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Original article

Mineral Nutrient Profile of Grasshopper (*Zonocerus variegatus*) subjected to Different Conventional Post-Harvest Processing Techniques

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ABSTRACT

The influence of roasting and sundrying on the mineral contents of edible grasshopper consumed in Niger State, Nigeria was determined using standard methods. Analysis was done on fresh, sundried and roasted grasshopper samples. The results of the study revealed that sundried grasshopper (SGH) had the highest Mn (10.57±0.21), Ca (1467±2.83) and Fe (23.35±0.21) contents. Fresh samples (FGH) had the highest Cu (11.05±0.21) content and least K (67.00 ±1.14), Mn (2.35 ±0.07), Na (16.55±0.35) and P (57.40±0.99) contents. Roasted grasshopper prepared in the laboratory (RGHL) had the highest Zn (1.06±0.04), Na (94.70 ±0.14), K (133.79±0.86), Mg (411.50±10.61) and P (107.00±1.41) contents while roasted grasshopper obtained from the market (RGHM) had the least Fe (14.95±0.49), Zn (0.54±0.01), Na (14.90±0.42), Mg (234.00±1.41) and P (59.10 ±0.57) contents. The composition of Cu, Fe and Ca in all the samples of grasshopper analyzed were above the WHO recommended limit. The results of this study showed that insect samples processed by roasting provided good sources of many minerals. Therefore, roasted grasshopper prepared in the laboratory is deemed suitable as complementary food source to alleviate under-nutrition especially among vulnerable groups (women and children) in developing countries.

Keywords: Grasshopper, Mineral contents, Pyrgomorphidae, Roasting, Sundrying.

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INTRODUCTION

Grasshopper (*Zonocerus variegatus*) belongs to the order orthoptera, family pyrgomorphidae. In Nigeria, grasshopper is called 'Fara' in Hausa, 'Tata' in Yoruba, 'Ukpana' in Igbo and 'Goro' in Nupe [1]. It has a higher nutritional content compared to other animal proteins but has received little attention globally for various reasons which includes allergic reaction and consideration as pest [2]. In Borno State, northern Nigeria, grasshopper is widely consumed and seen as delicacy. They are readily displayed in the markets and sold like meat [3]. During the rainy season, large swarms fall in fields on grasses and shrubs and are naturally collected for food, early in the morning before they are able to fly [4]. [5] reported that in Nigeria, grasshoppers are collected by children by handpicking. The insects are consumed in many forms during their swarming seasons. The usual steps in processing grasshopper include dewinging, boiling, roasting and salting or grinding into flour, though they are also consumed raw [6].

The global surge in demand for inexpensive alternative and sustainable protein sources has led the FAO to advocate the consumption of insects ([7]; [8]). In sub-Saharan Africa, entomorphagy based on harvesting from the wild is practiced, but many challenges such as seasonal availability, sustainability concerns, pathogen risks and high perishability of the harvested insects are associated with this practice ([9]; [10]). [3] revealed grasshopper as a source of suitable, alternative, digestible and highly nutritive protein for inclusion in food supplementation. [11] revealed that crickets, grasshoppers, termites, and locusts contain high essential minerals (Cu, Fe, Mg, Zn, Na, K) content and concluded that they could be used as alternative sources of these minerals in order to help complement the nutritional needs of individuals.

[12] reported that edible grasshopper contained significant amount of nutritional and mineral components with less concentrations of antinutrients. [13] reported the presence of nutrient and minerals such as manganese, copper and iron in short-horned grasshopper. From the foregoing, grasshoppers are future food source because they are rich in protein and vitamins [14]. Hence, the growing interest in domesticating and making them for food and feed readily available throughout the year.

Furthermore, biological properties such as high fecundity, high feed conversion ratio, omnivorous diet, low substrate, water and space requirements as well as univoltine life cycle highlights the potential of edible grasshopper contribution to global food security either via feed or directly as food ([15];[16]). Given that many insects including grasshopper are only seasonally available, there is the need to develop post-harvest processes to establish high quality, nutritious, safe and shelf stable-insect based products beyond the harvesting season as alternative to established protein sources.

