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Nutritional Value of Four Common Edible Insects in Zambia

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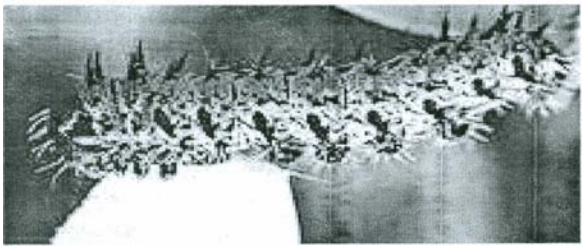
Abstract: ***Background and Objectives:*** ***Insects have played an important part in the history of human nutrition in Africa. The main objective of this research was to assess the nutritional value of four commonly edible insects in Zambia. The insects studied include the caterpillars (Gonimbrasia belina and Gynanisa maja), grasshopper (Ruspolia differens) and winged termites (Macrotermes falciger). Materials and Methods: The proximate composition and minerals of the insects were determined using standard methods. One way Analysis of Variance (ANOVA) was used in analysing the data. Results: The moisture content of the insects ranged from 4.1% ±0.3 to 9.2%±0.1. The highest amount of crude fat was found in Ruspolia differens with fat content of 49.0 % ±0.1 and the least amount was found in Gonimbrasia belina which had a mean fat content of 10.0 % ± 0.2. The difference in fat content among the insects was statistically significant with P<0.05. The highest amount of crude protein was found in Gonimbrasia belina with the protein content of 56.95 % ±0.03.There was no significance difference in protein content between the caterpillars, Gonimbrasia belina and Gynanisa maja P>0.05. However there was a significant difference in protein content between Gonimbrasia belina and the other two insects namely Ruspolia differens and Macrotermes falciger with the P-value <0.05. The insect richer in carbohydrates (32.8 %±0.7) was Macrotermes falciger, while the insect with a least value was Gonimbrasia belina with carbohydrate content of 7.8 % ±0.5. The highest amount of energy of 810.2 kcal/100g was recorded in Macrotermes falciger. The predominant amino acid was glutamic acid (4.35 ± 0.05 - 8.43 ± 0.16g/100g) while the least amino acid was cystein (0.11±0.02 - 0.13±0.05g/100g). Lysine was the most predominant essential amino acid in Gynanisa maja (4.02g/100g), Ruspolia differens (5.74g/100g) and Macrotermes falciger (3.72g/100g), while arginine was the most predominant in Gonimbrasia belina (4.57g/100g). The nutritional content of the insects was generally higher than that found in common meats such as beef and chicken meat and insects were generally cheaper than the common meats. Conclusions: The findings suggest that edible insects have the potential for exploitation to combat nutritional deficiencies that are of public health concern. The insects could form a base for new food products of considerable nutritive value.***

Keywords: Caterpillars, Termites, Grasshoppers, Crude fat, Crude protein, amino acids

1. Introduction

Many species of insects have been used as human food in Zambia. Some of the more important groups include caterpillars, grasshoppers, winged termites as well as winged ants. Ordinarily insects are not used as emergency food during shortages, but are included as a planned part of the diet throughout the year or when seasonally available. Caterpillars, locally known as "vinkubala" or "ifishimu", are liked by many Zambians and during the breeding season (September to November), people in Northern Zambia in Mpika, Chinsali, Kasama, Mporokoso and Luwingu districts catch them from trees, particularly the Julbernadia panuculata, in the forest. After harvesting and curing, people usually send them to city markets on the Copperbelt, Lusaka and Livingstone where they fetch more money. In this way the traders are able to sustain their families thereby alleviating poverty and poor nutrition. Those people involved in the practice are also able to take their children to school since "vinkubala" are their main economic activity. As food, Chavunduka [1] noted that in several areas of Zimbabwe, some families make a fairly good living from selling caterpillars.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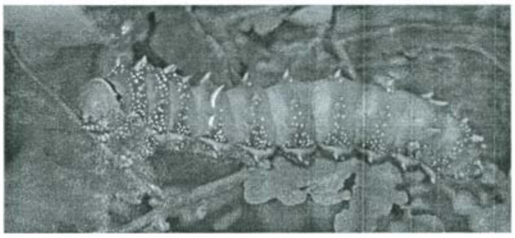
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Figure 1: (1a) Gonimbrasia belina Figure (1b) Gynanisa maja


(1c)

(1d)

Figure 1: (1c) Dish of caterpillars Figure (1d) Harvesting caterpillars

(1e)

(1f)

Figure 1: (1e) *Ruspolia differens* Figure (1f) *Macrotermes falciger*

The most commonly edible insects in Zambia are of three species, these include two species of Order *Lepidoptera (Gonimbrasia belina* and *Gynanisa maja*, one species of Order *isoptera (Macrotermes falciger,* and one species of Order Orthoptera *(Ruspolia differens)*, and these are shown in Table 1. Table 2 shows the season when the insects are available, with caterpillars *(Gonimbrasia belina* and *Gynanisa maja)* being available between August and October while the Grasshoppers are available from March up to May. *Macrotermes falciger* are available during the rainy season from November up to January. Table 1 describes the nomenclature of scientific taxonomy, English and local names as well as consumption of metamorphosis stage of insects.

