delta State and environs would serve as alternative protein while playing a key role in food security, environment management and health considering their nutritional requisites.

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Conflict of Interest

Authors declare that there is no conflict of interest related to this work.

References

Adalla CB & Cervancia CR 2010. Philippine edible insects: a new opportunity to bridge the protein gap of resource-poor families and to manage pests. In: Forest insects as food: Humans bite back. Proceedings of a Workshop on Asia-Pacific Resources and their Potential for Development, pp. 151 – 160.

Adeboye O, Bolaji T & Fatola L 2016. Nutritional composition and sensory evaluation of cookies made from wheat and palm weevil larvae flour blends. *Annals Food Sci. and Tech.,* 17(2): 543-548.

Adeyeye I & Olaleye A 2016. Nutrient Content of Five Species of Edible Insects Consumed in South-West Nigeria. *EC Nutr.,* 5(6): 1285-1297.

Agbemafle R, Obodai E, Afukpo G & Amprako D 2012. Effects of boiling time on the concentration of vitamin C and beta-carotene in five selected green vegetables consumed in Ghana. *Adv. in Appl. Sci. Res*., 3(5): 2815-2820.

Agbidye S, Ofuya I & Akindele O 2009. Marketability and nutritional qualities of some edible forest insects in Benue State, Nigeria. *Pak. J. Nutr*., 8(7): 917-922.

Ajifolokan M & Adeniran A 2016. Proximate and mineral composition of co-fermented bread fruit and cassava analogue. *J. Nutr. & Food Sci.,* 8(1).

Alamu T, Amao O, Nwokechi I, Oke A & Lawal O 2013. Diversity and nutritional status of edible insects in Nigeria. *Int. J. Biod. & Cons*., 5(4): 215 – 222.

AOAC 2000. Official Methods of Analysis. 15th Ed, Association of Official Analytical Chemists, Washington, DC.

Balinga P, Mapunzu M, Moussa B & N'gasse G 2004. Contribution of forest insects to food security – The example of Central African caterpillars. Food and Agriculture Organization of the United Nations, Rome, Italy, 117.

Banjo D, Lawal A & Songonuga E 2006. The nutritional value of fourteen species of edible insects in Southwestern Nigeria. *Afr. J. Biotech.,* 5(3): 298-301.

Bednářová M 2013. Possibilities of Using Insects as Food in the Czech Republic, Dissertationthesis Mendel University, Brno, pp. 50–92.

Bernard T & Womeni H 2017. Entomophagy: Insects as Food. Insect Physiology and Ecology, p. 14.

Bukken F 2005. Insects in the Human diet: The Nutritional aspects. In: MG Paoletti (Ed). Ecological Implication of Minilivestock: Role of Rodents, Frogs, Snails, and Insects for Sustainable Development. New Hampshire: Science Publishers, pp. 545-577.

Caparros MR, Alabi T & Nieus C 2016. Optimisation of a cheap and residential small-scale production of edible crickets with local by-products as an alternative protein-rich human food source in Ratanakiri Province, Cambodia. *J. Sci. Food Agric.,* 96: 627–632.

Chaney S 2006. Principles of Nutrition II: Micronutrients. In: T.M. Devlin, (Eds.), Textbook of Biochemistry with Clinical Correlation 6th Ed. New York: John Wiley and Sons, pp. 1093 – 1118.

Chang C 2003. Protein Analysis. In: Food Analysis. Nielsen S. Kluwer Academic Plenum Publisher, New York, p. 115.

DeFoliart R 2002. The human use of insects as food resource: A bibliographic account in progress. Wisconsin, USA: Department of Entomology, University of Wisconsin-Madison, USA.

Durst PB & Hanboonsong Y 2015. Small-scale production of edible insects for enhanced food security and rural livelihoods: experience from Thailand and Lao People's Democratic Republic. *J. Ins. Food &Feed*, 1: 25 –31.

Ebenebe I & Okpoko C 2015. Microbiological quality of raw and roasted African palm Weevil *(Rhynchophorus phoenicis*) consumed in the South Eastern Nigeria. *Ani. Res. Int*., 12(2): 2159 – 2165.

Ekpo KE, Onigbinde AO & Asia IO 2009. Pharmaceutical potentials of the oils of some popular insects consumed in southern Nigeria. *Afr. J Phar. & Pharmacol*., 3: 51–57.

FAO 2008. Locust Watch: Locust and the Migratory Pest Group. Food and Agricultural Organization of the United Nations, Available form: http://www.fao.org/ng/locusts/en/info/index.html

FAO 2015. http://www.fao.org/forestry/edibleinsects/en/info/info/index.html.

FAO 2015. The State of Food Insecurity in the World, Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress. Food and Agricultural Organization of the United Nations, Rome.

Gaunt M & Miles M 2002. An insect molecular clock dates the origin of the insects and accords with palaeontological and biogeographic landmarks. *Molecular Biology of Evolution*, 19: 748–761.

Heinrich M & Prieto M 2008. Diet and Healthy ageing 2100: Will we globalize local knowledge systems? *Ageing Res. Rev.*, 7: 249-274.

Igwemmar C, Kolawole A & Imran A 2013. Effect of heating on vitamin C content of some selected vegetables. *Int. J. Scientific and Techn. Res*., 2(11).

