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RESEARCH ARTICLE

EVALUATION OF THE BIOCHEMICAL AND NUTRITIONAL QUALITY OF SOME EDIBLE INSECTS: AN ALTERNATIVE TO FOOD NUTRIENT SOURCES IN CROSS RIVER STATE, SOUTH-EASTERN NIGERIA

Joseph Akaninyene Paul[1], Ekanem Sarah Nkereuwem[2], Etinosa-Okankan Osarenaye Peter[3]

1. Department of Zoology and Environmental Biology, Faculty of Biological Sciences, University of Calabar, Calabar, Cross River State.
2. Department of Science Technology, School of Applied Sciences, Akwa Ibom State Polytechnic Ikot Osurua, Ikot Ekpene, Akwa Ibom State.
3. Department of Biochemistry, Faculty of Science, Cross River University of Technology, Calabar, Cross River State.

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Abstract

The nutritional analysis of edible insects in Cross River State was studied. Insect samples were collected using entomological nets and hand-picking. Collected insects were stored in ice box and transported to Laboratory for identification. The mean proximate composition of Macrotermes bellicosus (termite) were 3.846 ± 0.050% (moisture), 4.200 ± 0.050% (ash), 26.300 ± 0.050% (fat), 2.656 ± 0.040% (fibre), 22.440 ± 0.216% (protein) and 7.420 ± 0.026% (carbohydrate). The mean proximate composition of Acheta domesticus (cricket) were 2.626 ± 0.097% (moisture), 4.590 ± 0.065% (ash), 22.500 ± 0.200% (fat), 3.400 ± 0.050% (fibre), 20.173 ± 0.155% (protein) and 6.356 ± 0.040% (carbohydrate). The mean mineral composition of M. bellicosus were 20.800 ± 0.200 mg/100g (Ca), 10.433 ± 0.251mg/100g (Mg), 16.366 ± 0.152 mg/100g (Fe) and 83.433 ± 0.305 mg/100g (P). Acheta domesticus had mean mineral levels of 15.566 ± 0.404 mg/100g (Ca), 13.266 ± 0.251mg/100g (Mg), 18.533 ± 0.305 mg/100g (Fe) and 70.166 ± 0.208 mg/100g (P). Termites (M. bellicosus) was more nutritious than termites (A. domesticus). Statistically, the moisture, ash, fat, fibre, protein, carbohydrate and iron content varied insignificantly ($p>0.05$), while calcium, magnesium and phosphorous level varied significantly between M. bellicosus and A. domesticus ($p<0.05$). Due to the capacity of edible insects to compensate for the inability of increasing food productivity to meet the growing population, we recommend that insects are consumed as alternative to other protein source. Similar researches on other insects should be carried out, so as to identify the most nutritious insects for consumption.

Corresponding Author:- Joseph Akaninyene Paul
Address:- Department of Zoology and Environmental Biology, Faculty of Biological Sciences, University of Calabar, Calabar, Cross River State.

Introduction:-
Insects have played an important part in the history of human nutrition in Africa, Asia and Latin America (Ramos-Elorduy et al., 1997; Kampmeier and Irwin, 2009). Indeed insects constitute as much as 80% of the animal kingdom (Premalatha, 2011). Though some insects are pests, as they affect man and destroy valuable materials and crops, edible insects are important dietary components in many developing countries (Ekop et al., 2010). Edible insects constitute an important part of the diet of a large proportion of population in many developing countries. The importance of edible insects as nutritional food source is beginning to be appreciated (Kampmeier and Irwin, 2009).

In African countries namely Zimbabwe, Nigeria, Nambia, Botswana, and some parts of Northern South Africa, grubs of the palm weevil (Rhynchophorus phoenicis) are consumed in fried form, and the insect is actively marketed in several parts of Nigeria. Edible insects constitute an important part of the daily diet of a large proportion of population in South-Western Nigeria (Banjo et al., 2006). Globally, there are more than 500 edible insects, the most popular being ants, grasshoppers, silkworm pupae, locusts, beetles crickets and bamboo worms (Kinyuru et al., 2013). Edible insect species are rich in proteins, amino acids, fats, vitamins and trace elements (Igwe, 2011; Ajayi, 2012; Ntukuyoh et al., 2012; Kinyuru et al., 2013). However, the nutrient levels reported vary greatly by species, environmental conditions, geographical location, feeding habits and the developmental stages of the insects (Srivastava et al., 2009; Raksakantong et al., 2010).

