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Nutritional Potential of Two Insect Species Consumed in Togo: *Gnathocera trivittata* (Swederus, 1787) and *Gnathocera impressa* (Olivier, 1789)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FB and AT-B conceived, designed and performed the experiments; author FB analyzed the data and wrote of the manuscript; Author AK supervised the experiments. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study is to determine the nutritional values of *Gnathocera trivittata* and *Gnathocera impressa* in order to promote their consumption for food security.

Place and Duration of Study: Samples of *G. trivittata* and *G. impressa* were caught in Togo in the three following localities: Kparatao (8°57'151"N; 1°11'838"E), Kpéwa (9°16'978"N; 1°14'149"E) and Soudou (9°21'604"N; 1°21'348"E), between September and December 2013.

Methodology: The contents of ash, protein, vitamins as well as lipids were determined. Fiber content was obtained. Minerals were analyzed by atomic absorption spectrophotometry and colorimetry. Fatty acid composition of the lipids was determined by gas chromatography and the amino acid composition was obtained by separation of the individual amino acids using the Biochrom 30+ amino acid analyzer.

Results: The results reveal that the average protein content of the insects studied ranged from 59.36 to 61.63%. Average lipid levels ranged from 9.09 to 9.86%. They contain all the essential fatty and amino acids. Their average fiber content fluctuates between 8.35 and 10.05%. Regarding the composition of micronutrients, the species studied are very rich in minerals and vitamins. The

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ratios of minerals, fatty acids and essential amino acids are balanced.
Conclusion: Given the nutritional potentials of the insects studied, they can contribute significantly to the fight against protein-energy and micronutrient malnutrition in Togo.

Keywords: Gnathocera trivittata; *Gnathocera impressa*; *nutritional value; Togo.*

1. INTRODUCTION

Researchers have long focused on studies of high-energy staple foods such as wheat, rice, and maize to achieve food security [1]. However, many of these foods contain very low amounts of micronutrients essential for human health [2]. They are therefore insufficient on their own to solve the problem of micronutrient deficiency. Micronutrients perform critical functions in the human body, both in energy metabolism and in the structure of the human body. Magnesium, for example, is vital for the bones, heart and nervous system [3]. Copper is necessary for the formation of hemoglobin and the maturation of red blood cells [4]. Zinc is involved in growth and the immune system. It also plays an essential role in many biological functions including cell renewal and wound healing [5]. The absence of nutrients in diet therefore has important implication for human health [6]. For example, vitamin A deficiency not only leads to eye damage and blindness, affecting 500000 children per year, but also leads to higher rates of infection (chronic diarrhoea, measles) because of its importance in the functioning of the immune system [7]. Iron and vitamin B12 deficiency can compromise adolescents' intellectual development and school performance [8]. However, insects, which are often overlooked because they are not a conventional food resource, can contain significant amounts of these micronutrients. Indeed, most insects consumed have high levels of minerals and vitamins. They also contain significant amounts of proteins and lipids of high nutritional quality [9,10]. Species of the order Coleoptera are consumed worldwide [11]. However, several species of insects consumed by local populations are not sufficiently known, particularly in terms of their nutritional quality. Consequently, data on their nutritional values are absent from international scientific directories. This work was initiated to fill this gap in the knowledge of the composition of edible insects. The objective of this study is to determine the nutritional values of two species of Coleoptera consumed in Togo in order to promote their consumption.

2. MATERIAL AND METHODS

2.1 Biological Material

Specimens of *G. trivittata* and *G. impressa* were caught in Togo in the following localities: Kparatao (8°57'151"N; 1°11'838"E), Kpéwa (9°16'978"N; 1°14'149"E) and Soudou (9°21'604"N; 1°21'348"E), between September and December 2013. Insects were carried to the laboratory of Applied entomology (University of Lomé) where they have been well characterized to confirm the species.

2.2 Laboratory Methods

The insect samples were killed by the cold by placing them in an ice box [12]. Determination of Moisture Content was done using the SCALTEC electronic moisture analyzer (SM01 Instrument GmH, Germany) on samples of both species.