Considering the high capacity and running cost associated with the freeze-drying process, alternative drying methods (sun or oven drying, drying over ashes, roasting, frying) are more frequently used in developing nations for preserving insects ([8]; [17]; [18]. While the storage of insects under deeply frozen conditions ensure food quality and safety, prolonged drying at high temperature affects the nutritional value of insects through chemical and physical modification or cause direct loss of mineral elements [17]. [18] reported that oven-drying increased majority of minerals concentration.

Investigations into the effect of different drying processes on nutritional properties of insects are limited. Thus, this research was carried out in order to ascertain the influence locally utilized processing methods of sundrying and roasting have on the mineral contents of grasshoppers with a view of revealing the nutritional potential of the processed insects.

MATERIALS AND METHODS

Sample Collection and Identification of Grasshopper

Fresh whole samples of grasshopper (*Zonocerus variegatus*) with average weight of 190g were purchased from markets in Minna and Kotongora, Niger State and Maiduguri, Borno State, Nigeria from December, 2016 to July, 2017. Fresh samples of the species were also collected using an entomological net and by handpicking; these were transferred to sterile perforated containers. The insects were identified and authenticated by an Entomologist in the Department of Animal Biology, Federal University of Technology, Minna. The insect samples were either used immediately or within 24 hours after storage at 4°C depending on the analyses.

Preparation of Collected Samples of *Zonocerus variegatus*

The collected samples were divided into four groups labeled; fresh (FGH), sundried (SDG), roasted (obtained directly from the marketers) (RGHM) and fresh samples processed by roasting at 45°C for 8 minutes (RGHL) [19]. Each sample in the group was crushed into powdered form using sterile mortar and pestle. Samples were analysed for their mineral profiles.

Determination of Mineral Composition of Grasshopper Samples

The methods of Association of Official Analytical Chemists [20] were employed in determining the mineral composition of the grasshopper samples. One gram (1g) of each pulverized sample was weighed into a 100 cm^3 beaker, 20 cm^3 of acid mixture 3:1 (Nitric acid/perchloric acid) was added to the beaker containing the sample. The beaker containing the sample was transferred to a hot plate under a pressured cupboard and digested at 150°Cuntil a clear solution was obtained. Sample was allowed to cool and made up to 100 cm^3 mark with distilled water. This was then transferred to a plastic sample bottle and was taken for analysis. Flame photometry method was used to determine sodium and potassium contents of the sample. Iron, magnesium, calcium, zinc, manganese, and copper were determined using Alpha 4 atomic absorption spectrophotometer (AAS) and phosphorus content was determined using a UV spectrophotometer.

Data Analysis

Results are expressed as mean values. Within groups, comparisons were performed by the analysis of variance using one way ANOVA test. Significant differences between control and experimental groups were separated by Duncan's Multiple Range Test [21].

RESULTS

Table 1 shows the results of mineral composition of *Zonocerus variegatus* studied. Among the various processed forms of the species, sundried grasshopper (SGH) had the highest manganese contents (10.75±0.21) when compared with the other processed forms of its species. This was followed by roasted grasshopper prepared in the laboratory (RGHL) (6.67±0.48). Although roasted samples from the market (RGHM) had lower manganese content than [22]permissible limit; it RGHL counterpart values were higher than the WHO permissible limit. Fresh samples (FGH) had the least manganese contents.

Fresh grasshopper (FGH) had the highest copper contents when compared with the other samples and [22]permissible limit and other groups of edible insects while roasted grasshopper prepared in the laboratory (RGHL) had the least copper contents. Higher copper content were recorded for sundried grasshopper (SGH) and roasted grasshopper obtained from the market (RGHM). Sundried grasshopper (SGH) had the highest iron contents when compared with the other samples and permissible limit while roasted grasshopper obtained from the market (RGHM) had the least iron contents (P>0.05). Fresh grasshopper (FGH) and roasted grasshopper prepared in the laboratory (RGHL) iron contents were similar and higher than the [22]permissible limit (P>0.05).

