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NUTRITIONAL POTENTIAL AND TRACE METAL ELEMENTS OF THREE EDIBLE GNATHOCERA SPECIES FROM TOGO

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Abstract. *Insects of the genus Gnathocera, commonly found on the panicles of grasses in the savannas of Togo, were once a valued food resource for local populations. However, this traditional practice is now declining. The present study aims to promote the consumption of these edible insects by evaluating their nutritional potential and their content of trace metal elements (TMEs), in order to contribute to food security in Togo. Three species (*Gnathocera flavovirens *Kolbe, 1892;* Gnathocera hyacinthina *(Janssens, 1885);* Gnathocera varians *Gory & Percheron, 1833) were analyzed. Protein, lipid, fiber, ash, and vitamin contents were determined using standard methods from AOAC and AFNOR, while minerals and TMEs were quantified using atomic absorption spectrophotometry and colorimetry. The results revealed high protein contents (62.30 - 63.60 %) and moderate lipid levels (8.61 - 8.67 %). Dietary fiber ranged from 6.75 to 11.13 %, and ash content from 9.42 to 10.46%. These beetles exhibited high energy density (1432.87 - 1602.41 kJ/100g). They also contain fat-soluble vitamins (retinol and tocopherol), water-soluble vitamins (thiamine, riboflavin, and niacin), as well as essential minerals like zinc, copper, manganese, and iron. The analyzed TMEs were detected at concentrations below regulatory limits, indicating a low risk of human exposure through the consumption of these insects in Togo. These findings highlight the high nutritional value of Gnathocera species and confirm their potential as a sustainable alternative source of protein and micronutrients to enhance food security*.

Keywords*: Edible insects, Gnathocera , nutrients,, trace metal elements, Togo*

INTRODUCTION

Food security remains a major concern in many sub-Saharan African countries, particularly in Togo, where rapid population growth, progressive degradation of agricultural land, and the effects of climate change increase the vulnerability of populations. In this context, identifying sustainable, accessible, and nutritionally adequate food sources has become a strategic priority. Among the alternatives considered, entomophagy, defined as the consumption of insects by humans, emerges as a credible and promising option, capable of addressing nutritional needs while limiting the environmental impact of food systems (VAN HUIS et al., 2013). Edible insects have been consumed for centuries in many tropical regions and play an important role in African food traditions, where their nutritional, cultural, and economic significance is well documented. More than 500 insect species are recorded as regular food sources in Africa (DURST et al., 2010). In Togo, several insect families, including Acrididae, Buprestidae, Dytiscidae, Gryllidae, Saturniidae, Scarabaeidae, and Termitidae, are part of traditional diets (BADANARO et al., 2015). Within the Scarabaeidae family, beetles of the genus *Gnathocera*, like *G. trivittata* (Swederus, 1787), *G. impressa* (Olivier, 1789), *G. varians* (Gory & Percheron, 1833), *G. flavovirens* Kolbe, 1892, *G. hyacinthina* (Janssens, 1885), and *G. angustata* (Kolbe, 1892), were formerly highly appreciated by populations in ecological zones I and II of Togo. Their collection and consumption were integral to ancestral food knowledge, particularly among the Bassar and Tem communities (KOKOETE et al., 2015). These species are primarily phytophagous, feeding mainly on grass panicles, which makes them easily observable and accessible during flowering periods, when panicles are abundant. Harvested directly from grass panicles, they constituted a complementary source of proteins and lipids to plant-based foods. However, like many other edible insect species, the consumption of *Gnathocera* has markedly declined in recent years (TCHIBOZO, 2023). Consequently, a local food resource with high nutritional and economic potential is being neglected. This situation highlights a major challenge for food security and the sustainability of local food systems: the rediscovery and promotion of edible insect species, particularly those deeply rooted in tradition but increasingly forgotten. Insects represent an important alternative source of proteins and micronutrients and could significantly contribute to combating malnutrition, provided that their nutritional value is clearly established (VAN HUIS et al., 2013). In a context where Togo seeks to strengthen its food resilience, the revalorization of local edible insect species appears especially relevant. The present study is part of ongoing efforts to valorize local food resources in Togo. It aims to determine the proximate composition, nutritional potential, and trace metal element profiles of three edible *Gnathocera* species (*G. flavovirens*, *G. hyacinthina*, and *G. varians*), which remain poorly documented. Specifically, the study seeks to generate reliable scientific data to assess their nutritional relevance and safety as alternative food resources, while providing evidence that may support their reintroduction into local diets and contribute to sustainable food security strategies in West Africa.