2.3 Biochemical Assays

Fresh samples of each insect species were dried in an oven at 40° C for 7 days and reduced to powder for the different assays. The fiber content was determined according to Weende's method [13]. After acid hydrolysis followed by basic hydrolysis, the samples are dried at 150° C for 1 hour and then incinerated at 550° C. for 6 hours. The compositions of ash (mineral substances), proteins and lipids were determined according to the AOAC methods [14]. The ashes were obtained by incineration of the samples at 550°C for 6 hours. Proteins were estimated by determination of total nitrogen according to the Kjeldahl method. The total quantity of protein was estimated by multiplying the quantity of nitrogen by 6.25. Lipids were extracted by hexane using Soxhlet and the extracts evaporated under vacuum at 35°C using a Buchi R114 rotavapor. The phosphorus content was determined by colorimetry using the phosphovanado molybdate method and the other minerals were analyzed by atomic absorption spectrophotometry [15]. The vitamins were determined by colorimetry according to the methods of the AOAC [16]. Optical density was measured by a Jenway Model 6300 colorimeter. Calibration curves were obtained from the preparation of a corresponding range of vitamin solutions. The percentage of total carbohydrates and metabolizable energy values of the samples were calculated.

The percentage of total carbohydrate was calculated as the difference from the percentages of other total constituents according to the following formula [17]:

$$\text{Carbohydrate} = 100 - (\text{Water} + \text{Protein} + \text{Fat} + \text{Carbohydrate} + \text{Fiber})$$

The energy contents of the samples were calculated from the protein, fat, carbohydrate and fiber contents by applying energy conversion factors using the formula [17]:

$$\text{E} = 17 \times \text{Protein} + 37 \times \text{Fat} + 17 \times \text{Carbohydrate} + 8 \times \text{Fiber}$$

Fatty acid composition of the lipids was obtained by separating their methyl esters using a gas chromatograph (HP 6890 series GC System). The fatty acids were transformed. Fatty acids were transformed into methyl esters by transesterification of the raw lipids using a methanolic solution of boron trifluoride [18]. Finally, amino acid composition of the insects studied was obtained by separating the different amino acids using the Biochrom 30+ amino acid analyzer. Amino acid ratios were calculated using the reference source WHO/FAO/UN [19].

Amino acid ratios (Raa) in percent were calculated by the following formula:

$$\text{Raa} = \frac{\text{Content of an essential amino acid in the sample}}{\text{Favorable content of the homologous amino acid according to WHO/FAO/UN(1985)}} \times 100$$

Amino acid number was then deducted for each species. Indeed, the amino acid number of a species is the minimum value of the Raa of the species.

2.4 Statistical Analysis

All the tests were carried out in triplicate. The mean values of the components were calculated on the basis of the three replicates. They were assigned their standard deviations (SD). The analysis of variance (ANOVA-1) was used to compare the means using SPSS 17.0 software.

3. RESULTS

3.1 Chemical Composition and Energy Value of the Insects Studied

The chemical parameters of the two insect species studied show that their water contents varies between 4.98 and 5.34% (Table 1). The species studied have protein contents ranging from 59.36 to 61.63%. As for the percentage of lipids, it is between 9.09 and 9.86%. Carbohydrates ranged from 1.42 to 3.08%. The insects studied are high-energy foods with calorific values ranging from 1493.06 to 1493.24 KJ/100g. Water, protein, lipid, carbohydrate and energy contents are not statistically significant between the two species. Differences in ash and fiber contents are statistically significant between the two species (Table 1). The ash content of *G. impressa* (14.36%) is statistically higher than *G. trivittata* (12.21%). Conversely, the fiber content of *G. impressa* (8.35%) is lower than that of *G. trivittata* (10.05%).

