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Aquatic Insects Consumed in Togo: Diversity and Nutritional Potential

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FB, PT and MM designed the project. Author FB carried out the sampled. Author FB and PT performed the experiments. Author FB analyzed the data. Authors FB, PT and MM wrote the manuscript; all authors agreed to the final version of the manuscript and its publication.

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ABSTRACT

This study identified the species of aquatic insects consumed in Togo, and determined the chemical composition of the most common species (*Cybister tripunctatus* (Sharp, 1882) (Coleoptera: Dytiscidae)). This was achieved through ethnoentomological surveys and species identification at the insectarium of the University of Lomé and it provided information on aquatic insects consumed in Togo. Samples of *C. tripunctatus* were collected in the three localities where ethnoentomological surveys were carried out. Ash, protein, vitamin and lipid contents were determined according to AOAC reference methods. Fiber content was determined using the Weende method. Minerals were analyzed by atomic absorption spectrophotometry and colorimetry. Lipid composition in fatty acids was determined by gas chromatography, and protein composition in amino acids was determined by separation of amino acids using the Biochrom 30+ analyzer. Forty-five out of 120 people interviewed from the Moba ethnic group said they occasionally consumed adult dytics. Four species

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consumed by this aborigine population was identified. None of these species is sold commercially. According to the respondents, the consumption of dytics is motivated by their nutritional and therapeutic virtues. *C. tripunctatus* consists of 10.32% moisture, 36.52% proteins, 26.98% lipids, 12.60% fibers, 4.94% carbohydrates, and has an energy value of 1804.19 kJ/100g. All essential amino acids are present in *C. tripunctatus*. Lipids are rich in unsaturated fatty acids, particularly essential fatty acids. In terms of micronutrient composition, the species studied is rich in minerals and vitamins. The mineral content is 10.32% and depends on the nature of the minerals present. Vitamins content also varies. The ratios of minerals, and fatty acids are balanced. These data show the socio-economic importance of dytics consumed in Togo and the quantitative and qualitative richness of *C. tripunctatus* in nutrients. This species could therefore contribute to the nutritional balance of consumers.

Keywords: consumed aquatic insects; diversity; dytics; Moba ethnic group; nutritional value; Togo.

1. INTRODUCTION

Continental waters are vast ecosystems made up of streams, rivers, lakes, ponds and estuaries of great ecological value. In these aquatic ecosystems, many species have established a complex food web, ensuring balanced functional and sustainable biocenoses [1]. Moreover, these biocenoses have evolved over millennia separately from one another and under different ecological conditions. As a result, many of them have acquired a certain identity, and even their own species, resulting in a high level of biological diversity in ecosystems [2-4]. Continental aquatic ecosystems account for just 0.8% of the earth's total surface area, but this tiny fraction is home to at least 6% of the species described [5]. These ecosystems are home to bacteria, plants and animals like fish, mammals, birds, insects, reptiles and amphibians. Because of this immense biodiversity, riverside populations have maintained close relationships with these aquatic ecosystems for millennia. Indeed, continental aquatic ecosystems provide a means of subsistence for a multitude of people in developing countries [6]. Populations living near these ecosystems harvest fishery products for food, medicine and other uses [7] or trade them for income or barter. Despite the ecological interest and socio-economic, therapeutic and nutritional values of these continental aquatic ecosystems, their biological species have remained neglected. Indeed, different species of fauna in continental aquatic ecosystems, like insects, are consumed by aborigine populations without any studies being carried out on their diversity, socio-economic importance and nutritional value [7]. In view of their importance, aquatic insects can supplement the dietary needs of populations living near these ecosystems, help to treat or prevent the development of a wide range of diseases associated with malnutrition and others illnesses [8], hence the need to value them. The aim of the present study is to promote the consumption of aquatic insects for food security in Togo. To this end, the species of aquatic insects consumed in Togo were identified, and the chemical composition of the most common species in the study environment (*C. tripunctatus*) were determined in order to assess its nutritional value.

2. MATERIALS AND METHODS

2.1 Ethnoentomological Surveys

Ethnoentomological surveys were carried out throughout Togo in two phases. An enthnoentomological prospecting and pre-survey phase was carried out between September 8 and December 16, 2012. Data were collected at sites selected based on stratified sampling. Two levels of stratification were used to select the sites: ecological zone and ethnic group [9]. The number of ethnic groups surveyed by ecological zone are shown in Table 1.

In total, 30 of the country's majority ethnic groups were surveyed in the 5 ecological zone of Togo. For each ethnic group, two localities were selected. Five households were selected per locality giving a total of 350 pre-surveyed households. The pre-survey information was gathered through interviews focusing on the ecology and traditional uses (food, economic and medicinal) of consumed aquatic insects. Semi-structured interviews were conducted to gather pre-survey information on the indigenous knowledge of aboriginal populations regarding aquatic insects consumed. These data enabled us to identify the Moba ethnic group in ecological zone 1 as consumers of aquatic insects in Togo. Ethnoentomological surveys on the consumption of aquatic insects were carried out between December 14 and 18, 2022 among the Moba ethnic group. The groups of individuals surveyed (regardless of religion or level of education) were men, women and children. The information collected from the subjects concerned the species of aquatic insects consumed in the area visited, the vernacular name of the species, their period of availability in the year, the quantities harvested, the stages harvested, their marketing, cooking methods, and therapeutic virtues, followed by a brief description of aquatic insects consommed. The ethnoentomological surveys covered 120 people spread evenly over 3 localities. This preliminary information was essential for guiding further fieldwork on the capture of dytic species and their identification in the laboratory.