Roasted grasshopper prepared in the laboratory (RGHL) had the highest zinc contents when compared with the other samples and [22]permissible limit while roasted grasshopper obtained from the market (RGHM) had the least zinc contents. Lower zinc contents were obtained for fresh grasshopper (FGH) and sundried grasshopper (SGH) when compared with [22]permissible limit (P>0.05). Roasted grasshopper prepared in the laboratory (RGHL) had the highest sodium contents when compared with the other samples and [22]permissible limit while similar sodium contents were recorded for roasted grasshopper obtained from the market (RGHM) and fresh grasshopper (FGH). They had the least sodium contents when compared with the [22]permissible limit. Sodium contents of sundried grasshopper (SGH) were lower than [22]permissible limit (P>0.05).

Highest potassium contents were recorded for roasted grasshopper prepared in the laboratory (RGHL) when compared with the other samples and [22]permissible limit while fresh grasshopper (FGH) had the least potassium contents. Potassium contents of sundried grasshopper (SGH) and roasted grasshopper obtained from the market (RGHM) were lower than [22]permissible limit (P>0.05). Sundried grasshopper (SGH) had the highest calcium contents 1467mg/100g when compared with other groups of edible insects and [22]permissible limit while fresh grasshopper (FGH) and roasted grasshopper prepared in the laboratory (RGHL) had calcium contents higher than [22]permissible limit but also the least calcium contents (P>0.05). Higher calcium contents were recorded for roasted grasshopper obtained from the market (RGHM) when compared with [22]permissible limit.

Roasted grasshopper prepared in the laboratory (RGHL) had the highest magnesium contents when compared to the [22]permissible limit while roasted grasshopper obtained from the market (RGHM) had the least magnesium contents. High magnesium contents were recorded for sundried grasshopper (SGH) and fresh grasshopper (FGH) which was higher than [22]permissible limit (P>0.05). Roasted grasshopper prepared in the laboratory (RGHL) had the highest phosphorus contents 140.36 mg/100g when compared with the other samples and permissible limit while fresh grasshopper (FGH), 57.40 mg/100g and roasted grasshopper obtained from the market (RGHM), 59.10Mg/100g had same and the least phosphorous contents. Lower phosphorous contents were recorded for sundried grasshopper (SGH) and roasted grasshopper prepared in the laboratory (RGHL) (P>0.05).

Table 1: Mineral composition of samples of grasshopper

Processed Forms of Grasshopper	Minerals Compositions (mg/100g)								
	Mn	Cu	Fe	Zn	Na	K	Ca	Mg	P
SGH	10.75±0.21[a]	9.90±0.14[b]	23.35±0.21[a]	0.80±0.07[b]	25.85±1.34[b]	119.50±2.12[b]	1467±2.83[a]	385.00±2.82[b]	72.95±
FGH	2.35±0.07[d]	11.05±0.21[a]	20.64±0.76[b]	0.73±0.02[c]	16.55±0.35[c]	67.00±1.41[d]	1188.00±2.83[c]	325.50±2.12[c]	57.40±
RGHM	3.80±0.00[c]	8.70±0.14[c]	14.95±0.49[c]	0.54±0.01[d]	14.90±0.42[c]	90.50±2.12[c]	1344.50±3.45[b]	234.00±1.41[d]	59.10±
RGHL	6.67±0.48[b]	4.45±0.21[d]	19.40±0.42[b]	1.06±0.04[a]	94.70±0.14[a]	133.79±0.86[a]	1194.00±11.31[c]	411.50±10.61[a]	107.00±
[WHO, 2004]		2	15	15	2400	3500	1000	350	1000

Values are means ± standard deviation for n=2. Mean values with the same superscript on the same column are not significantly different from each other using DMRT (P>0.05).