3.2 Mineral Composition of the Insects Studied

The mineral composition of the insects studied shows that all species are very rich in macro and trace elements (Table 2). These insects are rich in macroelements such as calcium (52.66 vs 66.54 mg/100g), magnesium (26.76 vs 33.43 mg/100g), phosphorus (53.28 vs 64.06 mg/100g), potassium (886.12 vs 1102.41 mg/100g), sodium (44.80 vs 56.34mg/100g) and trace elements such as iron (14.82 vs 16.75 mg/100g), copper (2.49 vs 4.39mg/100g), zinc (13.59 vs 13.94mg/100g) and manganese (0.09 vs 2.44 mg/100g). Except for zinc, iron and sodium all other minerals sought are statistically higher in *G. trivittata* than in *G. impressa*. The data in Table 2 was used to calculate the Sodium/Potassium and Calcium/Phosphorus ratios. Calculation of the ratios for the two species studied, shows that they all have a Sodium/Potassium ratio of less than 1 (Table 3). The Calcium/Phosphorus ratios of the two species ranged from 0.98 to 1.03.

3.3 Amino Acid Composition and Amino Acid Indices of the Insects Studied

The amino acid composition of the species studied is presented in Table 4. These amino acids are diversely concentrated in the species studied. All species contain all essential amino acids.

Table 1. Proximate composition (%) of insect species and their energy value (kJ/100g)

Parameters	*G. trivittata*	*G. impressa*	Statistics
Water	5.34 ± 0.05[a]	4.98 ± 0.23[a]	P=0.612
Ashes	12.21 ± 0.88[a]	14.36 ± 1.12[b]	P=0.016
Protein	61.63 ± 0.25[a]	61.63 ± 0.25[a]	P=0.34
Fat	9.09 ± 0.96[a]	9.86 ± 1.57[a]	P=0.367
Fiber	10.05 ± 1.09[a]	8.35 ± 0.32[b]	P=0.006
Carbohydrates	1.65 ± 0.42[a]	1.65 ± 0.42[a]	P=0.291
Energy	1493.06 ± 3.89[a]	1493.06 ± 3.89[a]	P=0.623

In each row, the averages affected by the same letter are not statistically different (ANOVA-1 followed by SNK at the 5% threshold)

Table 2. Mineral composition (mg/100g) of the studied species

Minerals	*G. trivittata*	*G. impressa*	Statistics
Calcium	66.54 ± 0.16[a]	52.66 ± 0.36[b]	P<0.001
Magnesium	33.43 ± 0.46[a]	26.76 ± 1.74[b]	P<0.001
Phosphorus	64.06 ± 0.135[a]	53.28 ± 0.14[b]	P<0.001
Potassium	1102.41 ± 2.34[a]	886.12 ± 1.23[b]	P<0.001
Sodium	44.80 ± 0.25[a]	56.34 ± 1.00[b]	P<0.001
Iron	1.65 ± 0.42[a]	1.65 ± 0.42[b]	P<0.001
Manganese	2.44 ± 1.76[a]	0.09 ± 0.04[b]	P<0.001
Copper	4.39 ± 0.21[a]	2.49 ± 0.03[b]	P<0.001
Zinc	13.59 ± 0.12[a]	13.94 ± 0.12[b]	P = 0.024

In each row, the averages affected by the same letter are not statistically different (ANOVA-1 followed by SNK at the 5% threshold)

Table 3. Sodium/Potassium and Calcium/Phosphorus ratios considering the mineral contents of *G. trivittata* and *G. impressa*

Ratios	*G. trivittata*	*G. impressa*
Sodium/Potassium	0.04	0.06
Calcium/Phosphorus	0.06	0.98

Table 4. Amino acid profile of the insects studied (g/100g)