The consumption of insects as food is referred to as Entomophagy. Entomophagy is a common culture in many parts of the world including Africa, Asia, Australia, Central and South America and New Zealand, but are also uncommon and even taboos in some societies (Gordon, 1998). The high cost of animal protein, which is beyond the reach of the poor has greatly encouraged entomophagy (Adesina et al., 2010). Some of the more popular insects eaten around the world are found in Orders Orthoptera like crickets, e.g Brachytrupes membranaceus (Drury), Grasshoppers e.g. Zonocerus variegates (Linn.), Locust e.g. Locusta migratoria, (the migratory locust), Nomadacris septemfasciata (the red locust) and Schistocerca gregaria (the desert locust); Hymenoptera, e.g. Apis mellifera; Isoptera e.g. Macrotermes bellicosus (Smeathman); Lepidoptera e.g. the mopane worm-caterpillar of Gonimbrasia belina (Westwood); Coloeptera e.g. Rhynchophorus phoenicis, Eretes sticticus, etc (Forte, 2004). The study was aimed at evaluating the biochemical and nutritional analysis of some insects eaten in Cross River State.

Materials And Methods:-
Study area:
Cross River State, which lies in the southeastern axis of Nigeria, was created on May 27, 1967. It is located between latitudes 4’30’ and 7’00’N, and longitudes 7”50’ and 9”28’E (Fig 1). The state shares common borders with Akwa Ibom, Abia and Ebonyi states to the west. Benue State to the north, Republic of Cameroon to the east, and the Atlantic Ocean to the south. The state is part of the Niger Delta region, occupying an area of about 20, 156km^2. Its headquarters is located in the ancient city of Calabar. The old Calabar served as a center of learning, as well as headquarters of several British parastatals during the colonial period. It was also the first capital of Southern Nigeria. The 2006 National Population Census puts the population of the state at about 2.8million people. The most prominent ethnic groups are Efik, Bekwarra and Ejagham. The state is divided into eighteen (18) Local Government Areas (LGAs). Besides Calabar, the state capital, other major towns in the state include Akamkpa, Ikom Obubra, Odukpani, Ogoja, Okundi, Ugep, Obudu, Obanliku and Akpabuyo.

Collection of edible insects:
Selection of insect species for nutritional assays was guided by availability of the species, frequency of consumption, local preference, market value, perceived nutritional value by the community and extent of anthropogenic pressure on species. This information was obtained from literature. Two species of edible insects which includes: Macrotermes bellicosus (Termites) and Acheta domesticus (House cricket) were used for the study.

