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(Research Article)

Proximate and heavy metal analysis of grasshopper species consumed in Katsina State

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Abstract

The study was conducted with the aim of determining some nutrients and metal concentrations in grasshopper samples consumed in Katsina State. The experimental group samples were purchased from Batsari, Jibia and Mai'adua markets while the control sample was obtained from the Biological Garden, Federal College of Education, Katsina. Samples were authenticated at the Entomology Unit, Usman Danfodiyo University, Sokoto and found to be the same species. Samples were prepared and analysed using standard procedures. Sample A (control) had the lowest moisture content (5.667%), ash (9.833%) and crude fibre (10.333%). It recorded the highest crude protein content (57.330%), crude lipid (10.667%) and carbohydrate (6.170%). Sample C had the highest moisture (9.500%), ash (15.167%) and crude fibre (14.500%). It had the lowest crude protein content (48.857%) and carbohydrate (2.810%). The concentration of all the metals are within the WHO permissible limits except for Mn, Cd and Pb in Sample D, and Pb in sample C which exceeds the limits. ANOVA indicated no significant difference in metal and nutrient concentrations within the sampling locations ($P= 0.07>0.05$ for metals and $P=1>0.05$ for nutrients). A significant difference was however indicated between the concentrations in the different samples ($P=0.04<0.05$ for metals and $P= 0.000<0.05$ for nutrients). From the result obtained, it can be concluded that grasshopper can be a good source of nutrients although there is need for continuous monitoring of metal concentrations. The location and preservation methods may also affect the concentrations of both nutrients and metals.

Keywords: Grasshopper; Heavy metal; Proximate; Analysis; Katsina

1. Introduction

Edible insects are considered as underutilized foods that offer significant potential to contribute to meeting future global food demands. Insects traditionally were an integral element of human diets in nearly 100 countries of the world (Durst *et al*., 2010) [1]. Edible insects provide satisfactory energy, protein, monounsaturated fatty acids, polyunsaturated fatty acids and rich in several minerals such as copper, iron, magnesium, manganese, phosphorous, selenium, zinc and vitamins such as riboflavin, pantothenic acid, biotin and folic acid (Rumpold, 2013) [2]. Besides nutritional importance, the edible insects also possess an ample sources of antioxidant properties such as phenol, flavonoid (Shantibala *et al.,* 2014) [3]. Insects may also have higher proportion of quality protein, fat along with higher energy value than other animal protein like beef and fish. The practice Entomophagy, has been proposed to warfare the deficiencies of these minerals in developing countries (Gibson, 2015) [4]. In view of the fact that the percentage of the world population at risk for these deficiencies is more than 17 % for zinc (Gibson, 2015) [4] and 25 % for iron (McLean *et al.*, 2009) [5]. Therefore, insects as a food source can prevent under-nutrition particularly in the developing world and underdeveloped countries (Nadeau *et al.,* 2015) [6]. The edible insects have been prescribed as a severe choice to conventional meat production, both as animal feed and as human food (Paoletti, 2005 [7],Ramos-Elordly *et al.*,1997 [8]). The high cost of protein sources and problems associated with meat consumption has led to renewed interest in

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new source of diets. The long standing bias against foods rich in saturated fats should be replaced with a view towards recommending diets consisting of healthy foods (Astrup *et al.*, 2020) [9]. Insects are institutionally accepted as food in many regions and historically consumed, providing sufficient nutritional value for humans (Zielinska *et al*., 2018) [10]. However, the rapid increase in food production through technological advancement has largely eliminated insects from our diets (Gao *et al.*, 2018) [11]. The reappearance of insects as a viable food group can be attributed to their nutritional, environmental, and economic value (Nongonierma and FitzGerald, 2017) [12].