Amino acids	*G. trivittata*	*G. impressa*	Statistics
Isoleucine*	1.17 ± 0.005[a]	1.85 ± 0.01[b]	P<0.001
Leucine*	2.18 ± 0.01[a]	3.32± 0.01[b]	P<0.001
Lysine*	1.67± 0.017[a]	1.45 ± 0.01[b]	P<0.001
Methionine*	0.73± 0.05[a]	0.73± 0.05[a]	P<0.001
Phenylalanine*	0.87 ± 0.01[a]	0.95± 0.01[b]	P=0.001
Tryptophan*	0.36 ± 0.01[a]	0.57± 0.01[b]	P<0.001
Threonine*	0.70 ± 0.005[a]	0.70 ± 0.005[b]	P<0.001
Valine*	1.92 ± 0.005[a]	2.43 ± 0.01[b]	P<0.001
Arginine	0.70 ± 0.1[a]	1.22 ± 0.01[b]	P=0.001
Histidine	2.58 ± 0.01[a]	1.47 ± 0.005[b]	P<0.001
Alanine	2.06 ± 0.01[a]	3.30 ± 0.1[b]	P<0.001
Aspartic acid	1.79 ± 0.005[a]	2.34 ± 0.005[b]	P<0.001
Glutamic acid	2.19 ± 0.005[a]	3.56 ± 0.005[b]	P<0.001
Cystine	0.68 ± 0.005[a]	0.81 ± 0.005[b]	P<0.001
Glycine	3.52 ± 0.005[a]	3.14 ± 0.005[b]	P<0.001
Proline	3.14 ± 0.005[b]	3.89 ± 0.01[b]	P<0.001
Serine	0.95 ± 0.005[a]	1.07 ± 0.005[b]	P<0.001
Tyrosine	5.78 ± 0.005[a]	7.46 ± 0.02[b]	P<0.001

*In each row, the averages affected by the same letter are not statistically different (ANOVA-1 followed by SNK at the 5% threshold). *Essential amino acids*

Table 5. Value of amino acid ratios (%) of the insects studied

Amino acids	*G. trivittata*	*G. impressa*
Threonine	77.78	133.33
Valine	147.69	168.92
Isoleucine	90	142.30
Leucine	114.73	174.73
Histidine	161.25	91.88
Lysine	105	90.63
Tryptophan	72	116
Tyrosine +Phenylalanine	350	443.15
Methionine +Cystine	81.17	95.88

The amino acid indices of the insects studied ranged from 72 to 90.63% (Table 5). These indices are therefore less than 100% indicating that the concentration of at least one essential amino acid is limiting. Tryptophan is the first limiting amino acid for *G. trivittata* and lysine for *G. impressa*.

3.4 Fatty Acid Composition of the Lipids of the Insects Studied

The lipids of the species studied contain saturated fatty acids such as myristic (0.86 vs 1.14%), palmitic (30.55 vs 49.73%), stearic (6.13 vs 7.38%) and lauric acid (2.51% in *G. trivittata*). These results are shown in Table 6. Monounsaturated fatty acids are also present in these species. These are palmitoleic (2.41% in *G. impressa*), oleic (33.13 vs 44.51%) and elaidic acid (0.62% in *G. impressa*) which is the transisomer of oleic acid. With the exception of elaidic acid, which is of trans configuration, all the other fatty acids in the lipids of the insects studied are of cis configuration. The polyunsaturated fatty acids contained in these lipids are linoleic (1.33 vs 6.54%) and α-linolenic acid (0.96 vs 1.77%) which are essential fatty acids. The Omega6/Omega3 ratios of these species are between 3.2 and 4.89 (Table 6). The values of the degree of saturation in lipids show that the species studied contain saturated fatty acids between 47.57 and 56.59% (Table 6). These species have unsaturated fatty acid contents between 43.12 and 51.97%. Monounsaturated (36.16 vs 44.51%) and polyunsaturated (6.96 vs 7.46%) fatty acids are represented at varying concentrations.

3.5 Vitamins Composition of the Insect Species Studied

All insect species studied have variable vitamin contents (100g of dry weight of the sample) (Table 7): vitamin A (0.01 vs 0.06mg), vitamin B1 (1.25 vs 1.89mg), vitamin B2 (1.43 vs 2.43mg), vitamin B3 (6.57 vs 8.33mg) and vitamin E (3.24 vs 4.63mg). The differences are statistically significant between the two species only for fat-soluble vitamins (Vitamin A and E).

