Nutritional Analysisand~~And~~ Functional Propertiesof~~Of~~ Some Commonly Consumed Insects ~~In~~inSouthernNigeria

Comment [Nura1]: All the four insects are consume in Southern parts of Nigeria. This need to be captured in the title. Grasshopper is the main insect consume in the Northern Nigeria

ABSTRACT

Edible insects have played a vital role in the history of human nutrition in Nigeria.Therefore, this study aimed to investigate the nutritional value and functional properties of some commonly consumed insects in Nigeria. These insects included*Rhynchophorusphoenicis* larva, *Oryctes rhinoceros* larva, *Achetadomesticus* and *Macrotermesbellicosus* from the orders of Coleoptera, Isoptera and Orthoptera. Proximate composition, vitamin content and functional properties of the insects were determined using standard analytical methods. Statistical analysis was performed using ANOVA to determine significant differences. The moisture content ranged from 9.2 ± 0.29% to 58.9 ± 0.78%. The highest lipid value of 28.7 ± 0.29% was found in *M. bellicosus* and the least value of 8.3 ± 0.51% found in *A. domesticus*. The difference in lipid content among the insects was statistically significant with P < 0.05. The highest amount of 38.2 ± 0.21% crude protein was found in *A. domesticus*. The difference in the crude protein content among the insects was also statistically significant with P < 0.05.*A. domesticus* had the ~~richest~~ carbohydrate value of 31.9 ± 0.37% with*R. phoenicis* having the least amount of 3.1 ± 0.14%. The ash content ranged from 2.9 ± 0.15%to 14.1 ± 0.24%.*A. domesticus*had the highest vitamin A value of 4.2 ± 0.01 with *M. bellicosus*having the lowest value of 2.2 ± 0.08 in µM. The observed vitamin C values were in the range of 56.8± 0.96to 11.5± 0.66 in µM. *M. bellicosus*had the highest vitamin E value of 32.6 ± 0.24µM. Water and oil absorption capacity ranged from 136.7 ± 0.19% to 170.0 ± 0.06% and 103.3 ± 0.06% to 146.7 ± 0.13%respectively. Emulsion activity, capacity and stability ranged from 39.7 ± 1.42% to 84.3 ± 1. 14%, 37.0 ± 0.58% to 87.7 ± 0.34% and 33.3 ± 0.34% to 79.0 ± 1.53% respectively. Foaming capacity and stability ranged from 5.3 ± 0.34% to 7.7 ± 0.34% and 1.3 ± 0.34% to 3.0 ± 0.58%. These results indicate that these insects/insect larva have potential for exploitation in combating nutritional deficiencies of public health concern and could form a base for new food products of considerable nutritive value.

Comment [Nura2]: vitamins

Comment [Nura3]: Recast

Comment [Nura4]: highest

Comment [Nura5]: You need to also conclude on the functional properties, particularly the industrial applications.

Keywords: *Rhynchophorusphoenicis* larva, *Oryctes rhinoceros* larva, *Achetadomesticus*, *Macrotermesbellicosus,* proximate analysis, functional properties.

1. INTRODUCTION

One of the prominent issue facing world development is that of under-nutrition and poverty. A recent report by the Food and Agriculture Organization (FAO and WHO, 2020) estimated the number of people globally experiencing food insecurity at 750 million, a number which rises to two billion when moderate food insecurity is considered, with over 20% ofunder five children ~~under five~~showing stunted growth.Increasing world population growth increases demand for protein but available farmland is limited. A lack of protein in the diet can greatly affect growth, immune function, metabolism and sometimes lead to protein-energy malnutrition (Sani et. al., 2014).

Many species of insects have been used as human food in Nigeria some of which include grasshoppers, winged termites caterpillars, beetles as well as crickets.They are conceived as alternative food source, oil and protein, providing essentials nutrients. Yet, unlike a meal-based approach, they are not considered as complete foods. In recent times, there has been a renewed research interest on the potentials of insects for food and animal feed (Van Huis, 2020; Babarinde et. al., 2021). This may be probably due to their high protein, vitamin and mineral benefits (Parker et. al., 2020; Naseem et. al., 2021).