In general, insects have high protein content and excellent production efficiency compared with other conventional food groups (Kohler *et al*., 2019) [13]. This characteristic is particularly valuable given that future protein consumption is expected to increase, but food supply declines (Gao *et al*., 2018) [11]. Interest in edible insects has increased rapidly because the Food and Agricultural Organization (FAO) has begun promoting insects as viable dietary options for humans (Van-huis *et al*., 2013) [14]. However, lingering negative perceptions of insects hamper global market expansion and limit insects as a mainstream dining option, which may be related to the fact that people are sceptical of novel foods due to general neophobic tendencies (Dobermann *et al*., 2017) [15]. Food insufficiency and malnutrition have been the major problem in developing countries, including Nigeria. Any approach to help fight this problem will go a long way in pushing the wheel of development in the country.

2. Material and methods

2.1. Study Location and Sample Collection

The study location is Katsina State (latitude between 110^{o}8′ N and 13023′ N and longitudes 6052′03′ E and 990 02′ E), situated in the Northwest geo-political zone of Nigeria. The state covers an area of 23,938 square kilometres and lies in the Northern Nigerian Sahelian Savannah. The state is bordered by Niger Republic to the North, Jigawa and Kano States to the East, Kaduna State to the South and Zamfara State to the West. The state has 34 Local Government Areas. The present investigation was designed to evaluate Nutritional and heavy metal concentrations of edible grasshopper species consumed in Katsina State. Out of the three senatorial zone within the state, three major markets, namely the Batsari, Jibia, and Mai'adua markets were purposively selected for the purchase of samples for the experimental group. The control group was collected from the biological garden Federal College of Education, Katsina. All the samples were identified to be of same species. Both experimental and control groups were taken to the Department of Biological Sciences, Entomology Unit, Usmanu Danfodiyo University Sokoto, Nigeria for authentication (Table 1). The wings of the samples were removed before the analysis. The control samples were air-dried, then all the samples were separately ground to fine powder using porcelain mortar, and stored in pre-cleaned labelled containers in a desiccator prior to analysis.

2.2. General Composition Analysis

The Association of the Official Analytical Chemists (AOAC), (1990) [16] methods were adapted for proximate analysis of the samples. An atmospheric heat drying at 105 °C for 4 h was used for analysis of moisture content, a direct ashing method at 600 °C was used for ash content, a Soxhlet extraction method for lipid content, and a micro Kjeldahl method for protein content. All analyses of general composition were done in triplicate.

2.3. Elemental composition Analysis

Table 1 List of Sample Species, Locations and their Group

Sample/Location	Specie	Group
Sample A/Katsina	*S. gregaria & L. migratoria manilensis*	Control
Sample B/Mai'adua	*S. gregaria & L. migratoria manilensis*	Experimental
Sample C/ Jibia	*S. gregaria & L. migratoria manilensis*	Experimental
Sample D/ Batsari	*S. gregaria & L. migratoria manilensis*	Experimental

In order to conduct Elemental composition analysis for grasshopper species consumed in Katsina, wet digestion method was used. In other words, 2 g of prepared sample was placed in a 50 mL beaker. 15mL HNO_3 was added to the sample and the heated at 250 °C on a hot plate until no more light brown fumes were evolved. 5mL per-chloric acid was then added, and heating continued until about 1mL of the digestion solution was left. The solution was then cooled, and filtered using Whatman No. 6 filter paper. The solution was made up to the mark with hot distilled/deionised water in a 50mL volumetric flask. All analysis was done in triplicate for each sample. Atomic Absorption Spectrophotometer (Buck Scientific Model 210VGP) was used to analyse the presence and concentrations of Calcium (Ca), Iron (Fe), Zinc (Zn), Magnesium (Mg), Manganese (Mn), Lead (Pb) and Cadmium (Cd). Sodium (Na) was analysed using Flame photometer Buck 210.

2.4. Statistical Analysis

Two-factor analysis of variance (ANOVA) without replication was applied to establish the differences in concentrations of metals in the samples. The emergent data have been presented in terms of mean values ± standard error of mean (SEM). The level of statistical significance was set at $p < 0.05$ (95% confidence interval). SPSS V.16 and Minitab V.17 software version was used for the data analysis.