Table 1: Commonly eaten insects in Zambia

Order	Family	Scientific Name (Species)	English Name	Local Name	Consumption Stage
Lepidotera	Saturniidae	*Gonimbrasia belina*	Caterpillar	''Mumpa''	Larvae
Lepidotera	Saturniidae	Gynanisa maja	Caterpillar	''Chipumi''	Larvae
Soptera	Termitidae	*Macrotermes falciger*	Termite	''Inswa''	Winged adults
Orthoptera	Acridiae	*Ruspolia differens*	Grasshopper	''Nshonkonono''	Adults

Table 2: Year round Insects availability

Insect	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Gonimbrasia belina	X	X	X	X	X	X	X	√	√	√	X	X
Gynanisa maja	X	X	X	X	X	X	X	√	√	√	X	X
Ruspolia differens	X	X	√	√	√	X	X	X	X	X	X	X
Macrotermes falciger	√	X	X	X	X	X	X	X	X	X	√	√

√ Available
X Not available

In many developing countries and among various cultures scattered throughout the world, insects remain a vital and preferred food and an essential source of protein, fat, minerals and vitamins [2]. Some edible insects have nutritional value that can be compared with that of meat and fish, while others have higher proportion of proteins, fat and energy value [2]. The main objective of this study was to determine some of the nutrient composition of commonly eaten insects in Zambia.

2. Materials and Methods

Four types of insects were taken for analysis. These included two different types of caterpillars *Gonimbrasia belina* and *Gynanisa Maja,* one type of termite namely *Macrotermes falciger* and a grasshopper, *Ruspolia differens.*The insects were bought from Masala market in Ndola district. These insects were bought from three different sellers and each batch was taken for analysis. The proximate compositions of the insects were determined as follows: The moisture content was determined by using the oven drying method as described by Association of Official Analytical Chemists (AOAC) [3]. The total ash was determined as described by Kirk *et al*. [4]. Fat content was determined using the procedure of AOAC [3] and n-hexane as solvent. The crude protein content was determined using macro kjeldahl method as reported by Kirk *et al*. [4]. The gram nitrogen obtained was multiplied by 6.25 to obtain the crude protein content. The method described by AOAC [5] was used for mineral analysis.

Amino acid determination was carried out using amino acid analyser, TSM (Technicon Instruments Corporation, Dublin, Ireland) as reported in Adeyeye and Afolabi [6]. 2g of each sample was defatted with petroleum ether using soxhlet extractor. The defatted sample was re-dried and milled into fine powder using porcelain pestle and mortar. 30mg sample were weighed in to a glass ampoules to which 5cm^3 of 6m

HCl and 5µmoles norcleucine were added. The ampoule were evacuated by passing nitrogen gas (to remove oxygen so as to avoid possible oxidation of some amino acids during hydrolysis), sealed with Bunsen burner flame and hydrolyse in an oven at 1100c for 24 hours. The ampoules were cooled, broken at the tip and the content filtered. The filtrate was evaporated to dryness at 400c under vacuum in a rotary evaporator. The residues were dissolved to 5µL (for acid and neutral amino acids) or 10µL (for basic amino acid) with acetate buffer, pH 2.2 and the solutions were dispensed in to the cartridge of TMS. The chromatograms (amino acid peaks) obtained from automatic pen recorder correspond to the quantity of each amino acid resent. Quantification was performed by comparing the peak area of each amino acid in the sample to the area of the corresponding amino acid standard of the protein hydrolysate. The samples were ashed at 550ºC. The ash was boiled with 10ml of 20% hydrochloric acid in a beaker and then filtered into a 100ml standard flask. This was made up to the mark with deionised water. The minerals were determined from the resulting solution. Sodium (Na) and potassium (K) were determined using the standard flame emission photometer. NaCl and KCl were used as standards [5]. Phosphorus (P) was determined calorimetrically using the spectronic 20 (Gallenkamp, UK) (Kirk and sawyer, 1991) with KH_2PO_4 as the standard. Calcium (Ca), magnesium (Mg) and iron (Fe) were determined using Atomic Absorption Spectrophotometer (AAS model SP9). All values were expressed in mg/100g. The analytical procedures were done in triplicate and the mean data recorded. The data were analyzed using SPSS version 16.00. The mean and standard error of means (SEM) of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means (p< 005). The estimated price of caterpillars was obtained from oral interviews with local women who trade the commodity at Ndola Main Masala market in May, 2014. The estimated cost of beef and chicken were determined by checking the prices in designated butcheries across Ndola city and calculated the average price per kilogram.