Table 1. List of ethnic groups surveyed by ecological zone

Ecological zones	Ethnic group names
Zone 1	Anoufo, Bissa, Gangan, Gourmantché, Konkomba, Lamba, Moba, Temberma, Yenga
Zone 2	Bassar, Kabyè, Nawdm, Sola, Tem
Zone 3	Adja, Agnagan, Agounagbé, Ani, Bago, Ifè, Kpéssi, Koussountou, Tchamana
Zone 4	Adélé, Akébou, Akposso, Igo, Ntribou
Zone 5	Ewé, Ouatchi

2.2 Sampling and Conditioning of Dytics

Once the results of the surveys had been tabulated, guides identified as being familiar with the species consumed in the environments surveyed helped with the actual field identification of the species consumed. Dytics were fished using troubeau nets. The collected samples were sent to the Laboratory of Entomology at the University of Lomé, where they were identified to the specific level using determination keys. Specimens of these species were captured in three localities in Togo where the ethnoentomological surveys took place, namely Lotogou (10°47'53.7″N ; 0°1'31.6″E), Nanergou (10°54'41.6″N ; 0°9'0.9″E) and Bogou (10°39'28.8″N ; 0°1'31.6″E). Biochemical analyses focused on the *C. tripunctatus* species, the most common species in the study environment, as it was found at all sampling sites. For the chemical analyses, *C. tripunctatus* adults were fished using troubeau nets in these same localities at the same period. They were placed in an icebox with a cold accumulator containing ice cubes to kill them [9] and then brought to the Laboratory of Biochemistry at the University of Lomé.

2.3 Biochemical Assays

-The SCALTEC electronic moisture analyzer (SM01 Instrument GmH) was used to determine the moisture contents of the samples [9].

-Fresh *C. tripunctatus* samples were oven-dried at 40° C for 7 days, then ground to powder for the various assays [9].
- Fiber content was determined using the Weende method [10].

After acid hydrolysis followed by basic hydrolysis, the samples were dried at 150° C for 1 hour, then incinerated at 550° C for 6 hours.

-Ashes (mineral substances), lipids and proteins compositions were determined according to AOAC methods [11].

*Ashes were determined by incinerating samples at 550° C for 5 hours.

*Proteins were estimated by total nitrogen determination using the Kjeldahl method.

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

-Minerals were analyzed by atomic absorption spectrophotometry and colorimetry.

*Phosphorus content was determined colorimetrically using the phosphovanado molybdate method [12].

*Other minerals were analyzed by atomic absorption spectrophotometry [12].

*To assess the nutritional quality of *C. tripunctatus*, Ca/P, Ca/Mg and Na/K ratios were calculated.

-The percentage of carbohydrates was calculated by difference between the percentages of other total constituents according to the following formula [13] :

$$\text{Carbohydrates}=100-(\text{Moisture}+\text{Proteins}+\text{Lipids}+\text{Ashes}+\text{Fibers})$$

- The metabolizable energy (E) values of the samples were calculated from the protein, lipid, carbohydrate and fiber values by applying the energy conversion factors via the formula [13]:

E=17 X Proteins+37 X Lipids+17 X Carbohydrates+8 X Fibers

- Lipid fatty acid composition was obtained by gas chromatography and the calculated Omega6/Omega3 ratio.

The fatty acid composition of lipids was obtained by separating their methyl esters using a gas chromatograph (HP 6890 series GC System). Beforehand, the fatty acids are converted into methyl esters by transesterification of the raw lipids using a methanolic solution of boron trifluoride [14]. The omega 6 found in the lipids of the species studied is linoleic acid and the omega 3 is α-linolenic acid. The Omega6/Omega3 fatty acid ratio was calculated from the Omega 6 and Omega 3 in the lipids of the insect studied.

-Protein amino acid composition was obtained by separating using the Biochrom 30+ amino acid analyzer and Amino acid ratio was calculated using the reference source WHO/FAO/UNO [15].

*The amino acid composition of the insect was obtained by separating the differnt amino acids using the Biochrom 30+ amino acid analyzer.

*Amino acid ratio was calculated using the reference source WHO/FAO/UNO [15].

Amino acid ratios (Raa) is the percentage ratio of the content of essential amino acids in samples to that of the corresponding essential amino acids recognized as favorable by a reference source were calculated using the following formula :

Raa= Content of an essential amino acid in the sample / Favorable content of the homologous amino acid according to OMS/FAO/ONU(1985) *100

The amino acid index was then deduced for the species. The amino acid index of a species is the minimum Raa value of the species.

- Vitamins were assayed according to AOAC methods [16].

Vitamins in different samples were determined colorimetrically. Optical density was measured using a Jenway model 6300 colorimeter. Calibration curves were obtained preparing a range of solutions of the corresponding vitamin molecule.

2.4 Statistical Analysis

The raw results from the ethnoentomological surveys were used to calculate the mean frequencies of aquatic insects reported as consumed in different localities of the Moba ethnic group [9] using Excel software. With regard to the chemical analyses, all 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).