3. Results and discussion

3.1. Proximate composition

Figure 1 shows the plot of the proximate compositions in the grasshopper samples in the four specified sampling areas. The error bars overlap results to insignificant difference of the proximate compositions in the sample within the same sampling location but with slight difference of the composition from one sampling location to another.

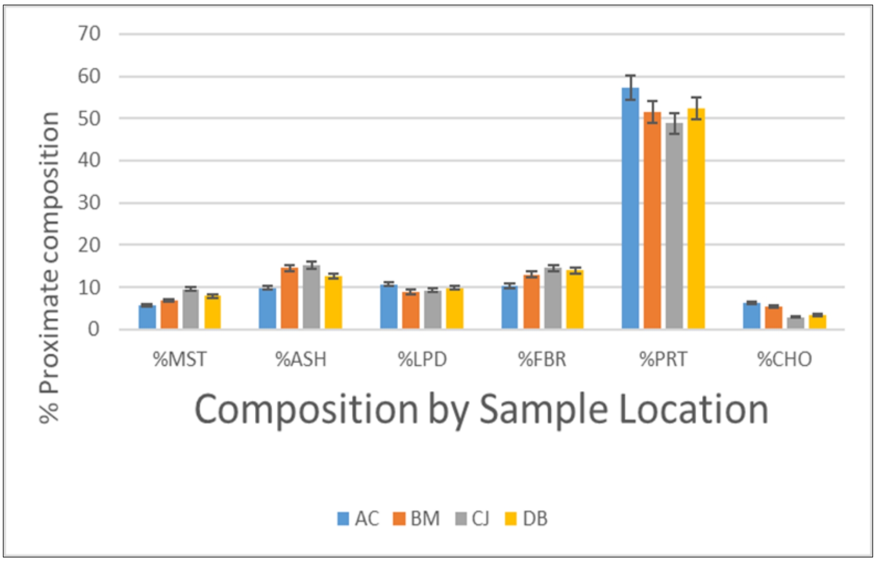

Figure 1 Proximate compositions in the Grasshopper samples in the four specified sampling areas

3.2. Moisture content

Moisture content is among the most vital and mostly used measurement in the processing, preservation and storage of materials (Onwuka, 2005) [17].

Highest moisture content (9.500%) was recorded in sample C and lowest (5.667%) was found in sample A (Table 2). The moisture content of the four different samples ranged from 5.667 to 9.500%. This is similar to the findings of Onwuka (2005) [17] and Adeduntan (2005) [18] who reported similar range of values (4.87 to 10.32%) of moisture content in eight different insect species. In this study, the control sample (sample A) recorded the lowest moisture content with 5.667%. This can be an indication that the preparation methods used in the experimental samples (samples B, C and D) probably aid moisture retention, thereby reducing the preservation period when compared to the control group (Sample A). Lower moisture content usually reduces the risk of microbial attack and thus increase the preservation period.

3.3. Crude protein content

The highest crude protein content (57.330%) was recorded in samples A and the lowest (48.857%) was observed in the sample C (Table 2). The crude protein content of sample A were similar to the result of Longvah *et al.*, (2011) [19], who reported a range of 54.00-54.80%. In the present investigation, high levels of crude protein (48.857-57.33 %) was recorded in all the samples and the results are within earlier values reported by Narzari and Sarmah, (2015) [20] who recorded 30.00 to 84.56% of protein in twenty species of wild edible insects. A high value of crude protein in different species of insect were also reported by Blasquez *et al*., (2012) [21] and Siulapwa (2014) [22]. The crude protein content (48.857%) of sample C which is lowest among the four sample was slightly higher than the results of Kinyuru *et al.,* (2012) [23] who recorded 39.79 to 44.64 %.