MATERIAL AND METHODS

Data Collection

Data were collected in 2022 during the period when cetoniid beetles are available, which is between September and October from *Andropogon* spp. (*Poaceae*) plants. This timeframe was selected based on previous ethnoentomological studies on edible insects in Togo. Adult beetles were caught by sight using sweep nets, with the assistance of local guides known for their expertise in edible insects. The collected specimens were transferred to the Applied Entomology Laboratory of the Faculty of Sciences (University of Lomé), where they were identified to the species level using appropriate identification keys. Biochemical analyses focused on adults of tree species *G. flavovirens*, *G. hyacinthina*, and *G. varians*. Specimens of these species were collected from three 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). The harvested insects were placed in a cooler containing cold packs and ice cubes before being transported to the Biochemistry Laboratory of the Faculty of Sciences (University of Lomé) for analysis.

Biochemical assays

Fifteen grams (15 g) of fresh samples of adult *G. flavovirens* from each of the three localities brought back to the laboratory were weighed and mixed to obtain an average sample. The same treatment was applied to adult *G. hyacinthina* and *G. varians*. The average samples were oven-dried at 40° C until a constant weight was obtained and then ground in a General electic; interlabs moulinex. The grounds samples were kept cool in a refrigerator for subsequent chemical analysis.

- *Fiber content was determined using the Weende method (*AFNOR, 1985)

After acid hydrolysis followed by basic hydrolysis, the samples were dried at 150°C for one hour and then incinerated at 550°C for 6 hours.

-*The compositions of ashes (mineral substances), lipids and proteins were determined according to the methods of the AOAC (*AOAC, 1995)

Ashes were determined by incinerating the samples at 550°C for 6 hours.

Proteins were estimated by determining total nitrogen using the Kjeldahl method. After adding 0.2 g of selenium sulfate and 20 ml of sulfuric acid to 0.5 g of crushed insect, the mixture was heated until discoloration occurred. This discoloration indicates that all organic forms of nitrogen have been converted to ammonium sulfate. Ammonia was distilled by introducing the resulting mixture, along with methyl red and 75 ml of 40 % sodium hydroxide, into the distillation apparatus. Heating the mixture released ammonia from the ammonium sulfate in a basic medium, which was then distilled off. An Erlenmeyer flask used to collect the distillate contained 20 ml of 0.1 N sulfuric acid and Tashiro's reagent as a color indicator. Once the pH paper indicated an acidic pH for the distilling solution, the distillation was stopped, and the excess acid was neutralized with a 0.1 N sodium hydroxide solution until the Tashiro reagent turned yellow-green. The percentage of nitrogen (%N) in the sample is calculated using the following formula:

$$N = \frac{0.14(20 - Volume\ of \text{sodium hydroxide solution used})}{\text{Mass of sample}} \qquad (1)$$

The crude protein was calculated by multiplying percentage nitrogen by a constant factor of 6.25, i.e.: % Crude Protein = % N × 6.25.

Lipids were extracted with hexane using a soxhlet and the extracts evaporated under vacuum at 35° C using a Buchi R114 rotavapor.

-*Mineral content was determined using the Pauwels method* (PAUWELS et al., 1992). Phosphorus content was determined by colorimetry using the phosphovanado molybdate method, and absorbance was assessed using a colorimeter (Jenway model 6300). Other minerals (calcium, magnesium, potassium, sodium, iron, manganese, copper, and zinc) and heavy metals (cadmium, mercury, lead, arsenic, and nickel) were analyzed by atomic absorption spectrophotometry. The solubilization of the insect crushers was performed by acid attack on sand bath, using two concentrated solutions: nitric acid and hydrogen peroxide. Indeed, one gram of each grind was introduced in a Teflon to which 1ml of hydrogen peroxide and 8 ml of nitric acid were added. After stirring, the Teflons were heated on a sand bath for about 2 hours at a temperature of about 150° C. The recovery of the products obtained after heating was done with 2 mL of distilled water. After cooling, the solution obtained after digestion was transferred to a 100 mL volumetric flask and supplemented with demineralized water. After homogenization, the solution was filtered through a Wattman paper. Thus, the filtrate was collected in a closed bottle. The determination of TMEs was carried out from this filtrate by flame atomic absorption spectrophotometer Agilent 7500 ICP-MS cu UP 213 using the standard solutions. The real concentrations are determined with the following formula :

$$RC = \frac{CS \times DV}{M} \qquad (2)$$

Where RC is real concentration, CS is the analyte concentration, DV is dilution volume and M is mass of the test sample.