3. RESULTS

3.1 Diversity of Aquatic Insects Consumed in Togo

Ethnoentomological investigations have identified 4 species of aquatic insects consumed in Togo by the Moba ethnic group. They belong to the Dytiscidae family and are divided into 2 genera (Table 2).

Table 2. Taxonomy of consumed dytic species

Genera	Scientific names of species
Cybister	*Cybister tripunctatus* (Sharp, 1882)
	Cybister senegalensis (Aubé, 1838)
	Cybister vulneratus Klug, 1834
Hydaticus	*Hydaticus dorsigers* (Aubé, 1838)

Table 3. Dytic consumption frequencies by the Moba ethnic group

Locations surveyed	Dytic consumption frequencies (%)
Lotogou	32.5
Nanergou	42.5
Bogou	37.5
Total	37.5

3.2 Dytic Consumption Frequencies by the Moba Ethnic Group

In all the localities surveyed, the dytics consumed have the same local name “Gnokoukouna”. Forty-five out of 120 people interviewed (37.5%) from the Moba ethnic group said they occasionally consumed raw or processed dytics (Table 3).

3.3 Socio-Economic Aspects of Dytics Consumed in Togo

According to the majority of respondents (77.5%), dytics are available all year round (Table 4). Being aquatic insects, dytics are collected by chance as part of fishing activities. Only traditional fishing is carried out with nets actually intended for harvesting fish. However, the quantities caught are small. The number caught is generally less than 10 individuals, according to 93% of respondents. According to the same respondents, only adult dytics are eaten (100%), and dytics are not sold commercially (0%). They can be eaten raw (40%). More often, however, they are cooked (60%) by braising after removal of the wings (92.7%), and in a few rare cases by roasting (7.3%). Consumption of dytics allows treatment of nasal haemorrhage (98%).

3.4 Chemical Composition of *C. tripunctatus*

3.4.1 Proximate composition and energy value

Table 5 shows the proximate composition of *C. tripunctatus*. It shows that 100 g of *C. tripunctatus* contains 10.32 ± 0.1 g moisture, 36.52 ± 0.46 g proteins, 26.98 ± 1.62 g lipids, 12.60 ± 0.14 g fibers, 4.94 ± 1.46 g carbohydrates, and 8.62 ± 0.33g ashes (Table 5). It is a high-energy food, with calorific values of 1804.19 ± 33.25kJ/100g.

3.4.2 Mineral composition

The mineral composition of *C. tripunctatus* is rich in macronutrients like calcium (82.88 ± 0.46 mg/100g), magnesium (44.27± 0.81mg/100g), phosphorus (82.14 ± 0.26 mg/100g), potassium (474.13 ± 2.09 mg/100g), sodium (161.83 ± 2.2 mg/100g) and trace elements such as iron (14.36 ± 0.09 mg/100g), copper (1.97 ± 0.00 mg/100g), zinc (6.07 ± 0.00 mg/100g) and manganese (3.64 mg/100g) (Table 6).

Table 7 shows the Sodium/Potassium, Calcium/Phosphorus and Calcium/Magnesium ratios for *C. tripunctatus* which are 0.34, 1.01 and 1.87 respectively.

3.4.3 Amino acid composition

The amino acid composition of *C. tripunctatus* is shown in Table 8. Of the 20 protein-forming amino acids anchored in the human genome, 18 have been identified in *C. tripunctatus* contains all the essential amino acids.

The amino acid index of this insect is 75.29%, i.e. less than 100% of that of the reference protein (Table 9). An amino acid index below 100 indicates that the concentration of at least one essential amino acid is limiting. Methionine and cystine are the first limiting amino acids for *C. tripunctatus*, followed by tryptophan, lysine and threonine. The valine, leucine, methionine, isoleucine, tyrosine, histidine and phenylalanine values obtained for this dytic exceed the WHO, FAO and UN recommendation [15].

Table 4. Socio-economic aspects of dytics consumed in Togo

Socio-economic aspects		Frequencies (%)
Period of availability	Year-round	77.5
	Seasonal	22.5
Quantity harvested	Less than 10 individuals	92.3
	More than 10 individuals	7.3
Stage consumed	Adult	100
	Larval	0
Marketing	Sold	0
	Not sold	100
Consumption mode	Raw	40
	Cooked	60
Cooking method	Braising	92.7
	Roasting	7.3
Therapeutic properties	Treats nasal hemorrhage	97.6
	No virtue	2.4

Table 5. Proximate composition (%) and energy value (kJ/100g) of *C. tripunctatus*

Parameters analyzed	Proximate composition (%) and energy value (kJ/100g)
Moisture	10.32 ± 0.1
Ashes	8.62 ± 0.33
Proteins	36.52 ± 0.46
Lipids	26.98 ± 1,62
Fibers	12.60 ± 0.14
Carbohydrates	4.94 ± 1.46
Energy	1804.19 ± 33.25

Table 6. Mineral composition (mg/100g) of *C. tripunctatus*

Minerals	Average minerals content (± SD)
Calcium	82.88 ± 0.46
Magnesium	44.27 ± 0.81
Phosphorus	82.14 ± 0.26
Potassium	474.13 ± 2.09
Sodium	161.83 ± 2.2
Iron	14.36 ± 0.09
Manganese	3.64 ± 0.05
Copper	1.97 ± 0.00
Zinc	6.07 ± 0.02