3. Results

The proximate and energy composition of the commonly eaten dried insects in Zambia are shown in Table 3. The highest amount of crude fat was found in *Ruspolia differens* with fat content of 49.0 % ±0.1 and the least amount was found in *Gonimbrasia belina* which had a mean fat content of 10.0 % ± 0.2. The difference in fat content among the insects was statistically significant with the P<0.05.

Table 3: Proximate and energy analysis

INSECT	*Moisture (%)*	*Ash (%)*	*Crude Fat (%)*	*Crude Protein (%)*	*Carbohydrates (%)*	*Energy (kcal/100g)*
Gonimbrasia belina	9.1 ± 0.1^{a}	7.0±0.6^{a}	10.0±0.2^{c}	56.95±0.04^{a}	7.8±0.5^{c}	385.0± 0.4^{c}
Gynanisa maja	9.2±0.9^{a}	7.4±0.4^{a}	12.1±0.2^{c}	55.92 ± 0.04^{a}	10.7±0.3^{b}	394.1±0.7^{c}
Ruspolia differens	4.5±0.2^{b}	2.2±0.1^{b}	49.0±0.1^{a}	44.59 ±0.03^{b}	8.4±0.4^{c}	618.2±0.6^{b}
Macrotermes falciger	4.1±0.3^{b}	7.3±0.4^{a}	43.0±0.2^{b}	43.26±0.03^{b}	32.8±0.6^{a}	810.2±0.6^{a}

All values except moisture content expressed as means ± SE on dry weight basis.

Values on the same column followed by the same letter are not significantly different (p > 0.05)

The highest amount of crude protein was found in *Gonimbrasia belina* with the protein content of 56.95 % ±0.03.There was no significance difference in protein content between the caterpillars, *Gonimbrasia belina* and *Gynanisa maja P>0.05.* However there was significant difference in protein content between Gonimbrasia *belina* and the other two insects namely *Ruspolia differens* and Macrotermes *falciger* with the P-value <0.05. The insect richer in carbohydrates (32.8 %±0.7) was *Macrotermes falciger*, while the insect with a least value was *Gonimbrasia belina* with carbohydrate content of 7.8 % ±0.5. The highest amount of energy of 810.2 kcal/100g was recorded in *Macrotermes falciger*. The moisture content of the insects ranged from 4.1% ±0.3 to 9.2%±0.1.

Table 4: Amino acid composition (per 100g) of edible Insects

Component g/100g	*Gonimbrasia belina(Caterpillars)*	*Gynanisa maja (Caterpillars)*	*Ruspolia differens (Grasshoppers)*	*Macrotermes falciger (Termites)*
Cystein	0.11 ± 0.02^{b}	0.22 ± 0.03^{a}	0.07 ± 0.02^{c}	0.13 ± 0.05^{b}
Tryptophan	0.48 ± 0.12^{b}	0.75 ± 0.16^{a}	0.03 ± 0.01^{d}	0.35 ± 0.11^{c}
Arginine	4.57 ± 0.42^{b}	3.14 ± 0.40^{c}	4.98 ± 0.15^{a}	3.01 ±0.44^{c}
Serine	1.75 ± 0.25^{d}	2.31 ± 0.12^{b}	2.59 ± 0.12^{a}	2.08 ± 0.37^{c}
Aspartic acid	3.13±0.05^{c}	3.99 ± 0.18^{b}	4.90 ± 0.13^{a}	3.73 ± 0.05^{b}
Glutamic acid	4.35 ± 0.05^{c}	5.24 ± 0.15^{b}	8.43 ± 0.16^{a}	4.68 ± 0.02^{c}
Glycine	1.79 ± 0.42^{b}	1.99 ± 0.25^{b}	2.60 ± 0.11^{a}	1.89 ± 0.18^{b}
Threonine	1.84 ± 0.35^{c}	2.26 ± 0.70^{b}	2.86 ± 0.45^{a}	1.95 ± 0.15^{c}
Alanine	2.36 ± 0.35^{a}	2.55 ± 0.22^{a}	2.66 ± 0.05^{a}	2.74 ± 0.15^{a}
Tyrosine	2.23 ± 0.08^{c}	4.17 ± 0.63^{a}	2.53 ± 0.23^{c}	3.44 ± 0.25^{b}
Proline	1.86 ± 0.18^{b}	2.50 ± 0.07^{a}	1.90 ± 0.15^{b}	1.93 ± 0.21^{b}
Methionine	0.41 ± 0.02	0.82 ± 0.04^{a}	0.43 ± 0.01	0.82 ± 0.03^{a}
Valine	1.91 ± 0.19^{b}	2.09 ± 0.36^{a}	1.64 ± 0.08^{b}	2.17 ± 0.02^{a}
Phenylalanine	1.35 ± 0.07^{c}	1.98 ± 0.03^{b}	2.61 ± 0.27^{a}	1.97 ± 0.06^{b}
Isoleucine	1.30 ± 0.04^{c}	1.88 ± 0.03^{b}	2.61 ± 0.27^{a}	1.89 ± 0.01^{b}
Leucine	1.83 ± 0 .02^{c}	2.72 ± 0.13^{b}	2.67 ± 0.11^{b}	3.16 ± 0.14^{a}
Histidine	1.84 ± 0.12^{c}	2.53 ± 0.22^{b}	4.41 ± 0.26^{a}	2.65 ± 0.04^{b}