3.4. Crude lipid content

The fats in insects provide the body with a large amount of energy and essential fatty acids, and some specific fatty acids, such as linoleic acid and alpha-linolenic acid, play an important role in maintaining human health (Finke, 2013) [24]. Therefore, insect fats are beneficial for human nutrition and health (Finke, 2015) [25]. As the second most important nutrient in the body, insects can contain up to 43% of their dry weight in fat (Siulapwa, 2014) [22]. However, the fat content of insects varies greatly between species. Out of the four samples, the highest (10.667%) crude lipid content was obtained in sample A and the lowest value (8.833%) was found in sample B (Table 2). The lipid content obtained for the four different samples ranged from 8.833 to 10.667%. Present findings corroborate the results of Ghosh *et al*., (2016) [25] who reported lipid content within the range of 6.90 to 14.50 %.

3.5. Ash content

Ash content can affect different characteristics of food including physiochemical and nutritional properties. Determining the ash contents ensure the safety of foods, making sure there are no toxic minerals present. The highest amount (15.167%) of ash content was recorded in sample C. The lowest ash (9.833%) content was observed in control sample group (Table 2). These findings are higher than the results recorded by Ghosh *et al*. (2016) [25] in four species of edible insect who reported the value of ash (3.80%-4.10%).

3.6. Crude fibre content

The highest crude fibre content (14.500%) was observed in sample C which was followed by sample D (14.000%), sample B (13.000%) and sample A (10.333%) (Table 2). This result is higher than the results of Agbidye *et al.,* (2009) [26] in some forest insects in Benue State, Nigeria, who reported crude fibre content ranging from 5.55 to 7.85 % in the insects they studied. The control samples had the lowest value in this study. Dietary fibres promote beneficial physiologic effects including laxation blood cholesterol attenuation.

3.7. Carbohydrate content

Carbohydrate is a major source of energy for most insects. Insects are able to convert carbohydrates into lipids, and many insects can synthesize lipids and accumulate them in fat body tissue (Nation, 2001) [27]. In this research, the highest carbohydrate content 6.170%) was recorded in control (sample A) followed by sample B (5.290%) and sample D (3.353%) (Table 2). The lowest carbohydrate content (2.810%) was recorded in sample C. Similar findings were reported by Bhulaidok *et al.,* (2010) [28]. Many insects use carbohydrate and the amino acid, proline, to support flight. Most insects are unable to use cellulose and other plant polymers because they do not have the enzymes to digest them (Nation, 2001) [27]. In some other insect species, nevertheless, these substances are made available as a result of symbiotic microorganism activities (Nation, 2001 [27], Chapman, 1998 [29]). For all insects, carbohydrate is a very important fuel source.

Table 2 Proximate composition of Samples Collected from four Locations

Mean ± SDV						
SMPL	**%MST**	**%ASH**	**%LPD**	**%FBR**	**%PRT**	**%CHO**
A^C	5.667 ±0.577	9.833 ±0.764	10.667 ±0.764	10.333 ±0.289	57.330 ±0.148	6.170 ±0.996
B^M	6.833 ±0.289	14.500 ±0.500	8.833±0.289	13.000 ±0.500	51.543 ±0.687	5.290 ±0.751
C^J	9.500 ±0.000	15.167 ±0.577	9.167 ±0.289	14.500 ±0.500	48.857 ±1.435	2.810 ±1.687
D^B	7.833 ±0.289	12.500 ±0.000	9.833 ±0.289	14.000 ±0.500	52.480 ±0.340	3.353 ±0.457

There was no statistically significant difference in the concentrations of nutrients (Proximate Analysis) within the sampling locations with a P value of 1.000 which is greater than the 0.05 significant level (1>0.05). However, a statistical difference was indicated in the concentration nutrients found in the different samples with a P value 0.000 (0.000<0.05), although the calculated mean values of the nutrients were almost the same. A (16.66667), B(16.6665), C(16.66683) and D(16.6665). This may be because all the samples are of the same species.