The larva of the beetle *Rhynchophorusphoenicis*(F) popularly known as snout beetlehas high nutritive value and therefore,is a delicacy in ~~various~~ regions in Nigeria. Some tribes (the Urhobo's and Isoko's in Delta state) strongly recommend it for their pregnant women, probably as a source of essential nutrients (Ekpo, 2003, Ekpo and Onigbinde 2005, 2008). The larva of *Oryctes rhinoceros* (coconut rhinoceros beetle)and adult *Macrotermesbellicosus*(winged termite) are delicacies served as snacks or taken with carbohydrate foods. *Achetadomesticus*popularly known as house cricket is dug from its hole and then roasted for eating.

Edible insects present a lot of benefits in combating nutritional deficiency. Although, ~~variable~~between insect species (Van, 2013), the high protein and fat contents of edible insects compares favorably to meat and fish (Barroso et. al., 2014). Furthermore, the amino acid profiles of several species have been demonstrated to contain a high proportion of essential amino acids. Edible insects also present a promising source of micronutrients. Knowledge dissemination is important in achieving global use of insects as food (Govorushko, 2019) and increasing willingness to pay for insect-based food (Lombardi et. al., 2019).

While individual nutrient compositions of these insects have been studied (Ekpo and Onigbinde, 2008), this research provides a comparative analysis across multiple species, contributing new insights for combating nutrient deficiency, industrial food processes and animal feed formulations.

2. Materials

Comment [Nura6]: Be consistent, use either "UPPER CASE" of "Title Case" for the headings.

Comment [Nura7]: Recast

Comment [Nura8]: Recast

Comment [Nura9]: some

Comment [Nura10]: varies

Comment [Nura11]: cite examples

Comment [Nura12]: out of context, expunge

Comment [Nura13]: Change to "Samples collection" and put it under "Methodology"

Live larvae of *R. phoenicis* and *O. rhinoceros* were collected from rot palm trees and raphia palms respectively at Illushi, Edo State, Nigeria.Live house crickets (*A. domesticus)* were collected by hand and live termites (*M. bellicosus*) by hand during their nuptial flight.

~~3. Methodology~~2. Methodology

Insect collection was performed in accordance with local regulations and ethical guidelines for environmental research. Within 24 hours of collection, the fresh samples were blended separately using an electric blender and stored in air-tight containers for further analytical use.

The proximate composition was determined as follows: Determination of crude protein content was performed by the modified Kjeldahl method of William (1964). By using a factor of 6.25 to multiply the Gram nitrogen, the crude protein content was obtained. Lipid was extracted by the method of Bligh and Dyer (1959). The moisture content was quantified by making use of oven drying method as described by Association of Official Analytical Chemists (AOAC) in 1990. The total ash was determined using the method described by Kirk and Sawyer (1991). The carbohydrate content was estimated by difference as the total percentage composition of moisture, lipid, protein and ash were summed up and subtracted from 100%.

Vitamin A was estimated using the method of Jakutowixzet. al., (1977). 0.5g of the grinded sample was weighed, homogenized with sulphate buffer saline and centrifuged. 5.0ml of supernatant was pipetted into test tube, 0.5ml of ethanol and 4.0ml of petroleum ether were added respectively. The absorbance was read using a spectrophotometer at 450nm and the amount of vitamin A extrapolated from a standard vitamin A curve. The vitamin E content was also quantified using the method of Jakutowixzet. al., (1977) while the vitamin C was evaluated by the method of Omayeet. al., (1979).