Table 6. Fatty acid profile (g/100g) of lipids in the species studied

Fatty acids		*G. trivittata*	*G. impressa*	Statistics
C12:0	Lauric	2.51 ± 0.01	ND	P<0.001
C14:0	Myristic	1.14 ± 0.00^{a}	0.86 ± 0.01^{b}	P<0.001
C16:0	Palmitic	30.55 ± 0.04^{a}	49.73 ± 0.01^{b}	P<0.001
C18:0	Stearic	7.38 ± 0.01^{a}	7.38 ± 0.01^{b}	P<0.001
Total SFA		56.59 ± 0.02^{a}	47.57 ± 0.05^{b}	P<0.001
C16:1	Palmitoleic	ND	2.41 ± 0.02	P<0.001
Cl8:1*cis*	Oleic	41.51 ± 0.01^{a}	33.13 ± 0.00^{b}	P<0.001
C18 :1*trans*	Elaïdic	ND	0.62 ± 0.01	P<0.001
Total MUFA		41.51 ± 0.01^{a}	36.16 ± 0.03^{b}	P<0.001
C18 :2	Linoleic	5.68 ± 0.00^{a}	5.78 ± 0.01^{b}	P<0.001
C18:3	α-linolenic	1.77 ± 0.01^{a}	1.18 ± 0.01^{b}	P<0.001
Total PUFA		7.46 ± 0.01^{a}	7.46 ± 0.01^{b}	P<0.001
Total omega6		5.68 ± 0.00^{a}	5.78 ± 0.01^{b}	P<0.001
Total omega3		1.77 ± 0.01^{a}	1.18 ± 0.01^{b}	P<0.001
Omega6/Omega3		3.2	4.89	

ND: Not detected; SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids. In each row, the averages affected by the same letter are not statistically different (ANOVA-1 followed by SNK at the 5% threshold)

Table 7. Vitamin content (mg/100g) of the insects studied

Vitamins	*G. trivittata*	*G. impressa*	Statistics
Retinol (A)	0.06 ± 0.04[a]	0.01 ± 0.00[b]	P= 0.002
Thiamine (B_1)	1.87 ± 0.03[a]	1.25 ± 0.24[a]	P= 0.114
Riboflavin (B_2)	1.75 ± 0.05[a]	1.67 ± 0.13[a]	P= 0.183
Niacin (B_3)	6.57 ± 0.18[a]	7.63 ± 0.05[a]	P= 0.450
Tocopherol (E)	4.63 ± 0.13[a]	3.41 ± 0.28[b]	P= 0.043

In each row, the averages affected by the same letter are not statistically different (ANOVA-1 followed by SNK at the 5% threshold).

4. DISCUSSION

Moisture contents of the insects studied are similar to those obtained by other authors whose work has focused on edible insects [20-21]. Compared to conventional meats such as beef, chicken, pork and fish that contain on average 65-75% water [17], *G. trivittata* and *G. impressa* are low moisture foods. This favours their preservation [22]. With regard to micronutrients, the insects studied are richer in mineral substances than conventional meat products including beef, pork, chicken and fish (1 to 2.5%) listed in the West African food composition table [17]. This is nutritionally advantageous because minerals are necessary for the proper functioning of various physiological processes [23]. The analysis of mineral constituents has revealed that these species contain appreciable quantities of various elements including iron. The species are rich in iron and may mitigate the effects of iron deficiency anaemia, which is widespread among pregnant women in developing countries [24]. In addition, the balance between sodium and potassium is critical. When the Sodium/Potassium ratio in a food is less than 1, as is the case for the species studied, the intake of these elements is beneficial to health. Sodium and potassium play the role of regulating the water content of the human organism. They also participate in maintaining the acid-base balance. Consumption of insects with a favorable Sodium/Potassium ratio can lead to a decrease in blood pressure and consequently a reduction in cardiovascular accidents [25]. Similarly in humans, the ratio of calcium to phosphorus in diet must be balanced as is the case for the species studied [26]. A diet balanced in calcium and phosphorus promotes the intestinal absorption of calcium. Calcium deficiency causes pathologies such as growth retardation and rickets in children, spasmophilia in adults and osteoporosis in the elderly [27]. *G. trivittata* and *G. impressa* also contain appreciable amounts of all desirable vitamins. This confirms the conclusion of several authors [10,21] that insects are an important source of vitamins. As already mentioned in the literature concerning several edible insect species [9,28], *G. trivittata* and *G. impressa* are rich in protein which make up to more than 60% or more of the total weight. These species could be an effective food source that can fight against protein-energy malnutrition. This malnutrition irreversibly affects the physical and cognitive growth of children [29]. Since insects are also known to be rich sources of essential amino acids, all essential amino acids are present in the species studied [9,30]. However, the amino acid indices of the species studied are slightly low (72 and 90.63%). In addition, our results show that tryptophan is the first limiting amino acid in *G. trivittata* in line with what has been observed in most edible insects [9,31]. This essential amino acid should therefore be supplemented in an insect-based diet by other food sources such as meat, fish, dairy products, eggs, legumes, banana, peanuts, almonds and cashews known to be rich in tryptophan [32].