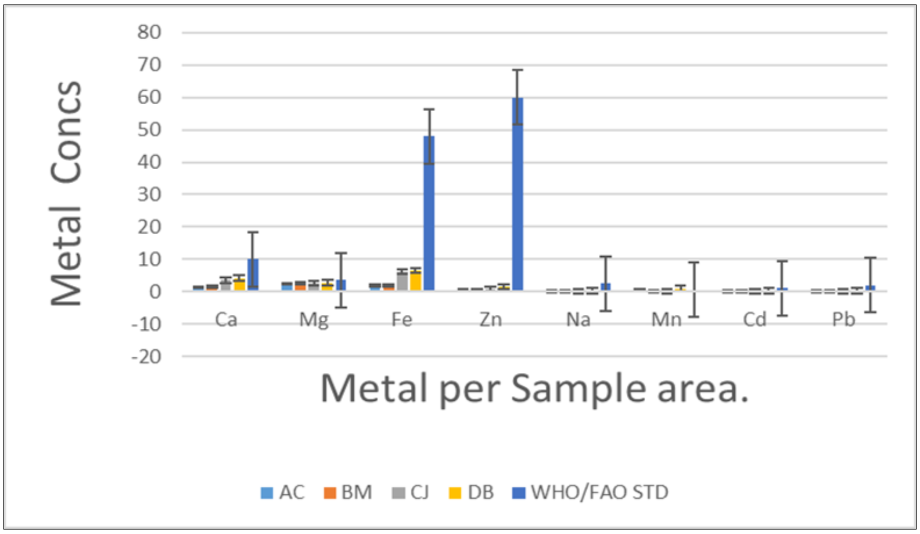

Figure 2 Concentration of metals in Grasshopper samples in the four specified sampling areas

3.8. Elemental composition

The concentrations of calcium (Ca), magnesium(Mg), iron(Fe), zinc(Zn), sodium(Na), manganese(Mn), cadmium(Ca) and lead(Pb) of the samples in mg/kg are presented in Table 3. The result showed that Ca, Mg, Fe and Zn concentrations (4.173± 0.242, 2.690± 0.000, 6.540± 0.010 and 1.493± 0.021) mg/kg respectively were highest in sample D when compared to samples A, B, and C. The concentrations of Mn (0.933± 0.012mg/kg), Cd(0.153± 0.015mg/kg) and Pb (0.2067± 0.021mg/kg) were above the WHO permissible limits in sample D. Pb concentration was also above WHO permissible limit in sample C(0.130± 0.021mg/kg). All other metal concentrations were within the WHO permissible limit. The control sample (sample A) had the lowest concentration of all the metals except for Fe where it is higher than sample B with a value of 1.960± 0.027mg/kg and Mn where it had higher concentrations than samples B and C.

Table 3 Elemental composition of Grasshopper Samples

	Mean Concentrations ± SDV (mg/kg)							
SMP	**Ca**	**Mg**	**Fe**	**Zn**	**Na**	**Mn**	**Cd**	**Pb**
A[C]	1.327 ±0.015	2.400 ± 0.000	1.960 ±0.027	0.470 ±0.000	0.029 ± 0.013	0.320* ± 0.000	0.000* ± 0.000	0.000* ± 0.000
B[M]	1.617 ±0.029	2.427 ± 0.006	1.777 ±0.025	0.5600 ±0.000	0.029 ± 0.023	0.107* ± 0.006	0.000* ± 0.000	0.063* ± 0.029
C[J]	3.530 ±0.145	± 2.500 ± 0.010	6.110 ±0.056	0.733 ±0.006	0.085 ± 0.015	0.137* ± 0.006	0.043* ± 0.046	0.130** ± 0.021
D[B]	4.173 ±0.242	2.690 ± 0.000	6.540 ±0.010	1.493 ± 0.021	0.308 ± 0.242	0.933** ± 0.012	0.153** ± 0.015	0.2067** ± 0.021

WHO Maximum permissible limits: Mn = 0.5 mg/kg; Cd = 0.05 mg/kg; Pb = 0.1 mg/kg.; *= mean concentration within WHO Maximum permissible limits, ** = mean concentration that exceed WHO Maximum permissible limit