3.4.4 Lipid characteristics

3.4.4.1 Fatty acid composition of C. tripunctatus

The results of the chemical screening carried out on *C. tripunctatus* lipids are shown in Table 10. The lipids of the species studied contain saturated fatty acids such as myristic acid (1.09 ± 0.00%), isopalmitic acid (36.61± 0.01%) and stearic acid (7.17 ± 0.01%). Monounsaturated fatty acids are also present in this species. These are oleic acid (34.13%) and elaidic acid (2.77 ± 0.01%). With the exception of elaidic acid, which is trans-configured, all the other fatty acids in the lipids of the species studied are cis-configured. The polyunsaturated fatty acids contained in the lipids are linoleic acid (6.54 ± 0.00%) and α-linolenic acid (1.63 ± 0.02%).

3.4.4.2 Degree of lipid saturation

The percentages of saturated and unsaturated fatty acids (monounsaturated and polyunsaturated) in the lipids of *C. tripunctatus* are shown in Table 11. It appears that *C. tripunctatus* contains more than 48% unsaturated fatty acids. Monounsaturated fatty acids represent 39.88% and polyunsaturated fatty acids represent 8.17%. Concerning the Omega6/Omega3 ratio of fatty acids in the insect studied, the value is 4.01.

3.5.5 Vitamin composition

The specie studied has variable vitamin contents (Table 12) per 100g: retinol (0.04 ± 0.00mg), thiamin (1.89 ± 0.01 mg), riboflavin (2.2 ± 0.01 mg), niacin (7.17± 0.06 mg) and tocopherol (3.29 ± 0.16 mg).

Table 7. Sodium/potassium, calcium/phosphorus and calcium/Magnesium ratios for *C. tripunctatus*

Ratios	Values
Sodium/Potassium	0.34
Calcium/Phosphorus	1.01
Calcium/Magnesium	1,87

Table 8. Amino acid profile (g/100g total product) of *C. tripunctatus*

Amino acids	Values (± SD)
Isoleucine	1.33 ± 0.04
Leucine	2.52 ± 0.15
Lysine	1.43 ± 0.09
Methonine	0.49 ± 0.01
Phenylalanine	1.48 ± 0.02
Tryptophan	0.44 ± 0.04
Threonine	0.85 ± 0.17
Valine	1.81 ± 0.02
Arginine	1.03 ± 0.01
Histidine	2.24 ± 0.02
Alanine	2.83 ± 0.22
Aspartic acid	2.82 ± 0.03
Glutamic acid	3.96 ± 0.29
Cystine	0.79 ±0.00
Glycine	4.24 ± 0.02
Proline	2.86 ± 0.19
Serine	1.20 ± 0.07
Tyrosine	5.90 ± 0.86

4. DISCUSSION

4.1 Diversity and Socio-Economic Aspects of Aquatic Insects in Togo

In Togo, aquatic insects have been reported to be consumed by the Moba ethnic group. A non-exhaustive list of 4 species was drawn up in the course of this study, and all the species consumed were adults belonging to the Dytiscidae family. Comparing edible aquatic insects with the list of insect species consumed in Togo compiled by Badanaro [17], the number is small. Edible aquatic insects account for just

Table 9. index values for amino acid for *C. tripunctatus*

Amino acids	Reference WHO/ FAO/ONU (1985)	Index values for *C. tripunctatus*
*Threonine	0.9	94.44
Valine	1.3	139.23
*Methionine +Cystine	1.7	75.29
Isoleucine	1.3	102.30
Leucine	1.9	132.63
Tyrosine +Phenylalanine	1.9	388.42
Histidine	1.6	140
*Lysine	1.6	89.39
*Tryptophan	0.5	88
Amino acid index	100	75.29

**Limiting amino acid*

14% of the insect species consumed in Togo. Globally, the number of aquatic insects is generally low compared to terrestrial species. They represent only 6.58% of consumed insect species [18]. Seventy-eight (78) belonging to 22 genera and are consumed in 27 countries, mainly Mexico and Asia (China, Japan).

Table 10. Percentage (%) of fatty acids of *C. tripunctatus*

Fatty acids	Percentage (± SD)
Myristic acid (C14:0)	1.09 ± 0.00
Isopalmitic acid (C16:0)	36.61 ± 0.01
Stearic acid (C18:0)	7.17 ± 0.01
Oleic acid *cis* (Cl8 :1)	34.13 ± 0.01
Elaïdic acid *trans* (C18 :1)	2.77 ± 0.01
Linoleic acid (C18 :2n 6)	6.54 ± 0.00
Acide α-linolénique (C18:3)	1.63 ± 0.02

Table 11. Lipid saturation (%) and omega6/omega3 ratio for *C. tripunctatus*

Lipid saturation and Omega6/Omega3 ratio	Values (± SD)
Saturated fatty acids	50.95 ± 0.03
Monounsaturated fatty acids	39.88 ± 0.00
Polyunsaturated fatty acids	8.17 ± 0.02
Unsaturated fatty acids	48.06 ± 0.02
Omega6/Omega3	4.01

The most widely consumed aquatic insect families in the world are the Dytiscidae and Hydrophilidae, which are the most diverse and largest in size [19]. The number of aquatic insect species consumed is therefore generally small compared with terrestrial species. The dytic species consumed by the Moba ethnic group have the same vernacular name "Gnokoukouna" in this ethnic community. Indeed, very often, when several insect species are eaten together, they all share a common vernacular name. Local populations find it difficult to distinguish between individual species. This linguistic tendency reflects long-standing traditional knowledge of the species [20]. The information provided by local people on the ecology and traditional uses (food, economic and medicinal) of the edible aquatic insects consumed in Togo demonstrates that local people have in-depth knowledge of these insects and have been using them for a long time.