SGH-Sundried grasshopper FGH -Fresh grasshopper

RGHM-Roasted grasshopper obtained from the market RGHL-Roasted grasshopper prepared in the laboratory

WHO-World Health Organization

DISCUSSION

The manganese content (10.75±0.21 mg/100g) obtained from sundried grasshopper (SDG) was higher than the manganese content (2.30±0.07 mg/100g) dry matter obtained from short-horned grasshopper by [13].The manganese content of 5.30% dry weight of *Ruspolia differens* (green grasshopper) reported by [23] was slightly lower than the manganese content of 6.67±0.48 mg/100g obtained for roasted grasshopper prepared in the laboratory (RGHL) in this present study. [24]obtained a manganese content of 0.28 to 0.39mg/g dry weight in *Cirina forda*; a value significantly ($P<0.05$) lower than the result obtained in this study.

The manganese content recorded for roasted grasshopper obtained from the market (RGHM) (3.80±0.00 mg/100g), in this investigation was lower than that obtained by [25] of 7.0 mg/100g from oven dried larva of *Cirina forda*.These values were significantly ($P<0.05$) lower than the values (25.5±0.2 mg/100g and 202±0.1 mg/100g) obtained from bebra seed and ripened beans by [26] and [27] respectively.[28]reported manganese contents of 16.93±2.01 mg/100g in sundried *Bunaea alcinoe;* a value significantly higher than the manganese content of 2.35±0.07 mg/100g from fresh grasshopper (FGH) obtained in this study. Manganese is an essential element in every animal species. Deficiencies in manganese result in poor reproductive performance, congenital malformations in the offspring, growth retardation, abnormal formation of bone and cartilage, and impaired glucose tolerance [29].

The copper contents of 11.05±0.21 mg/100g and 9.90±0.14 mg/g obtained from fresh grasshopper (FGH) and sundried grasshopper (SDG) respectively in this study, were significantly ($P<0.05$) higher than the copper content of 0.20±0.01mg/100g obtained by [12] from dried edible *Zonocerus variegatus and* higher than 1.13±0.50 mg/100g obtained from sundried *Bunaea alcinoe* by [28]. [30] obtained copper content of 0.10±0.00 mg/100g from oven dried silkworm,*Bombyx moripupal* value significantly ($P>0.05$) lower than the values obtained in the current study. [29] obtained copper contents of 0.01±0.01 mg/100g and 0.01±0.01 mg/100g from oven dried *Macrotermes nigeriensis* and *Oryctes rhinoceros* respectively,which was lower than the value (8.70±0.14 mg/100g), obtained from roasted grasshopper obtained from the market (RGHM) in this study. This variation can be attributed to ecological factors and variation in species [11].

The copper content of 4.45±0.2 mg/100g from roasted grasshopper prepared in the laboratory (RGHL) in this research, were moderately higher than the copper content of 1.74 mg/kg from oven dried *Oedaleus abruptus* reported by [31]. [23] obtained copper content of 0.50 mg/100g from dried *Ruspolia differens* (brown grasshopper); value lower than the result obtained in this study. Variation in copper contents can be attributed to ecological factors and variation in species. The edible insects analyzed in this study have been proven to be excellent sources of copper [28].

Copper is an important nutrient for all vertebrates and some lower animal species. Copper deficiency in animals results in skeletal defects, anemia and degeneration of the nervous system, defects in pigmentation and structure of hair or wool, myocardial degeneration, reproductive failure and decreased arterial elasticity [29].Sundried grasshopper (SDG) had the highest iron content of 23.35±0.21 mg/100g than the other insect samples evaluated in this study; value significantly (P<0.05) lower than the iron content of 131.44±1.38 mg/100g for oven dried grasshopper by [32].Similar iron contents of 19.40±0.42 mg/100g and 20.64±0.76 mg/100g were obtained for roasted grasshopper prepared in the laboratory (RGHL) and fresh grasshopper (FGH) respectively in this study. These values are significantly (P<0.05) lower than the iron content of 85.00 mg/100g for oven dried larvae of *Oryctes monoceros* reported by [33].