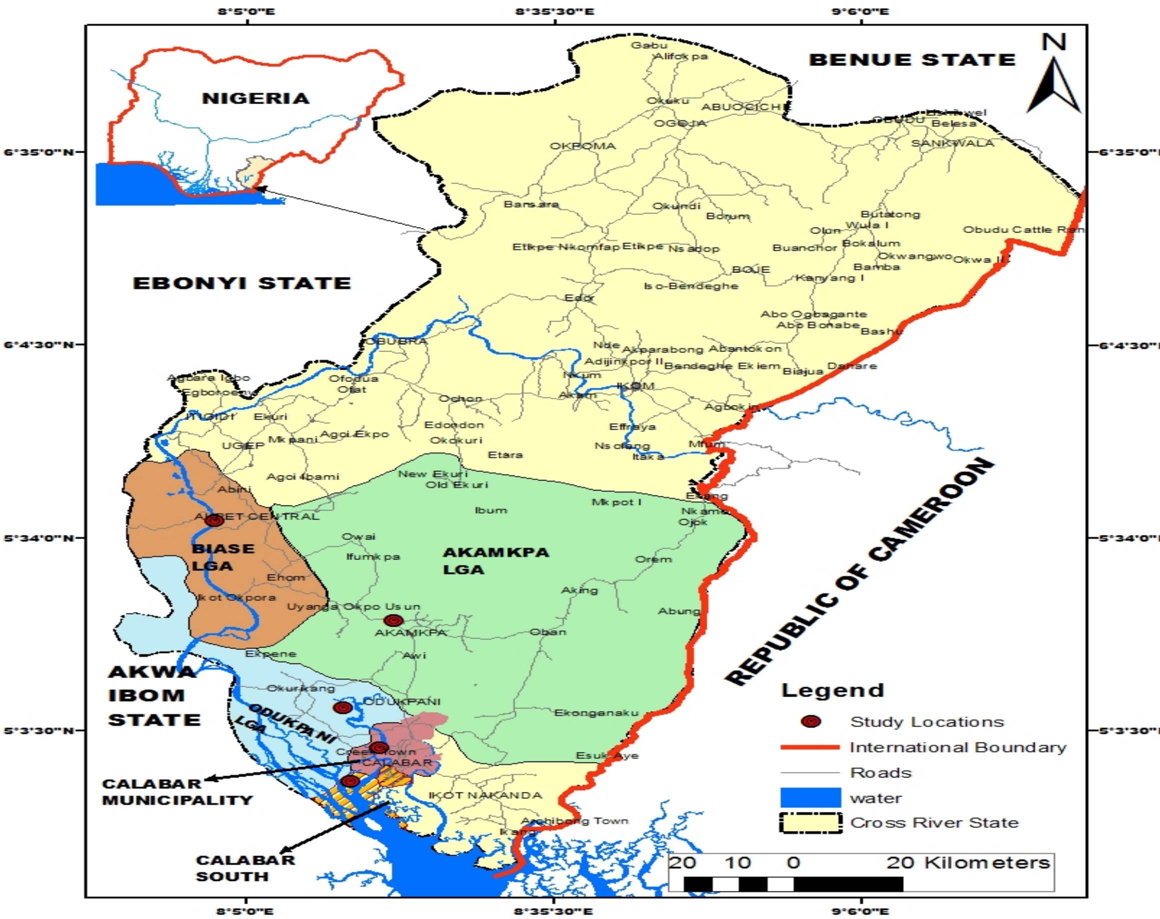

Fig 1:- Map of Cross River State showing insect sampling points.

The insects were randomly collected from Calabar South, Calabar Municipality, Odukpani, Biase and Akamkpa Local Government Areas of Cross River using entomological nets, and some handpicked from different local farms and houses within the study area using methods described by Van Huis (2003). The termites were collected when attracted to light, while the cricket was collected by picking. Collected insects were stored in a cool box with ice and transported to the Department of Zoology and Environmental Biology Laboratory, University of Calabar for identification according to Akullo et al., (2018).

Nutritional analysis in insects:

After identification of the collected insects, they were taken to Biochemistry Laboratory, University of Calabar for biochemical and nutritional analysis. Insects were de-winged, de-leged, washed three times to remove soil and dirt and then oven-dried at 40°C for 8 hours. Dried insects were ground into powder, vacuumed packed, labeled and stored at -4°C until analysis. Samples were analyzed for proximate composition in triplicate.

Moisture content:

Moisture content was determined by loss in weight on drying at 95-100°C for 8 hrs in Gallenkamp UK, hot box oven fitted with a fan according to AOAC (1999).

Crude protein content:

Total protein was quantified by determining total nitrogen using Kjeldahl method. A conversion factor of 6.25 was used (AOAC, 1999). About 0.2 g of samples was suspended in 15 mL of pepsin buffered solution in a conical flask and incubated for 3 hrs, then shaken gently after every 20 minutes. Digested samples were centrifuged at a force of 4025g for 15 minutes and the supernatant discarded. The residue was digested, centrifuged as before and filtered. The final residue was rolled up in the filter paper, placed into a Kjeldahl flask and dried in the oven at 100°C for 15 minutes. About 10 mL of concentrated sulphuric acid and Kjeldahl catalyst was added to the sample residues followed by heat digestion.

Crude fat:
Crude fat was quantified according to AOAC (1999) method. Extraction of fat was done on a soxhlet extracting machine (HT 1043 extraction unit, Tecator, Hoganas, Sweden), using petroleum ether (40-60 boiling points) as the extractant.

Fibre:
Dietary fibre was determined according to the procedure of Pearson et al. (1981). About 1g of each sample was placed in a 600 mL beaker; 100 mL of cetyl trimethyl ammonium bromide in NH_2SO_4 solution and the mixture boiled under reflux for 1hour on Labconco fibre analyser. The beaker was left to cool for 2 minutes and the content filtered through a cheese cloth- polyester material on bunchunar funnel connected to a vacuum pump through a glass fibre. The residue was washed with distilled water 4 times to free it of any acid and transferred into pre-weighed nickel crucibles and dried at 100 °C for 1 hour in Gallenkamp UK hot box oven.

The total dietary fibre was determined using the formular:

$$\text{Dietary fibre (\%)} = [W2/W1] \times 100$$

Where; W2 = Weight (g) of the fibre,
W1 = Weight (g) of the sample.

Ash content:
Total ash was determined by oxidizing the samples (AOAC, 1999). About 2 g of sample was weighed into a dry pre-weighed porcelain dishes, transferred into the Carbolite furnace CNF13/5 (Carbolite, parson's Lane, Hope Valley s33 6RB, England) and the content was completely oxidized at 550-600°C for 8 hrs. The ash content was then reported as the loss in weight which occurred from complete oxidation of the sample.

Carbohydrates:
Carbohydrate was obtained from the standard equation 100% - (% protein + % fat + % Ash + % moisture) and the energy content was obtained by multiplying the protein, carbohydrate, and fat content by the factors 4, 4, and 9, respectively.

Analysis of minerals:
Samples were analyzed for major minerals like; iron, calcium, phosphorous and manganese using PerkinElmer 23080 Atomic Absorption Spectroscopy (AAS) following wet digestion according to the method described by Okalebo et al. (2002).