Generally, insects are good sources of minerals, especially iron and zinc, which may be of considerable nutritional importance (Mwang *et al*., 2013) [30]. Globally, micronutrient deficiencies continue to affect the health of 2 billion people, particularly iron, zinc and iodine deficiencies (Bhutta *et al*., 2018) [31]. Micronutrient deficiencies are common in developing countries, especially among children and lactating women, with iron deficiency anemia, and iodine deficiency goiter being the main micronutrient deficiencies (Michaelsen *et al*., 2009) [32]. Among the four samples, sample D contained the highest (6.540 mg/kg) amount of Fe content. The result is similar to that of Omotoso, (2015)

[33] who reported a range of 5.30 to 6.33 mg/kg in grasshopper species (*S. gregaria*). The lowest amount (1.777 mg/kg) of Fe content was obtained in sample B.

The zinc content in sample D obtained from Batsari (*S. gregaria*) was found to be highest (1.493 mg/kg) and the control sample group, of the same specie (*S. gregaria*) recorded the lowest amount (0.470mg/kg) (Table 3). Present findings are lower than the results of Halliru *et al.,* (2022) [34] who recorded a Zn value of 1.705 mg/kg in grasshopper. Sample D obtained from Batsari also had the highest Ca concentration (4.173 mg/kg) among the four samples collected from different locations in Katsina State (Table 3). The control sample group of the same species recorded with lowest amount (1.327 mg/kg) of calcium content. The presence of calcium content in the samples suggests that the substrates could be used in complementary foods to help build the bones and teeth since calcium is one of the main components of teeth and bones (Mehas and Rodgers, 1997) [35].

The range of magnesium concentrations obtained was 2.400 to 2.690 mg/kg across all the four samples collected from different locations in Katsina State. Magnesium plays an important role in many physiological functions. Habitually low intake of magnesium and in general the deficiency of this micronutrient induce changes in biochemical pathways that can increase the risk of illness and in particular chronic degenerative diseases (Fiorentini *et al*., 2021) [36]. Magnesium is also involved in making proteins and releasing energy and helps hold calcium in the enamel of the teeth (Mehas and Rodgers, 1997) [35].

The concentration ranges of Na obtained is 0.029± 0.013mg/kg to 0.308± 0.242 mg/kg. The human body requires a small amount of sodium to conduct nerve impulses, and maintain the proper balance of water and minerals.

ANOVA indicated no statistically significant difference within the sampling locations in the concentrations of metals found in the grasshopper samples with a P-value 0.07 which is greater than the 0.05 significant value (0.07>0.05). However, between the samples, a statistically significant difference was indicated in the concentrations with a P value of 0.04 which is less than 0.05(0.04<0.05). Sample B obtained from Mai'adua. However, had an average concentration 0.8225mg/kg which is very close to that of the control (sample A) with a value of 0.81325 mg/kg. The average concentrations of metals in samples C and D obtained from Jibia and Batsari respectively, were however much higher than those of the control sample with average values 1.65mg/kg (Sample C) and 2.06 mg/kg (Sample D). The control (Sample A) had the lowest average value. Since they are all of the same species, collected from different locations, this may be an indication that the preparation method and environment/location contribute to the concentration of metals in the samples studied. A difference in average concentration was seen from one metal to the other. This may be due the difference in the concentrations of the metals in the environment.

4. Conclusion

From the result obtained, it can be concluded that grasshopper can be a good source of nutrients although there is need for continuous monitoring of the concentration of metals so that they do not exceed the recommended limits. The location and preservation methods may also affect the concentrations of both nutrients and metals.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

References

[1] Durst, P.B., Johnson, D.V., Leslie, R.N. and Shono, K. (2010). Forest Insects as Food: Humans Bite Back, Chiangmai, Thailand. RAP Publication, 231.

[2] Rumpold, B.A. and Schluter, O.K. (2013). Potential and Challenges of Insects as an Innovative Source Roar Food and Feed Production. Innovative Food Science and Emerging Technologies. 17, 1-11.