The iron content of sundried *B. alcinoe* [28] was higher than the iron contents of RGHM which had the least iron content from the present study. Variation in iron contents could be as a result of the insects feeding habits. The recommended dietary requirement (RDR) for iron in human is 2-5 mg/day [34].The edible insects' analyzed in this study have been shown to be excellent sources of iron. According to World Health Organization, iron plays an important role as a 'heme' molecule in red blood cells as it permits oxygen transport [32]. It can also serve as an antioxidant agent and can prevent cadiomyopathy and growth retardation [35]. It also facilitates the oxidation of carbohydrates, proteins and fats [35]. On the other hand, excessive intake of iron can cause enhancement of free radical activity in the body or damage the liver [36].

In this study, the zinc content of RGHL was higher than the other insect groups evaluated. These results were significantly lower than the zinc concentrations from oven dried silk worm, *Bombyx morilarvae* (35.63±4.98 mg/100g) and *Bombyx moripupal* (37.50±4.64 mg/100g) [33], but similar to 1.63±0.01 mg/100g obtained from dried edible *Zonocerous variegatus* by [12].The zinc contents of SGH and FGH obtained from this study were significantly low (P<0.05) when compared with the zinc contents obtained for oven dried short horned grasshopper by [13].[28] obtained high concentration of zinc (24.73±0.90 mg/100g) in sundried *B. alcinoe* while [29] obtained 15.50±0.14 mg/100g and 10.10±0.11 mg/100g in oven dried *M. nigeriensis* and *O. rhinoceros*, respectively.

From this study, the least zinc content of 0.54±0.01 mg/100gwere recorded for roasted grasshopper obtained from the market (RGHM). This result is comparable to the zinc contents of 0.13 to 0.56 mg/g from dried larva of *Cirina forda* reported by [24]. Similarly zinc content of0.70±0.00 mg/100g was obtained from sundried dung beetle larva by [37].Zinc is a component of many enzymes that help regulate gene expression and maintain structural integrity of proteins. Zinc metallo-enzymes include alcohol dehydrogenase, carbonic anhydrase, ribonucleic acid polymerases and alkaline phosphatase [38].The biological roles of zinc can be catalytic, structural or regulatory. More than 85% of total body zinc is found in skeletal muscles and bones [38]. Thelow zinc content observed in some of the edible insect groups studied showed that they may not be suitable to compliment the daily dietary zinc requirement of 15 mg/day of an adult of 60 kg body weight and 6 mg/day for boys and girls of 9-13 years ([39]; [30]).

Roasted grasshopper prepared in the laboratory (RGHL) had the highest sodium content (94.70±0.14 mg/100g) than other insects in this research. [40] obtained sodium content of 127.50 mg/100g for oven dried cricket, which was higher than the value obtained in this study. Sundried grasshopper (SGH) had sodium content which was comparable with that obtained by [29] for oven dried *O. rhinoceros.* In this study, similar sodium contents of 16.55±0.35 were obtained from fresh grasshopper (FGH) and roasted grasshopper 14.90±0.42 obtained from the market (RGHM). These results obtained in this research compared favourably with that documented by [29] for oven dried *M. nigeriensis*. Furthermore, lower sodium values were recorded for oven dried silk worm *B. morilarvae* and *B. moripupal* [30] respectively. This variation in sodium contents can be ascribed to differences in geographical locations as well as inter-elemental interactions [41].Considering the importance of sodium in human metabolism, the amount of sodium reported in the edible insects analyzed in this study were significantly lower than the RDA value (2400 mg) by[42].However, incorporating the edible insects in the diets of both adults and children may greatly promote the normal functioning of the system in the body.