Water and oil absorption capacity were determined by the method of Sosulki et. al., (1976). Water and refined vegetable oil were used respectively for the analysis. 1g each of blended sample was weighed into two measuring cylinders and 20ml of distilled water and vegetable oil added to each. The contents were stirred for 30 seconds with a glass rob and suspended for 10 minutes to rest. Each of the contents were poured individually into a blender and grinded for 10 minutes. The water and oil were decanted from each of the cylinder and percentage of water and oil absorbed were calculated as ratio of the weights of sample multiplied by 100.Emulsion capacity, activity and stability were determined by the method described by Okezie and Bello (1988). Foam capacity and stability were estimated by the method of Narayana and Narsinga (1982).

Analytical procedures were carried out in triplicate and the mean values recorded. The mean and Standard Error of Mean (SEM) of the triplicate analyses were calculated. Statistical analyses were conducted using one-way ANOVA to compare the proximate value, vitamin content and functional properties of the insects. A significance level of $P < 0.05$ was used to determine differences across the species.

Comment [Nura14]: Clearly mention the locations for samples collection and add GPS coordinates

Comment [Nura15]: Move to “Samples Collection”

Comment [Nura16]: Remove the “comma (,)” in all the references cited in this format

Comment [Nura17]: You cannot start sentence with number. Apply this to all affected sentences

Comment [Nura18]: Same as above

Comment [Nura19]: Mention the statistical software you use

~~4. Results~~3. Results

The order, local name and consumption stage of the studied insects are presented in Table 1.

Table 1: **Order, local name and consumption stage of four edible insects commonlyconsumed inSouthern Nigeria**

Order	Scientific name	Common Name	Local name	Consumption stage
Coleoptera	*Ryhnchophorus Phoenicis*	Palm weevil	Isoko: Odidi	Larva
Coleoptera	*Oryctes rhinoceros*	Rhinoceros beetle	Isoko: Akpakara	Larva
Orthoptera	*Acheta domesticus*	House cricket	Isoko: Ozeze	Adult
Isoptera	*Macrotermes Bellicosus*	Winged termite	Isoko: Ofuru-Ukpe	Adult

Comment [Nura20]: Local name will depend on the location within Nigeria, is better this been remove as it's localizing the work

Result of the proximate analysis of *R. phoenicis* larva, *O. rhinoceros* larva, *A. domesticus*and *M. bellicosus*are shown in Table 2.

Table 2: Proximate analysis (%) of four edible insectscommonlyconsumed in Southern Nigeria

Insects	Moisture	Lipid	Protein	Carbohydrate	Ash
Ryhnchophorus phoenicis	58.5± 0.78^{a}	23.8 ± 0.29^{b}	23.8 ± 0.29^{b}	3.1 ± 0.14^{c}	2.9 ± 0.15^{b}
Oryctes rhinoceros	58.2 ± 0.23^{a}	13.7 ± 0.29^{c}	13.9 ± 0.91^{c}	9.3 ± 0.27^{b}	4.9 ± 0.07^{b}
Acheta	9.2 ± 0.29^{c}	8.3 ± 0.51^{d}	38.2 ± 0.21^{a}	31.9 ± 0.37^{a}	12 ± 0.35^{a}

Comment [Nura21]: Check, the sum of the row is >100

Comment [Nura22]: Check, the sum of the row is <100

domesticus					
Macrotermes bellicosus	12.1 ± 0.59[b]	28.7 ± 0.29[a]	35.0 ± 0.91[a]	10.1 ± 0.33[b]	14.1 ± 0.24[a]

Results represent the Mean ± SEM of three estimations; Values are % wet weight of the larvae. Different letters within the same column indicate significant differences (P < 0.05).

Proximate analysis of the studied edible insects showed that, moisture was highest in *R. phoenicis* larva with a content of 58 ± 0.78% and the least value of 9.2 ± 0.29% was found in *A. domesticus*. The difference in moisture content among the insects was statistically significant with P < 0.05. The highest crude protein content was found in *A. domesticus*with a value of 38.3 ± 0.21%. The high protein content in *A. domesticus*may be attributed to its adult stage, as insect maturity can influence nutrient accumulation. The difference in protein content among the insects was also statistically significant with P < 0.05. The insect with the richest carbohydrate content of 31.9 ± 0.37% was *A. domesticus*while *R. phoenicis* larva had the least content of 3.1 ± 0.14%. The highest lipid value of 28.7 ± 0.29% was recorded in *M. bellicosus*. Ash value of the four insects ranged from 2.9 ± 0.15% to 14.1 ± 0.24%.