Jacob A, Emenike A, Kayode , Olusegun O, Uzoma A & Rukayat K 2013. Entomophagy: A panacea for protein – deficient Malnutrition and Food Insecurity in Nigeria. *J. Agric. Sci*., 5(6): 25 -31.

James J 1995. The Analytical Chemistry of Foods. Chapman and Hall Press, New York, p. 86.

Kagezi H, Kaib J, Nyeko P & Brandl R 2010. Termites as Food in the Luhya community (Western Kenya). *Sociobiol*., 55(3): 381 – 845.

Muzzarelli RAA, Terbojevich M, Muzzarelli C, Miliani M & Francescangeli O 2001. Partial depolymerization of chitosan with the aid of papain. In: RAA Muzzarelli (Eds.). Chitin Enzymology, Italy: Atec., pp. 405 – 414.

Ntukuyoh I, Udiong D, Ikpe E & Akpakpan A 2012. Evaluation of nutritional value of termites (*Macrotermes bellicosus*): Soldiers, Workers, and Queen in the Niger Delta Region of Nigeria. *Int. J. Food Nutr. & Safety*, 6(1): 9-24.

Oibiokpa F, Akanya O, Jigam A & Saidu N 2017. Nutrient and antinutrient compositions of some edible insect Species in Northern Nigeria. *Fount. J. Nat. & Appl. Sci*., 6(1): 9-24.

Ojianwuna CC & Enwemiwe VN 2020. Efficiency of ginger, pepper fruit and alligator pepper powders in the control of cowpea bruchid (*Callosobruchus maculatus*) (Fabricius, 1775). *FUW Trends in Sci. & Tech. J.*, 5(2): 445-450.

Omotoso O & Adesola A 2018. Comparative studies of the nutritional composition of some insect orders. *Int. J. Entomol. & Nem. Res*., 2(1): 1-9.

Omotoso T 2006. Nutritional quality, functional properties and anti-nutrient compositions of the larva of *Cirina forda* (Westwood) (Lepidoptera: Saturniidae. *J. Zhej. Uni. Sci. Biol*., 7(1): 51–55.

Onwuka I 2005. Food Analysis and Instrumentation Theory and Practice. 1st Edition. Napththali Prints, Nigeria, p. 10.

Oonincx DGAB & Dierenfeld ES 2012. An investigation into the chemical composition of alternative invertebrate prey. *Zoo Biol.*, 29: 1–15.

Paoletti G, Norberto L, Damini R & Musumeci S 2007. Human gastric juice contains chitinase that can degrade chitin. *Annals of Nutr. & Metabol*., 51(3): 244 -251.

Premalatha M, Abbasi T & Abbasi SA 2011. Energy-efficient food production to reduce global warming and eco degradation: the use of edible insects. *Renew. Sust. Ener. Rev*. 15: 4357-4360.

Ramos-Elorduy J 2005. Insects a Hopeful Food. In: Paoletti M. Ecological Implications of Minilivestock for Sustainable Development, USA: Science Publishers Inc., pp. 263–291.

Sani I, Haruna M, Abdulhamid A, Wara A, Bello F & Fakai M 2014. Assessment of nutritional and mineral composition of dried edible *Zonocerus variegatus* (Grasshopper). *Research and Reviews, J. Food and Diary Tech*., 2 (3): 1-6.

Seungeung L, Young C, Heon S & Junson L 2018. Effect of different cooking methods on the content of vitamins and true retention of selected vegetables. *Food Sci. Biotech. J*., 27(2): 333-342.

Siulapwa N, Mwambunay A, Lungu E & Sichilima W 2014. Nutritional value of four common Edible insects in Zambia. *Int. J. Sci. and Res.*, 3(60): 876 – 884.

Sogbesan A & Ugwumba A 2008. Nutritional evaluation of termite (*Macrotermes subhyalinus*) meal as animal protein supplements in the diets of *Heterobranchus longifilis*. *Turk. J. Fish. Aquat. Sci*., 8: 149–157.

Solomon M & Prisca N 2012. Nutritive value of *Lepidoptara litoralia* (edible caterpillar) found in Jos Nigeria: Implication for food security and poverty alleviation. *Afri. J. Food Agric. Nutr. and Devt.*, 12(6).

The Marck Index 2001. Monograph No. 10081 13th Edition, New Jersey, USA: Marck and Co, White House Station, p. 1787.

van Huis A, Itterbeeck V, Klunder H, Mertens E, Italloran A, Mui G & Vantomme P 2013. Edible Insects: Future Prospects for Food Security. FAO Forestry Paper, 171, Rome, pp. 67 – 105.

Wang D, Bai T, Li H & Zhang C 2004. Nutritional value of the field cricket (*Gryllus testaceus* Walker). *J. Entomol. Singapore*, 11: 275–283.

Womeni M, Linder M, Tiencheu B, Mbiapo B, Villeneuve P & Fanni J 2009. Oils of insects and larvae consumed in Africa: Potential Sources of Polyunsaturated Fatty Acid. *OCL*, 16(4): 112-120.

Xiaoming C, Ying F& Hong Z. 2010. Review of the nutritive value of edible insects. Edible insects and other invertebrates in Australia: future prospects. *Proceedings of a Workshop on Asia-Pacific Resources and their Potential for Development*, 19–21 February, 2010: Bangkok, pp. 85–92.