To assess the nutritional quality of each species, the Ca/P, Ca/Mg and Na/K ratios were calculated.

- *The percentage of carbohydrates and the metabolisable energy values of the samples were calculated.*

The percentage of carbohydrates was calculated by difference with the percentages of the other total constituents according to the following formula (FAO/INFOODS. 2019):

Carbohydrate=100-(Moisture + Protein + Fat + Ash + Fiber) (3)

The metabolizable energy (EM) values of the samples were calculated from the protein, lipid, carbohydrate and fiber values by applying the energy conversion factors using the following formula (FAO/INFOODS. 2019):

EM = 17 X Protein + 37 X Fat + 17 X Carbohydrate + 8 X Fiber (4)

- *Vitamins were assayed using AOAC methods (AOAC, 1990)*

Vitamins in the various samples were determined by colorimetry. Optical density was measured using a Jenway model 6300 colorimeter. Calibration curves were obtained from the preparation of a range of solutions of the corresponding vitamin molecule. The samplings were prepared as follows:

Retinol (A): One gram of the sample was placed into a 250 mL flask. After adding 5 mL of pyrogallol solution, 35 mL of ethanol, and 10 mL of potassium hydroxide solution, the mixture was heated for 30 minutes at 70–80°C under a reflux condenser, then allowed to cool under a stream of water. After cooling, 40 mL of distilled water and 100 mL of petroleum ether were added. Extraction was performed by stirring for 3 minutes. The mixture was then left to settle, and the upper phase was transferred to a separating funnel. The ethereal phase was washed to neutrality with three 50 mL portions of water and filtered through filter paper. A 5 mL sample of the ethereal phase was transferred into a 50 mL flask and diluted with petroleum ether. The retinol concentration of this solution was determined by measuring its optical density at 325 nm.

Thiamine (B1): The thiamine content of the samples was determined by adding 50 mL of 0.1 N sulfuric acid to one gram of each sample in a 100 mL volumetric flask. The mixture was heated in a water bath at 100°C for 30 minutes, with frequent stirring. Five milliliters of 2.5 N sodium acetate solution were added to the contents, and the mixture was left to cool. After cooling, the flask was capped and placed in a water bath at 45–50°C for 2 hours. The resulting solution was made up to 100 mL with distilled water and filtered through filter paper. A 10 mL volume of the filtrate was transferred and mixed with 5 mL of potassium chloride solution. Absorbance was measured at a wavelength of 285 nm.

Riboflavin (B2): One gram of each sample was weighed into a 250 mL volumetric flask. To this, 5 mL of 0.1 N sulfuric acid and 5 mL of dichloroethane were added, followed by 90 mL of distilled water. The mixture was stirred and heated on a sand bath for 30 minutes to extract the riboflavin. Afterward, the mixture was cooled and made up to 250 mL with distilled water, then filtered through filter paper. A 2 mL volume of the filtrate was transferred into another 250 mL volumetric flask and topped up with distilled water. The riboflavin concentration of the solution was determined by measuring its absorbance at 460 nm.

Niacin (B3): Five grams of the sample were extracted with 50 mL of distilled water. Extraction was performed by repeated stirring for 30 minutes. The mixture was then left to settle, and the upper phase was recovered and filtered. This operation was repeated three times with the same amount of distilled water (100 mL). Five milliliters of the combined filtrates were transferred into a 100 mL volumetric flask and topped up with distilled water. The absorbance of the resulting-colored solution, measured at a wavelength of 385 nm, was used to determine the nicotinic acid content of the sample.