Result of vitamin A, C and E of the studied insects are shown in Table 3 below.

Table 3: Vitamin Content (µM) of four edible insects in Nigeria

Insects	Vitamin A	Vitamin C	Vitamin E
Rhynchophorusphoenicis	3.2 ± 0.01[b]	56.8 ± 0.96[a]	21.8 ± 0.33[c]
Oryctes rhinoceros	2.6 ± 0.06[c]	27.5 ± 0.38[b]	25.3 ± 0.39[b]
Achetadomesticus	4.2 ± 0.01[a]	11.5 ± 0.66[d]	24.1 ± 0.31[b]
Macrotermesbellicosus	2.2 ± 0.08[c]	14.7 ± 0.22[c]	32.6 ± 0.24[a]

Results represent the Mean ± SEM of three estimations; Different letters within the same column indicate significant differences (P < 0.05)

Vitamin A value of the studied insects/insect larva ranged from 4.2 ± 0.01 to 2.2 ± 0.08 inµM. *A. domesticus*was richest in vitamin C when compared to the other insects investigated while *M. bellicosus*was observed to contain the highest vitamin E value.

Result of the functional properties (%) of the studied insects are presented in Table 4.

Table 4: Functional properties(%) of four edible insects in Nigeria

Parameters	*Ryhnchophorus Phoenicis*	*Oryctes rhinoceros*	*Acheta domesticus*	*Macrotermes bellicosus*
Water absorption capacity (WAC)	140.0± 0.21^{a}	136.7± 0. 19^{a}	166.7± 0.06^{a}	170.0± 0.06^{a}
Oil absorption capacity (OAC)	113.3± 0. 10^{b}	103.3± 0.06^{b}	146.7± 0.13^{b}	143.0± 0. 10^{b}
Emulsion activity (EA)	39.7± 1.42^{c}	79.3 ± 0.87^{c}	84.3± 1.14^{c}	81.6± 1.2^{c}
Emulsion capacity (EC)	37.0± 0.58^{c}	82.0± 1. 16^{c}	87.7± 0.34^{c}	82.5± 1.46^{c}
Emulsion stability (ES)	33.3 ± 0.34^{c}	75.7 ± 2.19^{c}	79.0 ± 1.53^{c}	76.3 ± 0.88^{c}
Foam capacity (FC)	7.7 ± 0.34^{d}	5.3 ± 0.34^{d}	6.7 ± 0.34^{d}	7.7 ± 0.34^{d}
Foam stability(FS)	3.0 ± 0.58^{d}	1.3 ± 0.34^{e}	1.7 ± 0.34^{e}	2.7 ± 0.67^{e}

Results represent the Mean ± SEM of three estimations; Different letters within the same column indicate significant differences ($P < 0.05$)

The results revealed that *Macrotermesbellicosus*had the highest water absorption capacity(WAC) of 170.0 ± 0.06% with *RyhnchophorusPhoenicis*and *Oryctes rhinoceros* having comparable values of 140.0 ± 0.21% and 136.7 ± 0. 19%. The difference in the water absorption capacity (WAC) among the insects was statistically significant with $P < 0.05$. Oil absorption capacity (OAC) was highest in *Achetadomesticus*with a value of 146.7 ± 0.13% and lowest in *Oryctes rhinoceros* with a value of 103.3 ± 0.06%. Emulsion activity (EA), Emulsion capacity (EC) and Emulsion stability (ES) were highest in *Achetadomesticus*. Foam capacity (FC) and foam stability (FS) were in the range of 7.7 ± 0.34% to 5.3 ± 0.34% and 3.0 ± 0.58% to 1.3 ± 0.34%.