[3] Shantibala, T., Lokeshwori, R.K. and Debaraj, H. (2014). Nutritional and Anti-Nutritional Composition of the Five Species of Aquatic Edible Insects Consumed in Manipur, India. Journal of Insect Science. 14, 1-10.

[4] Gibson, R.S. (2015) Dietary-induced Zinc Deficiency in Low Income Countries: Challenges and Solutions the Avanelle Kirksey Lecture at Purdue University. Nutrition Today. 50(1), 49-55.

[5] McLean, E., Cogswell, M., Egli, I., Wojdyla, D. and de Benoist, B. (2009). Worldwide Prevalence of Anaemia, WHO Vitamin and Mineral Nutrition Information System. Public Health Nutrition. 4, 444-454.

[6] Nadeau, L., Nadeau, I., Franklin, F. and Dunkel, F. (2015). The Potential for Entomophagy to Address Undernutrition. Ecology of Food and Nutrition. 54, 200-208.

[7] Paoletti, M.G. (2015). Ecological Implications of Mini Livestock: Role of Rodents, Frogs, Snails and Insects for Sustainable Development. Science Publication, 263-291.

[8] Ramos-Elordly, J., Moreno, J.M.P., Prado, E.E., Perez, M.A., Otero, J.L. and Guevara, O.L. (1997). Nutritional Value of Edible Insects from the State of Oaxaca, Mexico. Journal of Food Composition and Analysis. 10, 142-157.

[9] Astrup, A., Magkos, F., Bier, D.M., Brenna, J.T., Otto, M.C.O., Hill, J.O., King, J.C., Monte, A., Ordovas, J.M. Volek, J.S., Yusuf, S., and Krauss, R.M. (2020). Saturated Fats and Health: A Reassessment and Proposal for Food- Based Recommendations. Journal of the American College of Cardiology. 76 (7), 844- 857.

[10] Zielinska, E., Karas, M. and Baraniak, B. (2018). Comparison of Functional Properties of Edible Insects and Protein Preparations. LWT-Food Sci Technol., 168-174.

[11] Gao, Y., Wang, D., Xu, M. L., Shi, S. S. and Xiong, J. F. (2018). Toxicological Characteristics of Edible Insects in China: A Historical Review. Journal of Food Chem. Toxicol., 119, 237-251.

[12] Nongonierma, A. B. and FitzGerald, R. J. (2017). Unlocking the Biological Potential of Proteins from Edible Insects Through Enzymatic Hydrolysis: A Review. Journal of Innov. Food Sci. Emerg. Technol. 43, 239-252.

[13] Kohler, R., Kariuki, L., Lambert, C. and Biesalski, H. K. (2019). Protein, Amino acid and Mineral Composition of some Edible Insects from Thailand. Journal Asia Pac. Entomol. 22, 372-378.

[14] Van Huis, A., van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A, Muir, G. and Vantomme, P. (2013). Edible Insects: Future Prospects for Food and Feed Security. Journal of Food and Agriculture Organization of the United Nations, Rome

[15] Dobermann, D., Swift, J. A. and Field, L. M. (2017). Opportunities and Hurdles of Edible Insects for Food and Feed. Nutrition Bull, 42, 293-308.

[16] A. O. A. C (1990). Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edition. A.O.A.C Pub., Virginia, U.S.A;

[17] Onwuka, G. I. (2005). Food analysis and Instrument (theory and practice). Journal of Chemical Sciences. 2(2), 35-39

[18] Adeduntan, S.A. (2005). Nutritonal and Antinutritional Characteristics of Some Insects Foragaing in Akure Forest Reserve Ondo State, Nigeria. Journal of Food Technology. 3, 563-567.

[19] Longvah, T., Mangthya, K. and Ramulu, P. (2011). Nutrient Composition and Protein Quality Evaluation of *eri* silkworm (*Samia ricinii*) Prepupae and Pupae. Elsevier. 128(2), 400-403.

[20] Narzari, S. and Sarmah, J. (2015). Proximate Composition of Wild Edible Insects Consumed by the Bodo Tribe of Assam, India. International Journal of Bioassays. 4(7), 4050-4054.