Statistical analysis:
Data obtained were subjected to descriptive statistics (mean, standard deviation and ranges). Student t-test was used to check for the significance of difference in the biochemical and nutritional contents between the two (2) edible insect species. All analysis were done using predictive analytical software (PASW) version 20 at 0.05 level of significance and at their relevant degree of freedom. Error bar graphs were also be plotted for the respective nutritional contents of the insects using Microsoft Excel, 2013 version.

Results:-

Proximate composition of insects:
The summary of the proximate composition of termites and cricket from Cross River State is shown in Table 1. In termite (M. bellicosus), the moisture level ranged from 3.80 – 3.90%, with a mean and standard deviation of 3.846 ± 0.050%, while Ash content ranged from 4.15 – 4.25% and with a mean and standard deviation of 4.200 ± 0.050%. Fat content in termite ranged from 26.25 – 26.35%, having a mean and standard deviation of 26.300 ± 0.050%, while the fibre ranged from 2.62 – 2.70% and with a mean and standard deviation of 2.656 ± 0.040%. Protein ranged from 22.20 – 22.62%, having a mean and standard deviation of 22.440 ± 0.216%. The carbohydrate level ranged from 7.40 – 7.45%, having a mean and standard deviation of 7.420 ± 0.026% (Table 1).

In cricket (A. domesticus), the moisture level ranged from 2.52 – 2.71%, with a mean and standard deviation of 2.626 ± 0.097%, while Ash content ranged from 4.52 – 4.65% and with a mean and standard deviation of 4.590 ±

0.065%. Fat content ranged from 22.30 – 22.70%, having a mean and standard deviation of 22.500 ± 0.200%, while the fibre level ranged from 3.35 – 3.45% and with a mean and standard deviation of 3.400 ± 0.050%. Protein ranged from 20.00 – 20.30%, having a mean and standard deviation of 20.173 ± 0.155%. The carbohydrate level ranged from 6.32 – 4.40%, having a mean and standard deviation of 6.356 ± 0.040% (Table 1).

The distribution of the proximate nutrients showed variations between M. bellicosus and A. domesticus (Fig. 2). The moisture, fat, protein and carbohydrate level were higher in termite compared to that of cricket, except for ash and fibre which was the reverse (Fig. 2). Statistically, the moisture, ash, fat, fibre, protein and carbohydrate content varied insignificantly between termite and cricket ($p>0.05$).

Mineral composition of insects:

The summary of the mineral composition of termites and cricket from Cross River State is shown in Table 2. In M. bellicosus, the calcium level ranged from 20.60 – 21.00 mg/100g, with a mean and Standard deviation of 20.800 ±

Table 1:- Proximate composition of termites (M. bellicosus) and cricket (A. domesticus) from Cross River State throughout the study.

S/N	Proximate nutrient	Termite (%)	Cricket (%)
1	Moisture	3.846 ± 0.050[a] (3.80 – 3.90)	2.626 ± 0.097[a] (2.52 – 2.71)
2	Ash	4.200 ± 0.050[a] (4.15 – 4.25)	4.590 ± 0.065[a] (4.52 – 4.65)
3	Fat	26.300 ± 0.050[a] (26.25 – 26.35)	22.500 ± 0.200[a] (22.30 – 22.70)
4	Fibre	2.656 ± 0.040[a] (2.62 – 2.70)	3.400 ± 0.050[a] (3.35 – 3.45)
5	Protein	22.440 ± 0.216[a] (22.20 – 22.62)	20.173 ± 0.155[a] (20.00 – 20.30)
6	Carbohydrate	7.420 ± 0.026[a] (7.40 – 7.45)	6.356 ± 0.040[a] (6.32 – 6.40)

Values are in Mean ± Standard deviation

Ranges are in Parenthesis ( )

Values with different superscript are significantly different ($p<0.05$).

0.200 mg/100g, while magnesium content ranged from 10.20 – 10.70 mg/100g and with a mean and standard deviation of 10.433 ± 0.251mg/100g. Iron content in termite ranged from 16.20 – 16.50 mg/100g, having a mean and standard deviation of 16.366 ± 0.152 mg/100g, while the level of phosphorous ranged from 83.10 – 83.70 mg/100g and with a mean and standard deviation of 83.433 ± 0.305 mg/100g (Table 2).