Lysine	2.56 ± 0.09[d]	4.02 ± 0.51[b]	5.74 ± 0.16[a]	3.72 ± 0.71[c]

*All values expressed as means ± SE on dry weight basis.
*Values on the same row followed by the same letter are not significantly different ($p > 0.05$)

Table 4 showed the amino acid compositions of the four insects analysed. The predominant amino acid was glutamic acid (4.35 ± 0.05 - 8.43 ± 0.16g/100g) while the least amino acid was cystein (0.11±0.02 0.13±0.05g/100g). In this study, the values obtained for the amino acids content of the samples are comparable to their corresponding protein content and this implies that the amount of non-protein nitrogenous materials in these insects is insignificant.

Table 5: Essential amino acid composition (per 100g) of commonly edible insects

Essential amino acid	*Trp*	*Arg*	*Thr*	*Met*	*Val*	*Phe*	*Ileu*	*Leu*	*His*	*Lys*
Gonimbrasia belina	0.48	4.57	1.84	0.41	1.91	1.35	1.30	1.83	1.84	2.56
Gynanisa maja	0.75	3.14	2.26	0.82	2.09	1.98	1.88	2.72	2.53	4.02
Ruspolia differens	0.03	4.98	2.86	0.43	1.64	2.61	2.61	2.67	4.41	5.74
Macrotermes falciger	0.35	3.01	1.95	0.82	2.17	1.97	1.89	3.16	2.65	3.72

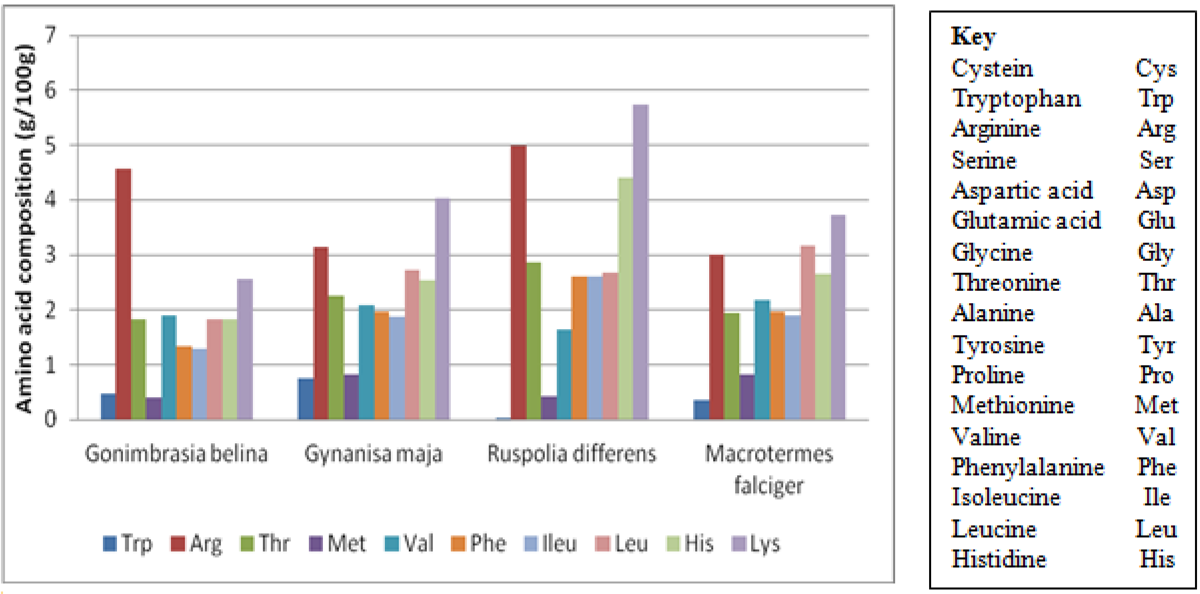

Figure 2: Essential amino acid composition (per 100g) of commonly edible insects

Table 5 and Figure 2 shows that the predominant essential amino acid in *Gonimbrasia belina* ,*Gynanisa maja* ,*Ruspolia differens* and *Macrotermes falciger* was arginine (4.57g/100g), lysine(4.02g/100g), lysine (5.74 g/100g) and lysine (3.72g/100g) respectively.