Roasted grasshopper prepared in the laboratory (RGHL) had the highest potassium content among all processed forms in this study. The value obtained was comparable to that obtained by [43] for termite. [43] also obtained similar potassium content for shea caterpillar with sundried grasshopper (SGH) in this research. This value was significantly higher than that obtained by [44] for dried grasshopper (*Ruspolia differens*) and dried *Encoptolophus herbaceous* (grasshopper) by [15]. [15] obtained a high potassium value dry matter for dried edible *Spernarium histrio* (adult grasshopper), which was significantly higher than the values obtained for RGHM and FGH. Lower potassium values were recorded in oven dried *M. nigeriensis* and *O. rhinoceros* respectively by [29]. Variation in the potassium contents could be attributed to the sampling location and the feeding habits of these insects. The high potassium content observed in this research showed that the edible insects studied could be good sources of essential mineral nutrients and play important role in the synthesis of amino acids and protein. They may also help compliment the nutritional deficiencies of individuals [11].

In the present study, calcium content was higher in sundried grasshopper (SGH) and roasted grasshopper obtained from the market (RGHM) than the other insects evaluated. [1] obtained calcium value of 552.00 mg/100g for oven dried grasshopper (*Zonocerus variegatus*) (1st instar larvae) which was significantly ($P<0.05$) lower when compared to the result obtained in this study.The high values obtained from the above-mentioned insects meet the recommended daily intake of calcium (1300.00 mg per day) for adults [22]. Similar calcium contents were recorded for fresh grasshopper (FGH) and roasted grasshopper prepared in the laboratory (RGHL) in this research. These values are significantly higher ($p<0.05$) when compared to the results obtained from oven dried grasshopper (adults) by [1] and the value obtained for oven dried *Ruspolia differens* (brown grasshopper) by [23].

Calcium is a major constituent of bone and plays an important role in vital functions in nerve conduction, blood clotting, muscle contraction and membrane permeability [45]. High intake of calcium-rich foods has been reported to cause reduction in osteoporotic fractures [45]. Therefore, incorporating the edible insects in the diets of both adults and children will greatly promote the vital functioning of the system in the body. In this study, magnesium content of 411.50±10.61 mg/100g for roasted grasshopper prepared in the laboratory (RGHL) was highest when compared with the other insect samples evaluated. Similar values have been reported by [15] for *Encoptolophus herbaceous* and *Sphenarium histrio* (adult) for oven dried grasshopper species. [15] obtained similar values for magnesium for oven dried *Sphenarium magnum* (adult grasshopper) which was similar to that obtained in this study for SGH and FGH.

Roasted grasshopper obtained from the market (RGHM) had the least magnesium value 234.00±1.41 mg/100g recorded in this research, which was significantly ($P<0.05$) lower than the value (498.00 mg/100g) obtained by [15] for oven dried grasshopper *(Encoptolophus herbaceous).* Magnesium is an important co-factor found in the structure of certain enzymes and is essential in several biochemical pathways [46]. Incorporating the edible insect in the diets of both adults and children will greatly promote the vital functioning of the system in the body.

In this study, roasted grasshopper prepared in the laboratory (RGHL) had the highest phosphorus content of 107.00±1.41 mg/100g than the other insect samples evaluated; [43] obtained phosphorus content of 100.20mg/100g for dried *Cytacanthacris aeruginosus* unicolor (grasshopper); a value similar to that obtained in this study.[43] obtained phosphorus content of 131.2 mg/100g from dried grasshopper; a value significantly ($P<0.05$) higher than 72.95±0.49 mg/100g obtained for sundried grasshopper in this research. Roasted grasshopper obtained from the market (RGHM) and fresh grasshopper (FGH) had the least phosphorus contents of (59.10±0.57 mg/100g) and (57.40±0.99 mg/100g) when compared to the other insects evaluated. This phosphorus content was significantly ($P<0.05$) lower when compared to the values (121.00 mg/100g) obtained for oven dried *Ruspolia differens* (brown grasshopper) by [23] and (114 mg/100g) obtained from dried *Macrotermes bellicosus* by [43]. The fairly high values of phosphorus content obtained for the edible insects suggest that they are good sources of phosphorus, which plays a vital role in calcification of bones and teeth, proper kidney function, cell growth and helps in maintaining the body's acid-alkaline balance [47].

CONCLUSION

The results of this study suggest that roasting improved the mineral composition of grasshopper which has the potential of contributing towards the reduction of malnutrition in developing nations.

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