In A. domesticus, the calcium level ranged from 15.20 – 16.00 mg/100g, with a mean and standard deviation of 15.566 ± 0.404 mg/100g, while magnesium content ranged from 13.00 – 13.50 mg/100g and with a mean and standard deviation of 13.266 ± 0.251mg/100g. Iron content in cricket ranged from 18.20 – 18.80 mg/100g, having a mean and standard deviation of 18.533 ± 0.305 mg/100g, while the level of Phosphorous ranged from 70.00 – 70.40 mg/100g

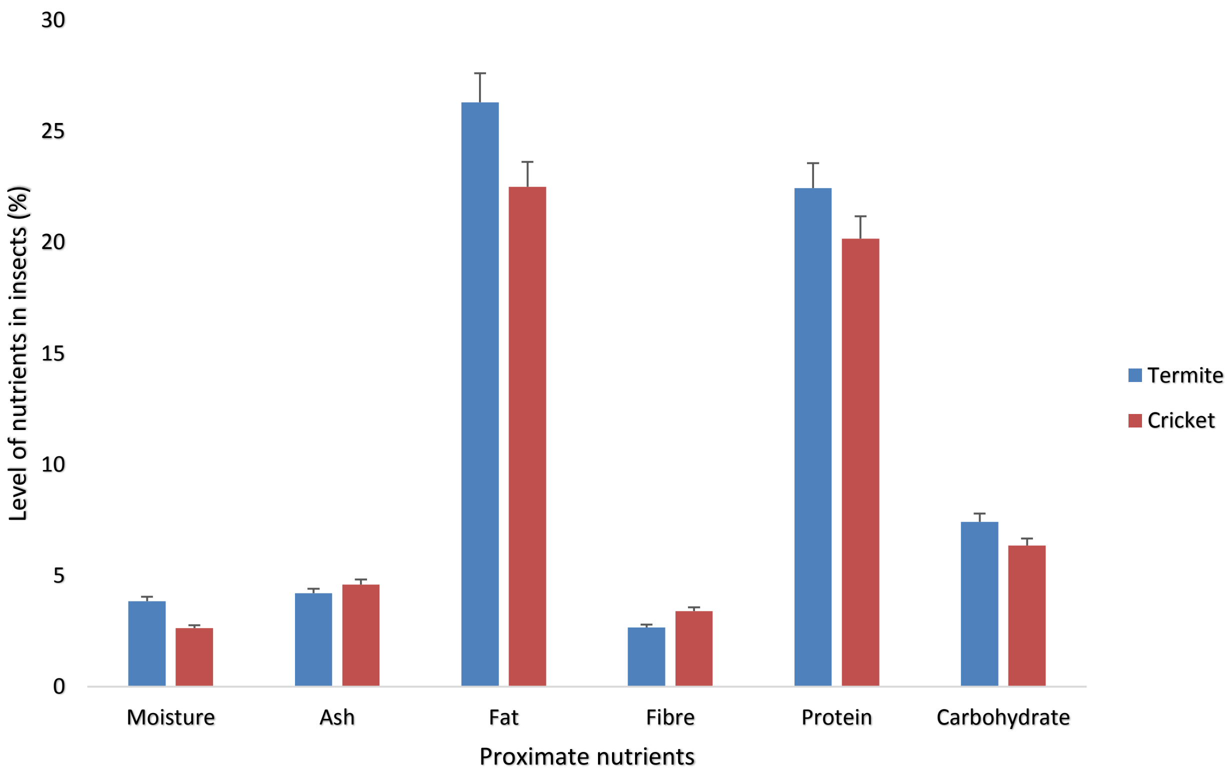

Fig 2:- Proximate composition of insects from the study area during the study.

and with a mean and standard deviation of 70.166 ± 0.208 mg/100g (Table 2).

The distribution of the mineral composition showed variations between M. bellicosus and A. domesticus as shown in Figure 3. The calcium and phosphorous level in termites were higher than that of cricket, except for magnesium and iron which was the reverse (Fig 3). Statistically, the calcium, magnesium and phosphorous level varied significantly ($p<0.05$), while the level of iron varied insignificantly between termite and cricket ($p>0.05$).

Discussion:-

Edible insects constitute an important part of the diet of a large proportion of the population in many developing countries. The importance of edible insects as nutritional food source is beginning to be appreciated (Kampmeier and Irwin, 2009), due to the high cost of animal protein, which is beyond the reach of the poor (Adesina et al., 2010) and

Table 2:- Mineral composition of M. bellicosus and A. domesticus from Cross River State throughout the study.

S/N	Mineral nutrients	Termite (mg/100g)	Cricket (mg/100g)
1	Calcium	20.800 ± 0.200[a] (20.60 – 21.00)	15.566 ± 0.400[b] (15.20 – 16.00)
2	Manganese	10.433 ± 0.251[a] (10.20 – 10.70)	13.266 ± 0.251[b] (13.00 – 13.50)
3	Iron	16.366 ± 0.152[a] (16.20 – 16.50)	18.533 ± 0.305[a] (18.20 – 18.80)
4	Phosphorous	83.433 ± 0.305[a] (83.10 – 83.70)	70.166 ± 0.208[b] (70.00 – 70.40)

Values are in Mean ± Standard deviation
Ranges are in Parenthesis ( )
Values with different superscript are significantly different ($p<0.05$).