~~5. Discussion~~4. Discussion

The consumption of edible insects (entomophagy) in Africa, is a traditionally and culturally acceptable way by which the income group in the society supplement the meagre protein content of their high carbohydrate diets (Ekpoet. al., 2009). In Nigeria, insects such as termites, crickets, beetle larva form an important portion of the diets of many cultures and communities, where they are included as a planned portion of the diet or snacks. Although, they are not available all through the year but processing them can help in extending ~~the period of~~their availability for consumption and income generation.

Comment [Nura23]: The discussion is generally poor. You need to compare the results with findings reported in recent literature

Comment [Nura24]: Recast

Results of this research agree with the broader cultural practice of entomophagy in Africa, revealing that edible insects can serve as sources of essential nutrients for the poor in the society.Specifically, *Achetadomesticus*and *Macrotermesbellicosus*were discovered to be rich in protein and other nutrients.

Some studies earlier conducted reported morphometric parameters and/or proximate values of insects/insect larva which closely agrees with observationsof this study. The insect larva had higher moisture values than their adult counterparts making most of their nutrients available to the body upon consumption. The major setback of high moisture content is that, it reduces the period of preservation due to risk of spoilage by micro-organisms.

Comment [Nura25]: Remove, your work doesn't include this

Edible insects have been reported to possess higher protein content when compared to other animal sources such as beef, chicken and fish (Defoliart, 1989).The protein content of the studied insects ranged from 13.9 ± 0.91% to 38.2 ± 0.21%. These results were quantitatively comparable to 11.1% and 20.1% (wet weight) reported by Davis(1918)for *Lachnosterna*larva and adult beetlespecies, 22.1% (wet weight) reported by Fleming (1968)for the Japanese beetle *Popillia japonica.*This result indicates that edible insects are indeed good sources of protein for man and animals.

Comment [Nura26]: This is too old, compare with findings reported in the last 5 years

Comment [Nura27]: Same as above

Protein play a vital role in the maintenance of body tissue including development and growth. In the absence of energy, it can be broken down to release energy, it is involved in the production of hormones, which help to control body functions and help regulate cell growth. It also plays a major role in the formation of enzymes which increases the rate of chemical reactions in the body.

The fat content in *Macrotermesbellicosus*and *Ryhnchophorus Phoenicis*were higher than in other insects, which could be the reason why their gross energy are high, as fat contributes more calorie than twice the contribution of carbohydrates and proteins. Although, the fat content in *M.bellicosus*was high but can be quantitatively compared with published data for insects of various species. Fast (1966) reported a fat content for *R. palmarum* as 22.3% (wet weight).Calvert et al., 1969, reported a fat content value of 15.5% for*Musca domestica* pupae. Fat functions as an important depot for energy storage, insulates and protects the body, regulates temperature and helps the body to absorb vitamins A, D and E.

The carbohydrate content of the studied insects are lower when compared to values of 24.7% for winged termite and 48.2% dry weight for grasshopper as reported by Ahmad et. al., (2013). Carbohydrates are important nutritive elements in human body. They are most valuable among other food components (Offiah et. al., 2019).

Ash is a reflection of the mineral content contained in a sample. Ash content analysis showed that *M. bellicosus*and *A. domesticus*had higher values than the other insects whose results closely agree with other values of 4.3% reported by Solomon et. al., 2012, 2.8% and 2.6% for green and brown *Ruspoliadifferens* reported by Kinyuru et. al., 2006.

Vitamins are a group of organic substances needed for normal cell function, growth and development. With the exception of vitamin D, vitamins cannot be synthesized in the human body, they must be supplied in the diet. The vitamin content of these insects/insect larva is suggestive of their potentials in alleviatingvitamin deficiency.