Table 6: Non-essential amino acid composition (per 100g) of commonly edible insects

Non-essential amino acid	Cys	Ser	Asp	Glu	Gly	Ala	Tyr	Pro
Gonimbrasia belina	0.11	1.75	3.13	4.35	1.79	2.36	2.23	1.86
Gynanisa maja	0.22	2.31	3.99	5.24	1.99	2.55	4.17	2.5
Ruspolia differens	0.07	2.59	4.90	8.43	2.60	2.66	2.53	1.90
Macrotermes falciger	0.13	2.08	3.73	4.68	1.89	2.74	3.44	1.93

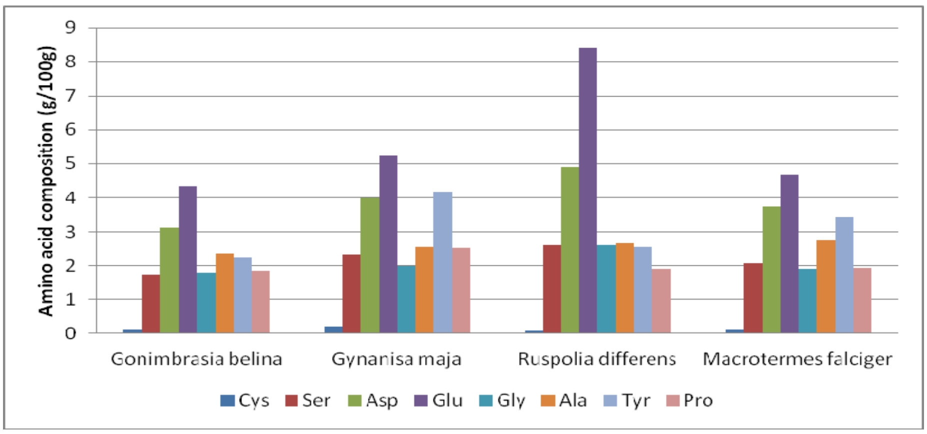

Figure 3: Non-essential amino acid composition (per 100g) of commonly edible insects

Table 6 and Figure 3 shows that the most predominant non-essential amino acid in all the four insects studied was glutamic acid with concentrations of 4.35g/100g, 5.24g/100g, 8.43g/100g and 4.68g/100g in *Gonimbrasia belina, Gynanisa* maja, Ruspolia *differens* and *Macrotermes falciger* respectively.

Table 7: Amino acid composition (per 100g) of common animal meats

Component (g/100g)	Beef meat	Chicken meat
Crude Proteins	21.35	19.40
Cystein	0.25	0.25
Tryptophan	ND	ND
Arginine	1.30	1.34
Serine	0.86	0.88
Aspartic acid	2.07	1.91
Glutamic acid	3.61	2.85
Glycine	1.08	0.90
Threonine	0.87	0.95
Alanine	1.32	1.15
Tyrosine	ND	ND
Proline	0.89	0.73
Methionine	0.61	0.62
Valine	1.02	1.04
Phenylalanine	0.86	0.82
Isoleucine	0.92	0.98
Leucine	1.82	1.64
Histidine	0.82	0.69
Lysine	1.94	1.79

Source: Longvah et al., 2011
ND: Not determined

Table 7 shows the crude protein and amino acid composition of beef and chicken meat as reported by Longvah et., 2011. Beef contains more proteins (21.35 g/100g) than chicken meat (19.40g/100g). The predominant amino acid in both beef and chicken meat was glutamic acid.

Table 8: Mineral Composition (mg/100g) of Commonly Eaten Dried Insects in Zambia

Insect	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
Gonimbrasia belina	127.8 ± 0.4^{b}	69.7 ± 0.2^{b}	42.1±0.3	10.2±0.5	26.7±0.1	1.5±0.1	0.3±0.01	0.3±0.02
Gynanisa maja	166.4 ± 0.3^{a}	100.0 ± 0.5^{a}	32.4±0.2	65.5±0.3	13.6±0.2	1.4±0.2	0.3±0.01	0.3±0.02
Ruspolia differens	9.0 ± 0.3^{d}	5.2 ± 0.4^{d}	14.6±0.3	9.1±0.2	2.0±0.3	0.0±0.1	0.1±0.01	0.04±0.01
Macrotermes falciger	78 ± 0.2^{c}	49.0 ± 0.3^{c}	12.7±0.1	12.7±0.2	24.8±0.3	1.5±0.3	0.7±0.02	0.5±0.03

All values expressed as means ± SE on dry weight basis .
Values on the same column followed by the same letter are not significantly different ($p > 0.05$)