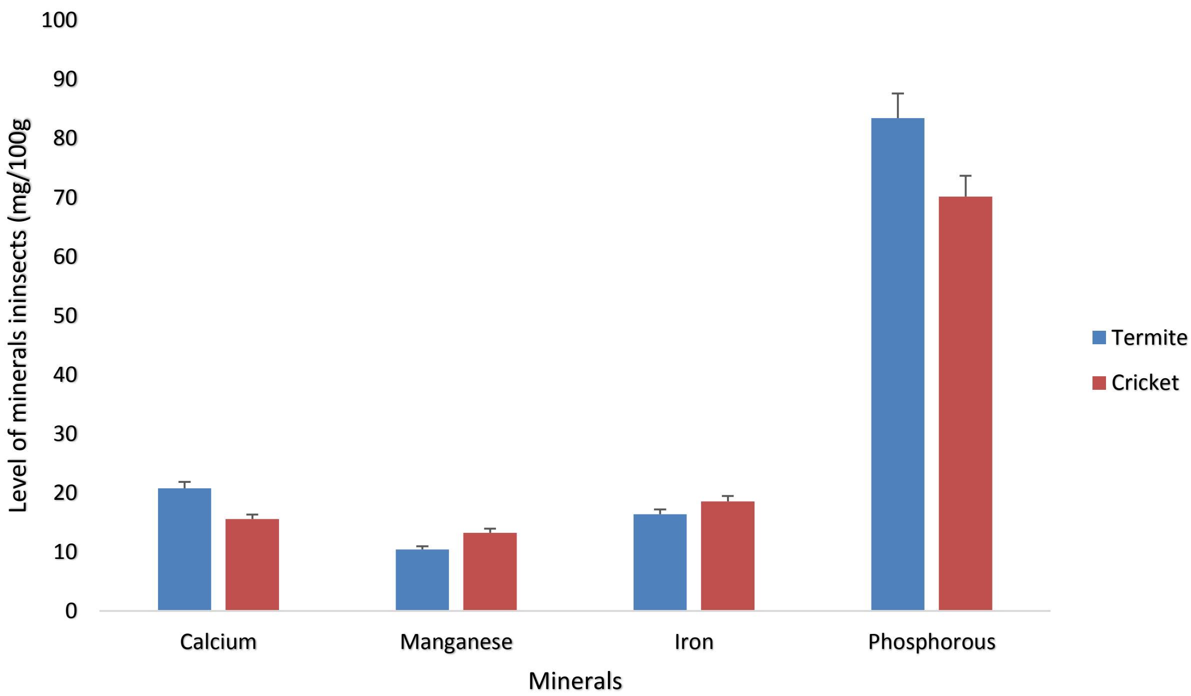

Fig 3:- Level of minerals in insects from the study area during the study.

because edible insect species are rich in proteins, amino acids, fats, vitamins and trace elements (Igwe, 2011; Ajayi, 2012; Ntukuyoh et al., 2012; Kinyuru et al., 2013). The rapid growth of the world population requires proportionate increases in food production. However, it is difficult to increase productivity to a level that meets the increasing global food demand (Verkerk et al., 2007; Mitsuhashi, 2010), leading to shortage of food particularly animal protein. Consumption of insects could contribute to the dietary protein quality, replacing higher animal protein usually deficient in diets of rural dwellers in developing countries (Banjo et al., 2006).