Winged termites (*M. bellicosus*) contained high content of vitamin A and C. Vitamin A plays vital role in vision, immune function, reproduction, growth and development. It also form and maintain healthy teeth, skeletal tissue, mucus membrane and skin.
R. Phoenicis had the highest vitamin C value when compared to the other insects studied. Vitamin C forms an important protein called collagen used to make skin, tendons, ligaments and blood vessels. It aids in the absorption of iron, wound healing, repair of cartilages, bones and teeth.
M. bellicosus was observed to contain the highest amount of vitamin E which is a fat-soluble nutrient found in many foods. It acts as an antioxidant in protecting the body tissues from damages caused by free radicals, helps keep the immune system strong against viruses and bacteria and helps the body in making use of vitamin K.
The water absorption capacity (WAC) ranged from 136 ± 0. 19% to 170.0 ± 0.06%. This shows that the insect/insect larva can be incorporated into aqueous food formulations. Oil absorption capacity (OAC) ranged between 103.3 ± 0.06% to 146.7 ± 0. 13%. Oil absorption capacity (OAC) is important since oil acts as flavor retainer and increases the palatability of foods. The emulsion capacity, activity and stability were high and can be compared to what other researchers earlier reported. The results suggests that these insect/insect larva would be highly desirable for preparing comminuted meats. Foam formulation and stability are functions of the type of protein PH, processing methods, viscocity and surface tension. Foam capacity and stability ranged between 5.3 ± 0.34% to 7.7 ± 0.34% and 1.3 ± 0.34%to 3.0 ± 0.58% respectively. Akubor and Chukwu (1999) reported that foams are used to improve the texture, consistency and appearance of foods.
Alimitation of this researchis that the nutritive value of these insect/insect larva can vary with seasons and environmental factors, which were unaccounted for here. Future research should find out how these factors affect nutritive levels in order to provide a broad knowledge of their potential in combating nutrient deficiency.

~~6. Conclusion~~5. Conclusion

Thehealth and well-being of an individual dependson the interaction between his/her genetic potential and on exogenous factors like adequacy of nutrition, safety of the environment and social interaction. Protein, lipid, carbohydrate and vitamins are vital food nutrients required in the body for growth, repair of worn out tissues, energyproduction, reproduction and health maintenance. Deficiency of these nutrients results in different disease conditions such as marasmus, night blindness, soft bones, stunted growth, poor immunity, kwashiorkor, sterility among others. Milk and eggs are great sources of these nutrients but due to their high cost, they are unavailable to the low-income group in the society.

Comment [Ma28]: This is not necessary, the conclusion shall focus on the major findings of the research.

This research affirms the fact that edible insects provide higher amounts of proteins, fats, carbohydrate and vitamins than beef and chicken. Their consumption could play a crucial role in alleviating protein-energy malnutrition and vitamin deficiencies, particularly in resource poorsettings.Moreover, this knowledge justifies the fact that these insect/insect larva are important food items requiring industrial application and commercialization to providesustainable solution in meeting nutritional needs.

References

Ahmad, S.M., Birnin-Yauri, U.A. and Bagudo, B. (2013). Comparative analysis on the nutritional values of crayfish and some insects. *African Journal of Food Science and Technology*, 4(1) 9-12.

Akubor, P.I. and Chukwu. J.K. (1999). Proximate composition and selected functional properties of fermented and unfermented African oil bean (*Pentaclethramacrophylla)* seed flour. Plant Foods for Human Nutrition 54: 227-238.

Babarinde, S.A., Mvumi, B.M., Babarinde, G.O., Manditsera, F.A., Akande, T.O. and Adepoju, A.A. (2021). Insects in food and feed systems in sub-Sahara Africa: the untapped potentials. *Intern. J. Trop. Insect Sci.*: 41 (3): 1923-1951.

Barroso, F.G., De Haro, C., Sanchez-Muros, M.J., Venegas, E., Martinez-Sanchez, A. and Perez-Banon, C. (2014). The potential of various insect species for use as food for fish. *Aquaculture* 3422:193-201. Doi: 10. 1016/j.aquaculture.2023.12.024.