Table 12. Vitamin contents (mg/100g dry weight) of *C. tripunctatus*

Vitamin	Average vitamin contents (± SD)
Retinol (A)	0.04 ± 0.00
Thiamin (B_1)	1.89 ± 0.1
Riboflavin (B_2)	2.2 ± 0.1
Niacin (B_3)	7.17 ± 0.06
Tocopherol (E)	3.29 ± 0.16

According to Johnson [21], some insects are available all year round, including many aquatic species. This is the case with dytics, which, according to respondents in the present study, are permanently present in water reservoirs all year round. However, the quantities of dytics harvested are small, contributing to a reduction in their consumption. It should be noted that consumers are complaining about the scarcity of dytics these days, resulting in small harvests. The scarcity of insects is the main reason for the decline in the consumption of dytics within the consuming ethnic group and the fact that no species is marketed, as is also the case for insect consumption among aboriginal groups in Madagascar [22]. Furthermore, entomophagy is declining among populations in tropical countries, where it was once widespread due to the westernization of diets. In tropical countries, insects are seen as a useful resource, but not always a positive one, as they are associated with ancestral, rural diets that are not conducive to development. Thus, the trend is reversed in relation to the Western population, which will prefer products that evoke a "return to nature", whereas populations in tropical countries are more inclined towards processed products [23].

Dytics are known to have therapeutic virtues within the ethnic community surveyed in Togo. They are used to treat nasal haemorrhage in this community. The same species are used as an anti-diuretic in China [24]. Indeed, several authors [25-27] have also reported numerous edible insect species as having therapeutic and stimulating virtues. Clinical trials need to be carried out on these dytic species to prove their efficacy.

4.2 Biochemical Analysis *of C. tripunctatus*

The moisture content of *C. tripunctatus* is 10.32% relative to its fresh mass. This is lower than that found by Shantibala et al [7] on the same species (38.03%). However, these contents are all lower than the moisture contents of conventional meat products such as beef, chicken, pork and fish, which have moisture contents in the 40-70% range [15]. The low moisture content of *C. tripunctatus* raises the relative concentrations of other food components. The ash from the incineration of *C. tripunctatus* has been used to quantify a number of minerals (calcium, phosphates, sodium, potassium, iron, zinc) essential to the organism and contained in the insect. The levels of the minerals obtained in during this work confirm that this beetle provides the populations that consume it with a sufficient quantity of minerals. The value of minerals content is relatively high for the beetle studied (8.62%), like many edible insects. [23,28] Indeed, compared to the values reported for meat products [15], insects are known to be rich sources of different macro and trace elements. Sodium and potassium regulate the water content of the human body and help maintain the acid-base balance. These two elements have been found in significant quantities in *C. tripunctatus*. Considering the Na/K ratio, which is equal to 0.34 and therefore less than 1, we deduce that consumption of *C. tripunctatus* would have a positive effect combating cardiovascular disease [29,30]. Calcium and phosphorus are necessary for bone growth. Calcium deficiency causes growth retardation, rickets in children, spasmophilia in adults and osteoporosis in the elderly. As intestinal absorption of calcium is favorable when the Ca/P ratio is balanced, as is the case for *C. tripunctatus*, the intake of these elements by *C. tripunctatus* is beneficial. The Calcium/Magnesium ratio of *C. tripunctatus* is close to 2, which favours significant calcium fixation in the organism [31]. Oligominerals like zinc, copper and maganese have also been found in *C. tripunctatus*. Zinc is essential for cell growth and wound healing. It enables the proper utilization of group B vitamins and vitamin A. Copper promotes intestinal absorption of iron, is involved in the formation of red blood cells, plays a role in energy production and contributes to the synthesis of many vital substances. It is also necessary for hemoglobin formation and red blood cell maturation [32,33]. *C. tripunctatus* consumed by the Moba ethnic group in Togo constitutes an important source of animal protein (36.52%), a value higher than that obtained in India by Shantibala et al [7] in the same species (22.64%). Comparison of this content with that of adults of other aquatic insects consumed, or with fish or meat shows that *C. tripunctatus* consumed in Togo is richer in protein than *Lethocerus indicus* (Lepeletier et Serville, 1825) (Hemiptera : Belostomatidae) (22.08%), *Hydrophilus olivaceous* Fabricius, 1781 (Coleoptera :Dytiscidae) (25.08%), beef (18.2%) and fish (18.3%) [7,16], however, *C. tripunctatus* is less protein-rich than adults of other aquatic insects like *Laccotrephes maculatus* (Fabricius, 1775) (Hemiptera : Nepidae) (66.5%) and *Crocothemis servila* (Drury, 1770) (Libellulidae) (70.48%) that are also consumed [7]. Protein quality in food is determined by its essential amino acid content. All essential amino acids are present in the protein portion of *C. tripunctatus*. Comparison of the protein composition of this insect with the WHO/FAO/ONU Reference [15] shows that the valine, leucine, isoleucine, tyrosine, histidine and phenylalanine values obtained for this dytic exceed the reference recommendation, however, in decreasing order, threonine, lysine, tryptophan, methionine and cystine are limiting amino acids for *C. tripunctatus*. These results are in line with those of Mabossy-Mobouna et al. [34], who noted low concentrations of tryptophan and sulfur amino acids (methionine and cystine) in the caterpillar