Tocopherol (E): One gram of the sample was weighed and placed in a 250 mL flat-bottomed flask. A solution of 10 mL of ethanol and 20 mL of 1 N sulfuric acid was added. The flask was wrapped in aluminum foil and heated under reflux for 45 minutes. The resulting solution was cooled for 5 minutes, followed by the addition of 50 mL of distilled water and transferred to an aluminum foil-covered separating funnel. The unsaponifiable matter in the mixture was extracted five times with 50 mL of dimethyl ether each time. The combined extract was washed with 1 N sulfuric acid solution and dried over anhydrous sodium sulfate. The evaporated extract was immediately dissolved in 15 mL of ethanol, 1 mL of concentrated sulfuric acid, and 1 mL of concentrated nitric acid. The resulting solution was placed in a water bath at 90°C for 30 minutes. After cooling, the tocopherol content of the extract was measured by ultraviolet absorption at 470 nm.

Statistical Analyzes

The experiments were performed in triplicate, and the results are expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was carried out using SPSS version 20.0 to compare mean values among the studied species. Differences were considered statistically significant at $P < 0.05$.

RESULTS AND DISCUSSIONS

Proximate composition and energy value

Chemical analyses (Table 1) show that, on a dry weight (DW) basis, the studied insect species present high nutritional value, with ash contents ranging from 9.42 ± 0.97 to 10.46 ± 1.25%, very high protein levels (62.30 ± 0.95 to 63.60 ± 1.84%), moderate lipid contents (7.80 ± 0.74 to 8.61 ± 0.54%), dietary fiber between 6.75 ± 1.82 and 11.13 ± 0.84%, and low carbohydrate contents (6.94 ± 2.54 to 10.97 ± 2.75%). Their energy values are high, ranging from 1585.8 ± 36.0 to 1655.2 ± 58.7 kJ/100g. These results confirm that the insects are mainly proteins and lipids rich foods. The very high protein content, consistent with previous reports on edible insects (VAN HUIS et al., 2013; ORDOÑEZ-ARAQUE et al., 2022), is comparable to or higher than that of conventional animal sources like meat and fish, highlighting their potential in combating protein malnutrition (VAN HUIS et al., 2013). The ash content indicates a significant mineral contribution (KŁOBUKOWSKI, et al., 2025), while lipids provide important energy and may include beneficial fatty acids. The fiber content is linked to chitin, which may support gut health, and the high energy values.

Table 1

Proximate composition (% dry weight) and energy values (kJ/100g) of insect species

Parameters analyzed	G. *flavovirens*	G. *hyacinthina*	G. *varians*
Ash	10.46 ± 1.25^b	9.42 ± 0.97^a	10.07 ± 0.77^b
Protein	62.80 ± 1.6^a	62.30 ± 0.95^a	63.60 ± 1.84^b
Lipid	8.67 ± 1.27^b	7.80 ± 0.74^a	8.61 ± 0.54^b
Fibre	11.13 ± 0.84^c	9.75 ± 0.40^b	6.75 ± 1.82^a
Nitrogen-free extract (NFE)	6.94 ± 2.54^a	10.73 ± 1.60^b	10.97 ± 2.75^b
Energy	1655.2 ± 58.7^c	1585.8 ± 36^a	$1625{,}0 \pm 42^b$

*Means followed by different letters in the same line are significantly different (ANOVA-1 comparison tests, P < 0.05)

Mineral composition

The mineral composition of the studied species shows that all analyzed insects are rich in both macrominerals and trace elements (Table 2). They contain high levels of calcium (63.71 ± 1.95 to 98.26 ± 0.08 mg/100g), magnesium (25.38 - 128.37 mg/100g), phosphorus (51.27 ± 1.08 to 64.05 ± 0.13 mg/100g), potassium (85.25 ± 0.74 to 1102 ± 2.34 mg/100g), and sodium (44.80 ± 0.25 to 84.91 ± 0.32 mg/100g), as well as important trace elements like iron (14.68 ± 0.09 to 18.90 ± 0.10 mg/100 g), copper (0.31 ± 0.01 to 3.50 ± 0.05 mg/100 g), zinc (15.03 ± 0.10 to 20.58 mg/100 g), and manganese (1.80 ± 0.08 to 2.36 ± 0.18 mg/100 g). Moreover, a 100 g serving of each species is sufficient to meet the recommended daily intake (RDI) for zinc (ANSES, 2021).Overall, these results highlight their strong nutritional value. The high levels of Ca, Mg, P, and K support bone health and metabolic functions, while the low Na/K ratios (0.04–0.07) suggest potential cardiovascular benefits (WANG et al., 2022). In addition, favorable Ca/P and Ca/Mg ratios indicate a good mineral balance and potential bioavailability. The high contents of iron, zinc, and copper further suggest that these insects may contribute to preventing micronutrient deficiencies, particularly anemia and immune-related disorders, confirming their value as nutrient-dense functional foods.