Calvert, C.C., Martin, R.D. and Morgan, N.O. (1969). Housefly pupae as food for poultry. *J. Econ. Entomol*. 62: 938-939.

Davis, J.J. (1918). Common white grubs. USDA Farmer's Bull. No 940:28.

DeFoliart, G.R. (1989). The Human use of Insects as Human Food and as Animal Feed. Bulletin of Entomological Society of America 35: 22-35.

Ekpo, K.E. (2003). Biochemical investigation of the nutritional value and toxicological safety of entomophagy in Southern Nigeria. Ph.D Thesis, Ambrose Alli University, Ekpoma, Edo State.

Ekpo, K.E. and Onigbinde, A.O. (2005). Nutritional potentials of *Rhynchophorusphoenicis*(F) larva. *Pakistan Journal of Nutrition* 4 (5): 287-290.

Ekpo, K.E. and Onigbinde, A.O. (2008). Nutritional and socio-cultural perception of entomophagy in Edo and Delta States of Nigeria. *Nigerian Journal of Nutritional Sciences* 29 (2): 201-209.

Ekpo, K.E., Onigbinde, A.O. and Asia I.O. (2009). Pharmaceutical potentials of the oils of some popular insects consumed in southern Nigeria. African J. Pharm. and Pharmacol. 3(2): 051- 057.

FAO, IFAD, UNICEF, WFP and WHO (2020). The State of Food Security and Nutrition in the World. Transforming Food Systems for Affordable Healthy Diets. Rome: FAO.

Fast, P.G. (1966). A comparative study of the phospholipids and fatty acids of some insect lipids. Science 155: 1680-1681.

Fleming, W.E. (1968). Biological control of the Japanese beetle. USDA Tech. Bull. No 1383:78pp.

Govorushko, S. (2019). Global status of insects as food and feed source: a review. Trends Food Sci. Technol., 91: 436-445.

Kinyuru, J.N., Kenji, G.M., Muhoho, S.N. and Ayieko, M. (2009). Nutritional potential of longhorn grasshopper (*Ruspoliadifferens)* consumed in Siaya District, Kenya, JAST.

Lombardi, A., Vecchio, R., Borrello, M., Caracciolo, F. and Cembalo, L. (2019). Willingness to pay for insect-based food: the role of information and carrier. Food Qual. Pref., 72: 177-187.

Naseem, R., Majeed, W., Rana, N., Koch, E.B.D.A. and Naseem, M.R. (2021). Entomophagy: an innovative nutritional and economic navigational tool in race of food security. *Intern. J. Trop. Insect. Sci.* 43 (3): 2211-2221.

Offiah, C.J., Fasalejo, O.F. and Akinbowale, A.S., (2019). Evaluation of nutritional and anti-nutritional values of *Oryctes rhinoceros* larvae in Ondo State, Nigeria. *J. Entomol. Zool. Stud*. 7 (5): 204-207.

Parker, M.E., Zobrist, S., Lutterodt, H.E., Asiedu, C.R., Donahue, C., Edick, C. and Laar, A. (2020). Evaluating the nutritional content of an insect-fortified food for the child complementary diet in Ghana. BMC Nutrit. 6: 1-11.

Sani, I., Haruna, M., Abdulhamid, A., Warra, A.A., Bello, F. and Fakai, F.I. (2014). Assessment of Nutritional quality and Mineral Composition of dried edible *Zonocerusvariegatus*(grasshopper*). J. Food Diary Technol*. 2(3): 1-6.

Solomon, M. and Prisca, N. (2012). Nutritive value of *Lepidoptera litoralia*(edible caterpillar) found in Jos, Nigeria: Implication for food security and poverty alleviation. Ajfand 6(12): 6737-6747.

Van Huis A. (2020). Insects as food and feed, a new emerging agricultural sector: a review. JIFF, 6 (1): 27-44.

Van Huis, A. (2013). A potential of insects as food and feed in assuring food security. *Annu Rev Entomol.* 58: 563 – 83. Doi: 10. 1146/annurev-ento-120811-153704.