Imbrasia truncata Aurivillius,1909 (*Lepidoptera : Saturniidae*). A diet based on *C. tripunctatus* needs to be supplemented with foods rich in these essential amino acids. The high protein content of *C. tripunctatus* is suggestive of its potential in combating protein deficiency in developing countries. This insect can provide a cheaper source of essential nutrients that is readily available and affordable to aborigines in the localities where it is consumed.

The lipid content of *C. tripunctatus* is quite high. On a fresh insect mass basis, the lipid content of *C. tripunctatus* (26.98%) is higher than the amount found in most conventional foods like beef, chicken, egg and milk [13]. The lipid saturation values show that the species studied contain saturated fatty acid levels of 50.95%. This is higher than recommended by the French Food Safety Agency (AFSSA), which advises a maximum dietary intake of 33% saturated fatty acids [35]. Indeed, high levels of saturated fatty acids in the diet are considered to be risk factors for cardiovascular disease. Saturated fatty acids are excellent energy nutrients, but their consumption in high proportions can increase the risk of cardiovascular disease and promote the formation of thrombosis, leading to cardiovascular disease [36,37]. Monounsaturated fatty acids are also present in this species. These are oleic acid (34.13%) and elaidic acid (2.77%), which is the trans isomer of oleic acid. The high oleic acid content is a nutritional advantage, as lipids with high levels of unsaturated fatty acids are good for human consumption. With the exception of elaidic acid (2.77%), which is trans-configured, all the other fatty acids in the lipids of the insect studied are cis-configured. Fortunately, the quantity found in this insect is low, as excessive consumption of trans fatty acids is likely to have a negative impact on health, just like saturated fatty acids [38]. At very high doses, these “trans” fatty acids, like saturated fatty acids, are capable of increasing levels of LDL-cholesterol, or bad cholesterol, while lowering levels of HDL-cholesterol, or good cholesterol [39]. The polyunsaturated fatty acids contained in these lipids are linoleic a (6.54%) and α-linolenic (1.63%) acids. The level of polyunsaturated fatty acid unsaturation observed in the insect studied is low (8.17%), since their content is less than 15% of fatty acids [35]. Their presence in food is beneficial to health, as they have the potential to lower LDL cholesterol levels in the blood [40]. This species contains the two essential fatty acids (linoleic acid and α-linolenic acid) that are the precursors of the two fatty acid families Omega6 and Omega3.The species studied has an Omega6/Omega3 ratio of less than 5. This underlines the nutritional quality of this insect's oil, as such a ratio reduces the risk of cardiovascular disease [41]. Linoleic and α-linolenic acids are essential to the functioning of the human body. In fact, linoleic acid is involved in the formation of phospholipids in cell membranes and molecules regulating cellular functions, reproductive functions and platelet functions [38]. α-Linolenic acid plays specific roles in the development and physiology of the retina, brain and nervous system [42]. Futhermore, as the species studied is rich in both proteins and lipids, its energy value is very high. A comparison of the total energy supplied by the insect studied with that of conventional foods in West Africa [13] shows that it is more energetic than most of the conventional foods, notably tubers (manioc, yam), cereals (maize, sorghum, rice), meats (beef, chicken) and legumes (beans, soya), whose the energy values fall within the range of energy supplied by insects for the same food mass.

C. tripunctatus also contains appreciable quantities of all the vitamins required. It contains appreciable quantities of retinol, thiamine, riboflavin, niacin and tocopherol making it a species of good nutritional quality. The presence of vitamins in *C. tripunctatus* confirms the conclusion of several authors [43-45] that insects are an important source of vitamins. These vitamins have several functions in the body. Vitamins A and E are antioxidants, while the B vitamins are co-enzymes [35].

The fiber content of the species studied is high compared to conventional meat products [13]. This species can therefore contribute to better digestion for people of all ages. Indeed, fiber in the diet can improve intestinal health [42]. In addition, fiber has a positive effect on accelerating satiety, thus limiting the risk of overeating. This helps prevent obesity [46]. On the other hand, insects are not a great source of carbohydrates according to several authors [17,20,47]. The content obtained in this study for the species studied is also low, confirming the findings of these authors. Carbohydrates represent the primary source of energy available to the human organism [48]. However, an excess of carbohydrates contributes to a number of adverse effects on the body, including obesity. As insects are low in carbohydrates and high in fiber, their consumption is beneficial in avoiding obesity, a risk factor for a number of pathologies, notably cardiovascular disease and diabetes.