Table 2

Mineral composition (mg/100g dry weight) of studied insects compared with RDI (ANSES, 2021)

Mineral	G. *flavovirens*	*G. hyacinthina*	*G. varians*	RDI (mg/day)	% of RDI per 100g
Calcium (Ca)	66.54 ± 0.16^{a}	63.71 ± 1.95^{a}	88.26 ± 0.08^{b}	1000	6.4 - 8.8
Magnesium (Mg)	33.9 ±1.37^{a}	32.60 ± 0.88^{a}	51.56 ± 0.12^{b}	420 (men), 360 (women)	7.9 - 12.3
Phosphorus (P)	64.05 ± 0.13^{c}	60.52 ± 0.19^{b}	76.27 ± 1.08^{a}	700	8.6- 10.9
Potassium (k)	1102 ± 2.34^{c}	1024.3 ± 2.05^{b}	1110 ± 0.74^{a}	3500	29.3 - 31.7
Sodium (Na)	44.80 ± 0.25^{a}	57.33 ±2,36^{b}	84.91 ± 0.32^{c}	<2000	2.2 - 4.2
Iron (Fe)	14.68 ± 0.09^{a}	18.90 ± 0.10^{c}	17.08 ± 0.19^{b}	11 (men), 16 (women)	106 - 172 (men), 92 - 118 (women)
Manganese (Mg)	2.44 ± 0.09^{b}	1.80 ± 0.08^{a}	2.36 ± 0.18^{b}	2	90 – 122
Copper (Cu)	0.31 ± 0.01^{a}	2.53 ± 0.07^{b}	3.50 ± 0.05^{c}	1.6 (men), 1.3 (women)	19 – 269
Zinc (Zn)	19.51 ± 0.06^{b}	19.41 ± 0.14^{b}	15.03 ± 0.10^{a}	11 (men), 8 (women)	137 – 244
Na/K	0.04	0.05	0.07		
Ca/P	1.04	1.05	1.28		
Ca/Mg	1.96	1.95	1.71		

*Means followed by different letters in the same line are significantly different (ANOVA-1 comparison tests, $P < 0.05$)

Vitamin composition

Vitamin analysis (Table 3) shows that the studied species contain variable vitamin levels per 100 g: retinol (0.01 - 0.03mg), thiamin (0.96 - 1.27mg), riboflavin (1.43 - 1.75mg), niacin (7.38 - 7.80 mg), and tocopherol (4.01- 4.82 mg). Among these, 100 g of the studied species is sufficient to meet or exceed the recommended dietary intake for adults for riboflavin (119.2-145.8% of the RDI) and thiamin (80.0-105.8% of the RDI) (ANSES, 2021). Riboflavin fully exceeds the RDI in all species, while thiamin meets or slightly exceeds daily requirements depending on the species. It also partially contributes to niacin (52.7 - 55.7% of the RDI) and tocopherol (33.4 - 40.2%), while retinol remains very low (1.4 - 4.3% of the RDI), confirming its limited contribution to vitamin A requirements. Overall, these findings indicate that the studied insects are particularly rich in B-group vitamins, especially thiamin (B1) and riboflavin (B2), which meet or exceed adult dietary requirements. This is consistent with previous studies reporting that edible insects are important sources of B vitamins involved in energy metabolism and nervous system function. Niacin (B3) and tocopherol (E) contribute moderately to daily requirements and support metabolic and antioxidant processes. However, retinol (A) levels are very low, confirming that edible insects are generally poor sources of vitamin A and should be complemented with other vitamin A–rich foods to ensure dietary balance.