The present study confirmed that edible insects like M. bellicosus and A. domesticus are rich in nutritional and mineral requirements of the body, which corresponded with the findings of Rumpold and Schlüter (2013), who observed that Insect contains satisfactory levels of essential macronutrients (protein, amino acid) and micronutrients (including iron, manganese, phosphorous, copper, riboflavin, magnesium) and Fromme (2005), who reported that insects often contained more protein, fats and carbohydrates than the equivalent of beef or fish. Also, caterpillars of many species are rich in potassium, calcium, magnesium, zinc and iron as well as B-vitamins (FAO, 2004). The nutritional and mineral components varied between M. bellicosus and A. domesticus, with termite (M. bellicosus) having a higher moisture, fat, protein, carbohydrate, calcium and phosphorous contents. This observation was similar to that of Srivastava et al. (2009) and Raksakantong et al. (2010) who reported that the nutrient levels vary greatly by species. The protein, fibre, ash content of M. bellicosus and A. domesticus were lower, while the fat content was higher in the present study than that reported by Akullo et al., (2018) for M. bellicosus from Uganda; the fibre and moisture content in the studied insects were lower, while the protein and ash content was higher than the findings of Chakravorty et al., (2011) for Aspongopus nepalensis from India; the protein, ash and carbohydrate content were lower, while moisture, and fibre content were higher than that reported by Adesina (2012) for Heteroligus meles. Also, iron, calcium and manganese levels in termites and cricket for the present study were higher than the findings of Nzelu (2010) for edible insects, while the calcium, manganese, iron and phosphorous contents were lower than that reported by Payne et al., (2015) for edible insects from South Africa. The variances in the proximate and mineral compositions of the studied insects and that of the other compared findings corroborated with the findings of Van Huis et al. (2013), who reported that within the same group of species, nutritional composition may vary with the metamorphic stage of the insect, its habitat and diet. The proximate and mineral composition differences in the compared findings with that of this study could be due to the difference in species, environmental conditions (diet, season and living temperature, geographical location, feeding habits and the developmental stages of the insects) (Srivastava et al., 2009; Raksakantong et al., 2010). The discrepancies could also be due to the fact that the nutritional values of insects vary even within species depending on season and life stages (Jensen et al., 2011; Ghosh et al., 2016). Also, biological factors such as digestibility; enzymatic activity, age, sex, and size are also known to influence fatty acid composition and concentration (Oranut et al., 2010).

Despite the fact that M. bellicosus (termite) and A. domesticus (cricket) studied were rich in proximate and mineral nutrients required by human body, it was observed that termites were nutritionally better for consumption, because they had higher moisture, fat, protein, carbohydrate, calcium and phosphorous contents and a lower levels of ash and fibre. Ash and fibres are required by the body at lower quantity, as a result, termites are better for consumption, from a nutritional point of view.

Conclusion:-

In conclusion, the study revealed richness in the proximate and mineral composition of the studied insects, which are relevant to the human body. The proximate and mineral content of the studied insects varied, with M. bellicosus being richer in nutrients, making it more nutritious than A. domesticus since it contains higher moisture, fat, protein, carbohydrate, calcium and phosphorous. It was also observed that edible insects have the capacity to provide the relevant nutrients and proteins, since fish productivity alone is not meeting up with the growing human population. As a result, eating insects can provide alternative source of nutrients.

Ethical Consideration:

The authors ensured that all ethical and other basic principles underlying behavior and advancing welfare for the use of animals in research, including handling, relevant laws and regulations were considered before proceeding with the research. Permission was also received from the relevant bodies for the use of insects for this experiment.

Competing Interests:

Authors have declared that no competing interests exist.

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References:-

1. Adesina, A.J. (2012): Proximate and anti-nutritional composition of two common edible insects: yam beetle (Heteroligus meles) and palm weevil (Rhynchophorus phoenicis). Elixir Food Sci.; 49: 9782-9786.
2. Adesina, A.J., Olagboye, S.A, Agbaogun. B. (2010): Proximate analysis of maggot’s meal as supplement for fish meal. Int. Jour. Biosci., 5(3): 59-63.
3. Ajayi, O.E. (2012): Biochemical Analyses and Nutritional Content of Four Castes of Subterranean Termites, Macrotermes subhyalinus (Rambur)(Isoptera: Termitidae): Differences in Digestibility and Antinutrient Contents among Castes. Intern. Journ. of Biol.; 4(4):54-59.
4. Akullo, J., Agea, J.G., Obaa, B.B., Okwee-Acai, J. and Nakimbugwe, D. (2018): Nutrient composition of commonly consumed edible insects in the Lango sub-region of northern Uganda. Intern. Food Resear. Journ.; 25(1): 159 - 165.
5. AOAC (1999): Official methods of analysis of the Association of Official Analytical Chemists.15th ed. U.S.A: Association of Official Analytical Chemists, pp85.
6. Banjo, A.D., Lawal, O.A. and Songonuga, E.A. (2006): The nutritional value of fourteen species of edible insects in southwestern Nigeria. Afri. Journ. of Biotech.; 5(3): 298-301.
7. Chakravorty, J., Ghosh, S., and Meyer-Rochow, V.B. (2011): Chemical Composition of Aspongopus nepalensis Westwood 1837 (Hemiptera; Pentatomidae), a Common Food Insect of Tribal People in Arunachal Pradesh (India). Int. J. Vitam. Nutr. Res., 81 (1): 1 – 14.
8. Ekop, K.E., Cerda, A.B., Onigbinde, A.O., (2010): Nutritional potentials of the larva of Rhynchophorus phoenicis (F). Pak. J. Nutr., 4: 287–290.
9. FAO (2004): Protein and Amino Acid Requirements in Human Nutrition. Report of a joint WHO/FAO/UNU Expert Consultation. WHO Technical Report Series No. 935.