5. CONCLUSION

In this study, four species of aquatic insects were identified as being consumed within the Moba ethnic group in Togo. These were *C. tripunctatus*, *C. senegalensis*, *C. vulneratus* and *H. dorsigers*. These species belong to the Dytiscidae family. The list of aquatic insects consumed in Togo drawn up in this study is not exhaustive. This work, which provides an initial overview of the aquatic insects consumed in Togo, must be followed by intensive studies in the aquatic ecosystems of the study area. *C. tripunctatus*, whose chemical composition has been analyzed, contains all the essential amino acids required by the human body. It provides lipids rich in unsaturated fatty acids, especially essential fatty acids. It also provides minerals and vitamins essential for the functioning of the human body. The ratios of amino acids, essential fatty acids and minerals in this insect are balanced. As a result, it has an excellent nutritional value. The quantity and quality richness of *C. tripunctatus* nutrients suggest that it could be an essential tool for applications in the agri-food and pharmaceutical industries.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lacroix G, Danger M, From food networks to the functioning of lake ecosystems: towards an integration of heterogeneity and complexity. Journal of Water Sciences. 2008;21(2):155-172. French.
2. Jorgensen SE, Encyclopedia of ecology. Elsevier, Amsterdam; 2008.
3. Fontaneto D, Tommaseo-Ponzetta M, Galli C, Risé P, Glew RH, Paoletti MG. Differences in fatty acid composition between aquatic and terrestrial insects used as food in human nutrition. Ecology of Food and Nutrition. 2011;50(4):351-67.
4. Gómez B, Munekata PE, Zhu Z, Barba FJ, Toldrá F, Putnik P, Kovačević DB, Lorenzo JM. Challenges and opportunities regarding the use of alternative protein sources: Aquaculture and insects. Advances in food and Nutrition Research. 2019;89:259-95.
5. Michelet P, The biodiversity of continental aquatic environments in mainland France: current situation and threats. Annals of Mines - Responsibility and environment. French. 2017;86(2):36-36. DOI:10.3917/re1.086.0036
6. Atangana JAK, Africa's continental aquatic ecosystems and their contribution to improving food security and nutrition. Nature & Wildlife. 2019;32(2):89-93. French.
7. Shantibala T, Lokeshwari RK, Debaraj H, Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. Journal of Insect Science. 2014;14(1):14. DOI: 10.1093/jis/14.1.14.
8. Mishra N, Hazarika NC, Narain K, Mahanta J, Nutritive value of non-mulberry and mulberry silkworm pupae and consumption pattern in Assam, India. Nutrition Research. 2003;23:1303-1311.
9. Badanaro F, Bilabina I, Awaga KL, Sanbena Banibea B, Amevoin K, Amouzou K, Identification and nutritional composition of some species of Orthoptera consumed in Togo. CAMES magazine. French. 2015;3(1):10-16.
10. Association Française de Normalisation (AFNOR). Animal foods. French and community analysis methods: Collection of french standards. Paris, French; 1985..
11. Association of Official Analytical Chemists (AOAC), Official methods of Analysis, 16th edition, Washington DC; 1995.
12. Pauwels JM, Van Ranst E, Verloo M, Mvondo ZA, Pedology Laboratory Manual. Plant soil analysis methods, equipment, inventory management of glassware and chemicals. Agricultural Publications – 28, Brussels. French; 1992.