Table 3

Vitamin contents (mg/100g DW) of studied insects compared with RDI (ANSES, 2021)

Vitamin	G. *flavovirens*	*G. hyacinthina*	*G. varians*	RDI (mg/day	% of RDI per 100g
Retinol (A)	0.03 ± 0.01^{ab}	0.02 ± 0.01^{ab}	0.01 ± 0.00^{a}	0.7 mg	1.4 – 4.3
Thiamin (B_1)	0.96 ± 0.06^{a}	1.17 ± 0.28^{a}	1.27 ± 0.06^{ab}	1.2 mg	80.0 – 105.8
Riboflavin (B_2)	1.72 ± 0.11^{b}	1.43 ± 0.20^{a}	1.75 ± 0.21^{b}	1.2 mg	119.2 – 145.8
Niacin (B_3)	7.80 ± 0.33^{b}	7.38 ± 0.07^{a}	7.79 ± 0.30^{b}	14 mg	52.7 – 55.7
Tocopherol (E)	4.51 ± 0.07^{b}	4.01 ± 0.19^{a}	4.82 ± 0.08^{c}	12 mg	33.4 – 40.2

*Means followed by different letters in the same line are significantly different (ANOVA-1 comparison tests, $P < 0.05$)

Trace metal elements (TMEs) of studied insects

The results of trace metal element analysis (Table 4) revealed extremely low concentrations (× 10^{-3} mg/kg) of cadmium (0.019 - 0.023), mercury (0.001), and lead (0.039 - 0.041) in all studied insect species. These values are far below the maximum regulatory limits established for edible insects and other foodstuffs intended for human consumption (Regulation (EU) nº 1881/2006; Regulation (EU) nº 2023/58), indicating negligible contamination by these highly toxic metals and confirming the safety of these species with respect to these contaminants. Slightly higher concentrations were recorded for arsenic (2.01-2.21) and nickel (3.09 - 3.12). However, these concentrations remain very low and do not suggest any immediate toxicological concern. Their presence likely reflects natural environmental background levels or trace accumulation from ecological exposure. Overall, the very low levels of all analyzed trace metals indicate good environmental quality in the collection areas and are consistent with previous studies reporting minimal contamination in edible insects collected from relatively unpolluted habitats (Alejandro Ruiz et al., 2025). These findings support the potential of these insect species as safe and sustainable alternative protein sources for human consumption.

Table 4

Trace metal elements (x 10^{-3} mg/kg) of insects studied

TMEs	G. *flavovirens*	*G. hyacinthina*	*G. varians*
Cadmium	0.022± 0.0^{a}	0.019± 0.0^{a}	0.023± 0.0^{a}
Mercury	0.001± 0.0^{a}	0.001± 0.0^{a}	0.001± 0.0^{a}
Lead	0.040± 0.1^{a}	0.039± 0^{a}	0.041± 0^{a}
Arsenic	2.01± 00.12^{a}	2.21± 00.02^{a}	2.11± 0.05^{a}
Nickel	3.09 ± 0.3^{a}	3.11 ± 0.1^{a}	3.12 ± 0.0^{a}

*Means followed by different letters in the same line are significantly different (ANOVA-1 comparison tests, $P < 0.05$)

CONCLUSIONS

The present study highlights the significant nutritional potential of three edible insect species of the genus *Gnathocera* (*G. flavovirens*, *G. hyacinthina*, and *G. varians*) from Togo. The results demonstrate that these insects are highly rich in proteins, with substantial energy density, and contain appreciable amounts of essential minerals and B-group vitamins. Their favorable mineral ratios, particularly low Na/K values, further suggest potential health benefits, especially in relation to cardiovascular health. In addition, the detected trace metal elements (TMEs) were generally below internationally recommended safety limits, with very low levels of cadmium, mercury, and lead, indicating minimal contamination and a low risk for human consumption. Although arsenic and nickel were detected at relatively higher concentrations, their levels remain within acceptable ranges, but warrant continued monitoring to ensure long-term food safety. However, the low vitamin A content indicates that these insects should be consumed as part of a diversified diet to ensure nutritional balance. Overall, the findings confirm that *Gnathocera* species constitute promising alternative sources of high-quality protein and micronutrients. Their valorization could contribute significantly to improving food and nutrition security in Togo and other regions where entomophagy is culturally relevant, while also supporting more sustainable and resilient food systems.

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