[21] Blasquez, J.R.E., Moreno, J.M.P. and Camacho V.H.M. (2012). Could Grasshoppers be a Nutritive Meal. Food and Nutrition Sciences. 3, 164-175.

[22] Siulapwa, N., Mwambungu, A., Lungu, E. and Sichilima, W. (2014). Nutritional Value of Four Common Edible Insects in Zambia. International Journal of Science and Research. 3(6), 876-884.

[23] Kinyuru, J.N., Kenji, G.M., Muhoho, S.N. and Ayieko, M. (2010). Nutritional Potential of Longhorn grasshopper (*Ruspolia differens*) Consumed in Siaya District, Kenya. Journal of Agriculture, Science and Technology. 12(2).

[24] Finke, M.D. (2013). Complete Nutrient Content of Four Species of Feeder insects. Zoo Biol. 32, 27-36

[25] Finke, M.D. (2015). Complete Nutrient Content of Four Species of Commercially Available Feeder Insects Fed Enhanced Diets During Growth. Zoo Biol. 34, 554-564.

[26] Agbidye, F.S., Ofuya, T.I. and Akindele, S.O. (2009). Marketability and Nutritional Qualities of Some Edible Forest Insects in Benue state, Nigeria. Pakistan Journal of Nutrition. 8(7), 917-922.

[27] Nation, J.L. (2001). Insect Physiology and Biochemistry. Boca Raton, Fla., CRC Press. 485.

[28] Bhulaidok, S., Sihamala, O., Shen, L. and Li, D. (2010). Nutritional and Fatty Acid Profiles of Sun-dried Edible Black Ants (*Polyrhachis vicina* Roger). Maejo International Journal of Science and Technology. 4(01), 101-112.

[29] Chapman, R.F. (1998). The Insects: Structure and Function. 4th edition. Cambridge University Press, UK. 770.

[30] Mwangi, M.N. Oonincx, D.G.A.B., Stouten, T., Veenenbos, M., Melse-Boonstra, A., Dicke, M. and van Loon, J.J.A. (2018). Insects as Sources of Iron and Zinc in Human Nutrition. Nutr. Res. Rev. 31, 248–255.

[31] Bhutta, Z.A, Das, J.K, Rizvi, A., Gaffey, M.F., Walker, N., Horton, S., Webb, P., Lartey, A. and Black, R.E. (2013). Evidence-based Interventions for Improvement of Maternal and Child Nutrition: What can be done and at what cost? Lancet. 382, 452-477.

[32] Michaelsen, K.F., Hoppe, C., Roos, N, Kaestel, P., Stougaard, M., Lauritzen, L., Mølgaard, C., Girma, T. and Friis, H. (2009). Choice of Foods and Ingredients for Moderately Malnourished Children 6 Months to 5 Years of Age. Food Nutr. Bull. 30, S343-S404.

[33] Omotoso, O.T. (2015). An Evaluation of the Nutrients and Some Anti-nutrients in Silkworm, *Bombyxmori* L. (Bombycidae: Lepidoptera). Jordan Journal of Biological Sciences. 8(1), 45-50.

[34] Halliru, A., Muhammad, S. J. and Ahmed, A. (2022). Comparative Proximate and Mineral Compositions Between Beans Seed and Dried Edible Grasshopper. Bayero Journal of Pure and Applied Sciences. 13(1), 92-96.

[35] Mehas, K. Y. and Rodgers, S. L. (1997). The Biochemistry of Food and Nutrition. 3rd Edition. Glencoe / McGraw-Hill, Peoria. Illinois, U.S.A. 35:169-171.

[36] Fiorentini, D., Cappadone, C., Farruggia, G. and Prata, C. (2021). Magnesium: Biochemistry, Nutrition, Detection and Social Impact of Diseases Linked to Its Deficiency. *Nutrients.*13(4),1136. https://doi.org/10.3390/nu13041136