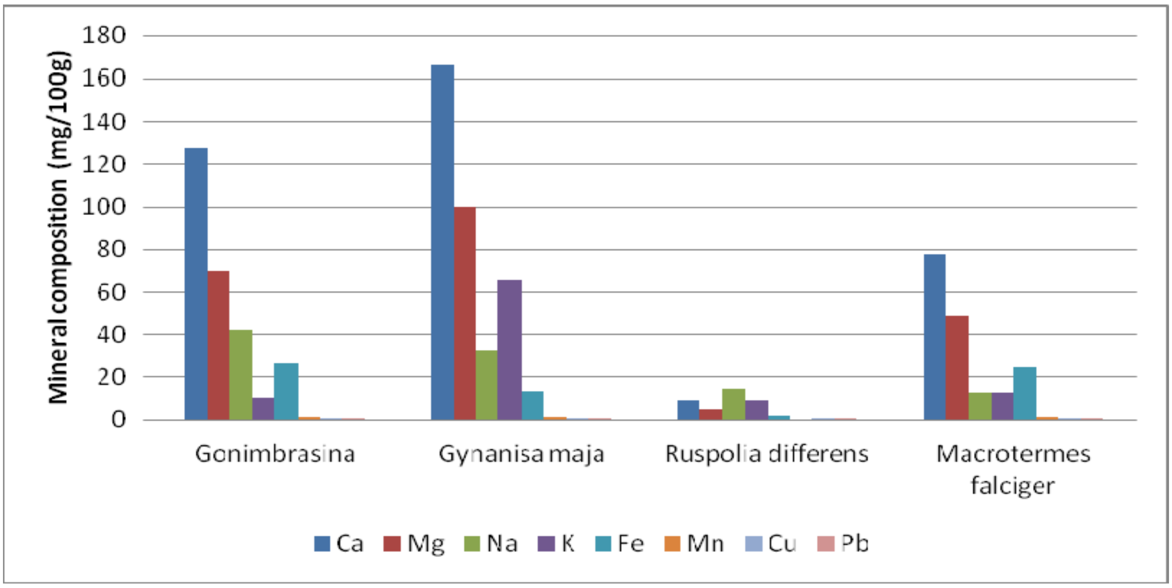

Figure 4: Mineral Composition (mg/100g) of Commonly Eaten Insects in Zambia

Table 8 and Figure 4 show the mineral composition of commonly eaten dried insects in Zambia. *Ruspolia differens* had the lowest content of all the minerals studied in comparison to other insects. *Gonimbrasia belina* had significantly higher content of Na (42.1±0.3 mg/100g) and Fe (26.7 mg/100g±0.1) than all the insects studied P<0.05. *Gynanisa maja* had significantly higher Ca (166.4 m/l00g±0.3) than the other insects. *Macrotermes falciger* had the highest content of Cu (0.7 mg/100g±0.02) and Pb (0.5 mg/100g±0.03) among the insects studied. The highest content of Mn (1.5mg/100g±0.3) was found in *Macrotermes falciger* and *Gonimbrasia belina*.

Table 9: Price comparison of commonly edible insects with common meats in Zambia

	Average Price Per Kilogram (Kg) (US Dollars)
Gonimbrasia belina	2.50
Gynanisa maja	2.50
Ruspolia differens	2.00
Macrotermes falciger	2.00
Chicken	3.50
Beef	7.00

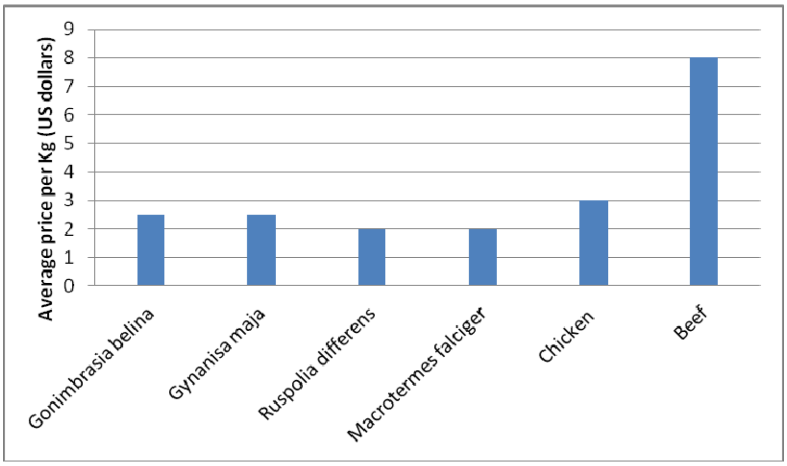

Figure 5: Price comparison of commonly edible insects with common meats in Zambia

Table 9 and figure 5 shows that the average price per kilogram (Kg) of beef ((U$ 8.00 dollars) and chicken (U$ 3.50 dollars) is higher than the cost of all the insects per kg.

4. Discussion

In Africa, entomophagy is traditionally and culturally acceptable way by which low income persons supplement the meagre protein content of their high carbohydrate diets [8]. In Zambia caterpillars, grasshoppers and termites constitute an important part of the diets of many cultures and communities, where they are included as a planned part of the diet or snacks. The seasons when these insects are available are usually short-lived. However, the processed products can be stored for 2-3 months, which increases the period of availability for consumption and income generation.