13. Vincent A, Grande F, Compaoré E, Amponsah Annor G, Addy PA, Aburime LC et al., FAO/INFOODS food composition table for West Africa. User guide and condensed food composition table. FAO. Rome. English; 2020.
14. American Oil Chemists' Society (AOCS), Official methods and recommended practices of the American Oil Chemists' Society, 5th edition. Firestone;1998.
15. WHO/FAO/UNU, Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, WHO Technical Report, Series, No. 724, Geneva; 1983.
16. Association of Official Analytical Chemists (AOAC), Official methods of analysis, 15th edition, Washington DC; 1990.
17. Badanaro F, Edible insects in Togo: Ethnoentomology and nutritional potential. University of Lomé. French ; 2015.
18. Zhi Yi L, Insects as traditional foods in China. In Paoletti MG (ed), Ecological implications of minilivestock (Potential of Insects, Rodents, Frogs and Snails), New Hampshire: Science Publishers Inc. Enfield; 2005.
19. Ramos-Elorduy J, Moreno JMP, Camacho VHM, Edible aquatic coleoptera of the world with an emphasis on Mexico. Journal of Ethnobiology and Ethnomedicine, 2009;5:11.
DOI:10.1186/1746-4269-5-11.
20. Food and Agriculture Organization (FAO), Contribution of forest insects to food security: The example of caterpillars from Central Africa. Non-Timber Forest Products Program, Knowledge Synthesis. FAO. Rome. French;2004.
21. Johnson DV, The contribution of edible insects to human nutrition and to forest management. In: Durst PB, Johnson DV, Leslie RN, Shono K (Eds), Forest insects as food: humans bite back. Proceedings of a workshop on Asia-Pacific resources and their potential for food development, Bangkok; 2010.
22. Ralantoarinaivo VR, Entomophagy in the humid and subhumid ecoregions of Madagascar: inventory of edible insects and exploratory study of practices and habits. Master memory. University of Antananarivo French; 2020..
23. Ramos-Elorduy J, Energy supplied by edible insects from Mexico and their nutritional and ecological Importance. Ecology of Food and Nutrition. 2008;47, 280–297.
24. Hoffmann WE, Insects as human food. Proceedings of the Entomological Society of Washington.1947;49(9):233-237.
25. Bizé V, Insects in oral tradition. Insects. French. 2001;120(1): 9-12.
26. Motte-florac E, Thomas MCM J, Insects in oral tradition. Editions Peeters, Paris. French; 2003..
27. Chakravorty J, Ghosh S, Meyer-Rochow VB, Practices of entomophagy and entomotherapy by members of the Nyishi and Galo tribes, two ethnic groups of the state of Arunachal Pradesh (North-East India). Journal of Ethnobiology and Ethnomedicine. 2011;7:5.
DOI: https://doi.org/10.1186/1746-4269-7-5
28. Finke DM, Complete nutrient content of four species of feeder insects. Zoo Biology. 2012;32(1):1-120.
DOI: https://doi.org/10.1002/zoo.21012
29. Kemi VE, Kärkkäinen MUM, LambergAllardt CJE, High phosphorus intake acutely and negatively affect calcium and bone metabolism in a dose-dependent manner. In Practical Pharmacognocy (19th edn), Khandewal KR (ed). Nirali Prakashan: Pune; 2006.
30. He FJ, Macgregor GA, Beneficial effects of potassium on human health. Physiol Plant. 2008;133(4):725-735.
31. Gayet B, Cazel AR, The keys to nutritherapy: Summary of orthomolecular nutrition. Paris. French; 2002.
32. Chaney SG, Principles of Nutrition II: Micronutrients. In: Devlin, TM (Ed.). Textbook of Biochemistry with Clinical Correlate, New York: John Wiley and Sons; 2006.
33. Roussel AM, Favier-Hininger I, Essential trace elements in human nutrition: chromium, selenium, zinc and iron. EMC (Elsevier Masson SAS), Endocrinology-Nutrition, 10-359-B-10. Paris. French; 2009.
34. Mabossy-Mobouna G, Kinkela T, Lenga A, Nutrient contributions of Imbrasia truncata caterpillars consumed in Congo-Brazzaville. Journal of Animal and Plant Sciences. French. 2017;31(3):5050-5062.
DOI: /http://www.m.elewa.org/JAPS
35. Martin A, The recommended nutritional intakes (ANC) for the French population, Reproduction Nutrition Development. French. 2001;41,119-128.

36. Downs SM, Thow AM, Leeder SR, The effectiveness of policies for reducing dietary trans fat: A systematic review of the evidence. Bulletin of the World Health Organization. 2013;91: 262-269.
37. Agence française de sécurité sanitaire des aliments (Afssa), Omega-3 fatty acids and the cardiovascular system: nutritional value and claims, Report. 2003;
Accessed on April 8th, 2023. French.
DOI:https://www.anses.fr/en/system/files/NUT-Ra-omega3.pdf
38. Tarrago-Trani MT, Phillipis KM, Lemar LE, Holden JM, New and existing oils and fats used in products with reduced trans-fatty acid content. Journal of the American Dietetic Association. 2006;106: 867-880.
39. Dallongéville J, Gruson E, Dauchet L, Dietary fatty acids and cardiovascular risk. Dietetic Nutrition Workbook. French. 2008;43:152-157.
40. Harris WS, The omega-6/omega-3 ratio and cardiovascular disease risk: uses and abuses. Current Atherosclersis Reports. 2006;8:453-459.
41. Vancassel S, Aïd S, Pifferi F, Morice E, Chalon S, Lavialle M. Cerebral asymmetry and behavioral lateralization in rats chronically lacking n-3 polyunsaturated fatty acids. Biological Psychiatry. 2005;58: 805-811.
42. Rumpold BA, Schlüter OK, Nutritional composition and safety aspects of edible insects. Molecular Nutrition Food Research. 2013;57:802–23.
43. Kouřimská L, Adámková A, Complete nutrient content of four species of feeder insects. Nutrition and Food Journal. 2016; 4:22-26.
44. Van Huis A, Rumpold B, Maya C, Roos N. Nutritional qualities and enhancement of edible insects. Annual Review of Nutrition. 2021;41:551-576.
45. Selenius O, Korpela J, Salminen S, Gallego CG, Effect of chitin and chitooligosaccharide on *in vitro* growth of *Lactobacillus rhamnosus* GG and *Escherichia coli* TG Otto. Applied Food Biotechnology. 2008; 5(3):163-172.
46. Park Y, Subar AF, Hollenbeck A, Schatzkin A, Dietary fiber intake and mortality in the NIH-AARP Diet and Health Study, Archives of Internal Medicine. 2011; 171(12):1061-1068.
47. Schabel HG, Forests insects as food: a global review. In: Durst PB, Johnson DV, Leslie RN, Shono K (Eds.), Forest insects as food: Humans bite back. Proceedings of a workshop on Asia-Pacific resources and their potential for food development, Bangkok: Food and Agriculture
Organization of the United Nations Publications; 2010.
48. Mann J, Cummings JH, Englyst HN, Key T, Liu S, Ricardi G et al., FAO/WHO Scientific Update on carbohydrates in human nutrition: conclusions, European Journal of Clinical Nutrition. 2007;61(1):132-137.

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