10. Forte, Y. (2004): "Westwood, John Obadiah (1805–1893)". Oxford Dictionary of National Biography. Oxford University Press, pp2855.
11. Fromme, A. (2005): Edible Insects. Zoogoer; 34(4): 25 - 33.
12. Ghosh, S., Jung, C., Meyer-Rochow, V.B. (2016): Nutritional value and chemical composition of larvae, pupae, and adults of worker honey bee, Apis mellifera ligustica as a sustainable food source. J. Asia Pac. Entomol. 19: 487–495.
13. Gordon, D. G. (1998). The Eat-A-Bug Cookbook. Berkely, California: Ten Speed Press, pp83.
14. Igwe, C.U. (2011): Chemical analysis of an edible African termite, Macrotermes nigeriensis; a potential antidote to food security problem. Biochem. and Analy. Biochem.; 1(1): 25 - 33.
15. Jensen, K., Mayntz, D., Toft, S., Raubenheimer, D., Simpson, S.J. (2011): Nutrient regulation in a predator, the wolf spider Pardosa prativaga. Anim. Behav., 81: 993–999.
16. Kampmeier, G.E. and Irwin, M.E. (2009): Commercialization of Insects and Their Products. In Vincent, H. R. and Ring, T. C. Encyclopedia of Insects, 2nd ed. San Diego: Academic Press, pp220-227.
17. Kinyuru, J., Konyole, S., Roos, N., Onyango, C., Owino, V., Owuor, B. and Kenji, G. (2013): Nutrient composition of four species of winged termites consumed in western Kenya. Journ. of Food Composition and Analys.; 30(2):120-124.
18. Mitsuhashi, J. (2010): Insects as traditional foods in Japan.Ecol. of Food and Nutri.; 36(2-4):187-199.
19. Ntukuyoh, A.I., Udiong, D.S., Ikpe, E. and Akpakpan, A.E. (2012): Evaluation of Nutritional Value of Termites (Macrotermes bellicosus): Soldiers, Workers, and Queen in the Niger Delta Region of Nigeria. Intern. Journ. of Food Nutri. and Safe.; 1(2): 60-65.
20. Nzele, A. (2010): Chemical composition and mineral elements of edible insects (at larvae and adult stages). Nig. Food Journ.; 28(1): 1- 8.
21. Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (2002): Laboratory methods of soil and plant analysis: A working manual. 2nd ed. Nairobi, Kenya: TSBF-Ciat and Sacred Africa, pp155.
22. Oranut, S., Subhachai, B., Shen, L.R. and Li, D. (2010): Lipids and fatty acid composition of dried edible red and black ants. Agric. Sci. in China, 9(7):1072-1077.
23. Payne, C.L.R., Umemura, M., Dube, S., Azuma, A., Takenaka, C. and Nonaka, K. (2015): The mineral composition of 5 insects as sold for human consumption in Southern Africa. Afri. Journ. of Biotech.; 14(31): 2443 – 2448.
24. Pearson, D., Egan, H., Sawyer, R. and Kirk, R.S. (1981): Pearson’s chemical analysis of food. 8th ed. Edinburg: Churchhill Livingstone, pp55.
25. Premalatha M, Abbasi T, Abbasi T, Abbasi S.A. (2011): Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. Renewable and Sustain. Energy Rev. 15: 4357–4360.
26. Raksakantong, P., Meeso, N., Kubola, J. and Siriamornpun, S. (2010): Fatty acids and proximate composition of eight Thai edible terricolous insects.Food Resear.Int.; 43(1):350-355.
27. Ramos-Elorduy, J., Moreno, J.M.P., Prado, E.E., Perez, M.A., Otero, J.L. and De Guevara, O.L. (1997): Nutritional value of edible insects from the state of Oaxaca, Mexico. Journ. of Food Composition and Analys.; 10(2): 142-157.
28. Rumpold, B.A. and Schlüter, O.K. (2013): Nutritional composition and safety aspects of edible insects. Molecular Nutri. and Food Resear., 57 (3): 44-50.
29. Srivastava, S.K., Babu, N. and Pandey, H. (2009): Traditional insect bioprospecting-As human food and medicine. Indian Journ. of Traditional Knowledge; 8(4):485- 494.
30. Van Huis, A. (2003): Insects as food in sub-Saharan Africa. Intern. Journ. of Tropical Insect Sci; 23(3):163-185.
31. Van Huis, A., Itterbeek, J.V., Klunder, H., Mertens, E., Halloran, A., Muir, G., Vantomme, P. (2013): Edible Insects: Future Prospects for Food and Feed Security. FAO Forestry Paper, pp171.
32. Verkerk, M., Tramper, J., Van Trijp, J. and Martens, D. (2007): Insect cells for human food.Biotech. Advances; 25(2):198-202.