The proximate composition of the insects seen from the results of this study, closely agrees with the observations of other researchers. All the insects studied had increased moisture content. However the caterpillars *(Gonimbrasia belina and Gynanisa.maja)* had higher moisture content than the grasshopper *(Ruspolia differens*) and winged termite (*Macrotermes falciger*). The main disadvantage of having higher moisture content is that preservation period is reduced due to the risk of microbial deterioration and spoilage when stored longer [9].

The fat content of *Macrotermes falciger and Ruspolia differens was* higher than that of caterpillars and this could be the reason why the gross energy of these insects was high, as fat contributes more calorie than twice the contribution of carbohydrates and proteins. The crude fat content of *Macrotermes falciger* is appreciably high in comparison with the reported mean crude fat content of 20% for most adult insects on a dry weight basis [10]. Our observation is in agreement with reported fat content of 28.37 ± 0.00% for *M. nigeriensis* [11], 22.5% for *M. notalensis* [12], and 28.2% [12] and 36.12 ± 0.28% [13] for *M. bellicosus*. The fat content we obtained, along with those mentioned above, are however lower than a fat value of 46.1% (moisture free basis) earlier reported for *M. bellicosus* [14].

The fat content of the grasshoppers as shown in Table 1 was considerably higher than the fat values reported for other insects studied by Banjo *et al* [12]. The result for fat content demonstrates that Insects can offer a high fat content for the human diet among the communities practicing entomophagy. Fat is essential in human diets because it increases the palatability of foods by absorbing and retaining their flavours [15]. Fat is also vital in the structural and biological functioning of cells. However, one implication of the high fat content in the insects is that it may increase susceptibility of insects with high fat content to storage deterioration via lipid oxidation [13]. Malnutrition in developing countries is also a problem of calorie deficiency. According to DeFoliart [16], caterpillars rank high in fat content with little or no cholesterol, especially leaf eater ones, and fatty acid profile is similar to those of fish and poultry. Caterpillars have the advantage of converting plant materials that may not often be consumed by humans to a highly palatable food. Consumption of caterpillars would, therefore, not pose any danger or risk of cardiovascular disease.

The carbohydrate content of the insects studied is lower than that reported by Ahmad et al. [9], who reported carbohydrate content of 24.7 and 52.0 %, dry weight for grasshopper and winged termite respectively. Carbohydrates are important nutritive elements in the human body. They are the main energy source, can reduce consumption of protein and help detoxification. These insect species may not be desirable as a good source of carbohydrate as human adult need about 400 to 500 g carbohydrate intake as starch. The results of this study also showed that the termite had an appreciable content of carbohydrate (32.8 ± 0.6%). However, the carbohydrate content observed is low in comparison with those reported for *M. bellicosus* (43.3%) and *M. notalensis* (42.8%) by Banjo et al., [12].
The caterpillars had the highest crude protein content than the other insects included in this study. The crude protein content obtained in caterpillars accords results of other studies [17, 18]. Furthermore all the insects in this study showed higher protein content in comparison to common lean red meat of different sources [19] who reported 23.2% for beef, 24.8% for veal and 21.5% for mutton. The results for protein content in all the insects were higher than that obtained by Longvah et al., [7] in beef and chicken meat as shown in Table 7. The protein content exhibited by the

insects was significantly higher than the conventional animal meats and therefore insects may offer an affordable source of protein to counteract the protein malnutrition [20]. Edible insects have been shown to have higher protein content, on a mass basis, than other animal and plant foods such as beef, chicken, fish, soybeans, and maize [21]. The crude protein content we observed for *M.falciger* was higher than the 14.2% reported for *M. subhyalinus* [22], but quantitatively comparable with 20.4% and 22.1% reported for *M. bellicosus* and *M. notalensis* respectively [12]. The result indicates that insects are a good source of protein for man and animals. Meanwhile, an adult male of about 70kg body weight requires 35g of protein daily. Therefore, only about 61g of the termite delicacy would be required to provide an average adult man's minimum daily protein need, with an allowance of 25% made for indigestibility and the limiting sulphur amino acid content [23]. Thus, a small amount of the delicacy needs to be consumed per day, especially for children, to meet the requirement. Proteins are the basis of all organism activity and constitute many important materials such as enzymes, hormones and haemoglobin. Protein is an important component of antibodies as it bolsters the immunity function of the body. It is the only material to produce nitrogen for maintaining acid and alkali balance, transforming genetic information and transporting important materials in the human body. As a nutritive element that produces heat, it can supply energy. Insect proteins are highly digestible (between 77% and 98%) [24], although insect forms with an exoskeleton have lower values, due to the presence of chitin. Chitin is a carbohydrate polymer, supposedly the most abundant in nature, exceeding cellulose, found in invertebrate exoskeletons, protozoa, fungi and algae. Chitin removal increases the quality of insect protein to a level comparable to that of products from vertebrate animals [25]. Furthermore, humans are still able to digest some chitin, as 2 catalytically active chitinases have been discovered, AMCase and chitotriosidase, both belonging to the family of 18 glycosylhydrolases [26, 27]. AMCase is more active at acidic pH [28, 29], where as chitotriosidase [30, 31] has a different pH optimum than AMcase. AMCase as a potential to moderately digest chitin in the human stomach [32, 33].