The insects studied also have high lipid contents but the nutritional value of these lipids depends on their quality. Quality is expressed by the concentration of fatty acids. The unsaturation of the lipids of these species is confirmed by the results of the screening carried out on the lipids. The concentration of unsaturation especially in polyunsaturated fatty acids observed in the insects studied is higher than in most lipids of animal origin [33]. The presence of mono- and especially short-chain polyunsaturated fatty acids in food has been shown to be beneficial to health as they have the potential to lower LDL-cholesterol levels in the blood [34]. The Omega6 and Omega3 found in the lipids of the species studied, respectively linoleic and α-linolenic acid, are the precursors of these two families of fatty acids. The species studied have their Omega6/Omega3 ratios lower than 5. This raises the nutritional quality of the oils of these insects because such a ratio reduces the risk of cardiovascular disease [35]. However, palmitic acid, a saturated fatty acid, is quantitatively the most important in the species studied. In *G. impressa*, palmitic acid represents about 50% of the total fatty acid content of this insect. Saturated fatty acids are excellent energy nutrients, but a high level of saturated fatty acids in food may be undesirable because of the link between saturated fatty acids and atherosclerosis [36]. This same species contains elaidic acid (0.62%) which is the trans isomer of oleic acid. Trans fatty acids are capable in high doses of producing the same adverse effects on human health as saturated fatty acids [37]. However, the amount of elaidic acid found in *G. trivittata* in this study is low. In addition, the species studied, being both rich in protein and lipids, their energy values are very high. Comparison of the total energy provided by the insects studied with that of conventional foods in West Africa [17] shows that they are more energetic than most of the conventional foods, particularly tubers (cassava, yam), cereals (rice) and meats (beef, chicken), with the exception of certain legumes such as beans, soybeans and certain cereals such as maize and sorghum, whose energy values are in the range of energy provided by insects for the same food mass.

The fiber content of the species studied is high compared to conventional meats [17]. These species can therefore contribute to better digestion for people of all ages. Indeed, a deficiency in dietary fiber can lead to gastric and intestinal disorders [38]. In addition, fiber has a positive effect on accelerating satiety, thus limiting the risk of overeating. This helps prevent obesity [39]. Conversely, insects are not a great source of carbohydrates according to several authors [40]. The concentrations obtained during this study for the species studied are also low, thus confirming the results of these authors. Carbohydrates are the primary source of energy available to the human body [41]. However, an excess of carbohydrates contributes to a number of adverse effects on the body, including obesity. Since insects are low in carbohydrates and high in fiber, their consumption is beneficial in avoiding obesity, which is a risk factor for several pathologies including cardiovascular disease and diabetes.

5. CONCLUSION

Although there is significant variation in the chemical composition of the edible insect species studied, they provide nutrients in quantities and qualities satisfactory to the humans body. The two species of insect studied contain all the essential amino acids for the human body. They provide lipids rich in unsaturated fatty acids and especially in essential fatty acids. They also provide minerals and vitamins essential for the functioning of the human body. The ratios of amino acids and essential fatty acids, as well as minerals in these insects are balanced. As a result, they have an excellent nutritional value. The quantity and quality of *G. trivittata* and *G. impressa* suggest that they could be essential items for applications in the food and pharmaceutical industries.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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