The nutritional value of food largely depends on the quality of the protein that it contains. This in turn, is determined to a great extent, by the amino acid composition. In the majority of edible insects, either tryptophan or lysine is the first limiting amino acid [34]. The amino acid profile obtained for different insects in this study further confirms the high quality of the insects' protein in which all essential amino acids were present. These findings further confirm that caterpillars, winged termites and grasshoppers are indeed a good source of proteins. Their consumption by vulnerable children should be encouraged. Vantomme et al., [35] have reported that in some regions of Africa, flour made from caterpillars is mixed with staple foods to prepare pap to counter malnutrition in children and information from the indigenous of Plateau State, Nigeria reveals that the processed caterpillars are added to other foods such as the local porridges. It is therefore believed that the consumption of insects can to a large extent, supplement protein in predominantly cereal diets.

The analysis of ash content indicated an ash value for the *Gonimbrasia belina* and *Gynanisa maja* higher than the values indicated for other edible caterpillars such as *Lepidoptara litoralia* (4.3%) as reported by Solomon *et al.* [36]. While the ash content for the grasshopper, *Ruspolia differens* obtained in this study was consistent with the values obtained by Kinyuru et al.[37] who obtained ash content of Green and brown *Ruspolia differens* of 2.8% and 2.6% repectively.The ash content of *Macrotermes falciger* was higher than obtained in other winged termites [38]. There is a consensus among researchers that ash content of a given sample correlates the minerals contents of the sample. The mineral content of *Gonimbrasia belina and Gynanisa Maja* was higher than that of *Ruspolia differens* and *Macrotermes falciger.* Generally, the mineral content of the four insects studied indicates that they all had a fair source of mineral elements in accordance with other studies [9]. The termite, *Macrotermes falciger* had higher mineral content with the major macrominerals being potassium, sodium and calcium, while the microminerals were iron, manganese and copper. The high content of sodium observed could be attributed to addition of seasonings such as bouillon cubes, sodium chloride (NaCl), or table salt during processing. The high content of iron in *Gonimbrasia belina* and *Macrotermes falciger* is of particular interest. Micronutrient deficiency, which is referred to as hidden hunger, is of great concern particularly among pregnant women and children in poor urban and rural dwellers, which often manifests as anaemia. The levels of minerals present in the insects indicate that they are good sources of minerals for young, pregnant and lactating mothers. Iron and zinc deficiency is widespread in developing countries, especially in children and women of reproductive age [39]. Iron deficiency leads to anaemia, reduced physical activity and increased maternal morbidity and mortality [40]. Zinc deficiency causes impaired growth and contributes considerably to the high infectious disease burden [41]. Zinc deficiency has also been known to cause poor growth and impairment of sexual development [42]. Vegetarians are at risk of zinc deficiency [43]. The cereal based diets for feeding infants and young children observed in most third world countries could receive a boost with the addition of the insects to the diets. Minerals are known to play important metabolic and physiologic roles in the living system. Iron, zinc, copper and manganese strengthen the immune system as antioxidant enzyme cofactors [44]. Similarly, magnesium, zinc and selenium prevent cardiomyopathy, muscle degeneration, growth retardation, impaired spermatogenesis, immunological dysfunction and bleeding disorder [45]. Magnesium is needed for more than 300 biochemical reactions in the body. It helps to maintain normal muscle and nerve function, keeps heart rhythm steady, supports a healthy immune blood and regulates blood sugar levels [46]. Therefore, edible insects can supply necessary nutritive elements for human body functions and could be consumed along with other food and animals rich in other essential minerals to further complement the diet of these insects.

Findings from this study revealed that the average cost of the insects per kilogram was cheaper than the cost of common meats (beef and chicken). However in terms of nutrient content, insects were far much superior to beef and chicken meat.

5. Conclusion

This research provides an overview of the nutrient composition of the grasshoppers (*Ruspolia differens*), caterpillars (*Gonimbrasia belina* and *Gynanisa maja)* and the winged termite *(Macrotermes falciger)*. The insects were found to contain significant proportion of proteins, fats and other nutrients than found in common meats such as beef and chicken meat. Consumption of these insects can therefore contribute significantly to the recommended daily requirements of iron, zinc, calcium and potassium. In addition, the insects were found to contain all the essential amino acids important for human growth. Therefore, these delicacies, if adequately promoted, can help in controlling protein energy malnutrition, which is currently ravaging children in developing countries. Moreover, the cost of these insects was found to be lower as compared to the cost of beef and chicken meat. This knowledge therefore creates a justification that edible insects are important food items that needs industrial application and commercialisation and ought to be cultivated with modern techniques in order to increase their commercial value and availability.

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