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Aquatic insects consumed in Togo: Diversity and nutritional potential

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 groups said they occasionally consumed adult dytics. Four species 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.

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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 [2,47,48]. 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 [3].

24 These ecosystems are home to bacteria, plants and animals like fish, mammals, birds,
 25 insects, reptiles and amphibians. Because of this immense biodiversity, riverside populations
 26 have maintained close relationships with these aquatic ecosystems for millennia. Indeed,
 27 continental aquatic ecosystems provide a means of subsistence for a multitude of people in
 28 developing countries [4]. Populations living near these ecosystems harvest fishery products
 29 for food, medicine and other uses [5] or trade them for income or barter. Despite the
 30 ecological interest and socio-economic, therapeutic and nutritional values of these
 31 continental aquatic ecosystems, their biological species have remained neglected. Indeed,
 32 different species of fauna in continental aquatic ecosystems, like insects, are consumed by
 33 aboriginepopulations without any studies being carried out on their diversity, socio-economic
 34 importance and nutritional value [5]. In view of their importance, aquatic insects can
 35 supplement the dietary needs of populations living near these ecosystems, help to treat or
 36 prevent the development of a wide range of diseases associated with malnutrition and others
 37 illnesses [6], hence the need to value them. The aim of the present study is to promote the
 38 consumption of aquatic insects for food security in Togo. To this end, the species of aquatic
 39 insects consumed in Togo were identified, and the chemical composition of the most
 40 common species in the study environment (*C. tripunctatus*) were determined in order to
 41 assess its nutritional value.

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43 2. MATERIAL AND METHODS

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45 2.1 Ethnoentomological surveys

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47 Ethnoentomological surveys were carried out throughout Togo in two phases. An
 48 ethnoentomological prospecting and pre-survey phase was carried out between September
 49 8 and December 16, 2012. Data were collected at sites selected based on stratified
 50 sampling. Two levels of stratification were used to select the sites: ecological zone and
 51 ethnic group [7].The number of ethnic groups surveyed by ecological zone are shown in
 52 table 1.

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54 **Table 1: List of ethnic groups surveyed by ecological zone**

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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

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57 In total, 30 of the country's majority ethnic groups were surveyed in the 5 ecological zone of
 58 Togo. For each ethnic group, two localities were selected. Five households were selected
 59 per locality giving a total of 350 pre-surveyed households. The pre-survey information was
 60 gathered through interviews focusing on the ecology and traditional uses (food, economic
 61 and medicinal) of consumed aquatic insects. Semi-structured interviews were conducted to
 62 gather pre-survey information on the indigenous knowledge of aboriginal populations
 63 regarding aquatic insects consumed. These data enabled us to identify the Moba ethnic
 64 group in ecological zone 1 as consumers of aquatic insects in Togo. Ethnoentomological
 65 surveys on the consumption of aquatic insects were carried out between December 14 and
 66 18, 2022 among the Moba ethnic group. The groups of individuals surveyed (regardless of
 67 religion or level of education) were men, women and children. The information collected from
 68 the subjects concerned the species of aquatic insects consumed in the area visited, the

69 vernacular name of the species, their period of availability in the year, the quantities
70 harvested, the stages harvested, their marketing, cooking methods, and therapeutic virtues,
71 followed by a brief description of aquatic insects consumed. The ethnoentomological
72 surveys covered 120 people spread evenly over 3 localities. This preliminary information
73 was essential for guiding further fieldwork on the capture of dytic species and their
74 identification in the laboratory.

76 2.2 Sampling and conditioning of dytics

78 Once the results of the surveys had been tabulated, guides identified as being familiar with
79 the species consumed in the environments surveyed helped with the actual field
80 identification of the species consumed. Dytics were fished using trousseau nets. The
81 collected samples were sent to the Laboratory of Entomology at the University of Lomé,
82 where they were identified to the specific level using determination keys. Specimens of these
83 species were captured in three localities in Togo where the ethnoentomological surveys took
84 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
85 Bogou (10°39'28.8"N ; 0°1'31.6"E). Biochemical analyses focused on the *C. tripunctatus*
86 species, the most common species in the study environment, as it was found at all sampling
87 sites. For the chemical analyses, *C. tripunctatus* adults were fished using trousseau nets in
88 these same localities at the same period. They were placed in an icebox with a cold
89 accumulator containing ice cubes to kill them [7] and then brought to the Laboratory of
90 Biochemistry at the University of Lomé.

92 2.3 Biochemical assays

94 -The SCALTEC electronic moisture analyzer (SM01 Instrument GmH) was used to
95 determine the moisture contents of the samples [7].

97 -Fresh *C. tripunctatus* samples were oven-dried at 40° C for 7 days, then ground to powder
98 for the various assays [7].

99 - Fiber content was determined using the Weende method [8].

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

104 -Ashes (mineral substances), lipids and proteins compositions were determined according to
105 AOAC methods [9].

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

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

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

111 -Minerals were analyzed by atomic absorption spectrophotometry and colorimetry.

112 *Phosphorus content was determined colorimetrically using the phosphovanado molybdate
113 method [10].

114 *Other minerals were analyzed by atomic absorption spectrophotometry [10].

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

118 - The percentage of carbohydrates was calculated by difference between the percentages of
119 other total constituents according to the following formula [11]:

121 Carbohydrates=100-(Moisture+Proteins+Lipids+Ashes+Fibers)

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123 - The metabolizable energy (E) values of the samples were calculated from the protein, lipid,
124 carbohydrate and fiber values by applying the energy conversion factors via the formula [11]:

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$$E = 17 \times \text{Proteins} + 37 \times \text{Lipids} + 17 \times \text{Carbohydrates} + 8 \times \text{Fibers}$$

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128 - Lipid fatty acid composition was obtained by gas chromatography and the calculated
129 Omega6/Omega3 ratio.
130 The fatty acid composition of lipids was obtained by separating their methyl esters using a
131 gas chromatograph (HP 6890 series GC System). Beforehand, the fatty acids are converted
132 into methyl esters by transesterification of the raw lipids using a methanolic solution of boron
133 trifluoride [12]. The omega 6 found in the lipids of the species studied is linoleic acid and the
134 omega 3 is α -linolenic acid. The Omega6/Omega3 fatty acid ratio was calculated from the
135 Omega6 and Omega3 in the lipids of the insect studied.

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137 -Protein amino acid composition was obtained by separating using the Biochrom 30+ amino
138 acid analyzer and Amino acid ratio was calculated using the reference source
139 WHO/FAO/UNO [13].

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

142 *Amino acid ratio was calculated using the reference source WHO/FAO/UNO [13].

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

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

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

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151 - Vitamins were assayed according to AOAC methods [14].

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

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156 **2.4 Statistical analysis**

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158 The raw results from the ethnoentomological surveys were used to calculate the mean
159 frequencies of aquatic insects reported as consumed in different localities of the Moba ethnic
160 group [7] using Excel software. With regard to the chemical analyses, all tests were carried
161 out in triplicate. The mean values of the components were calculated on the basis of the
162 three replicates. They were assigned their standard deviations (SD).

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164 **3. RESULTS**

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166 **3.1 Diversity of aquatic insects consumed in Togo**

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

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172 **Table 2. Taxonomy of consumed dytic species**

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

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3.2 Dytic consumption frequencies by the Moba ethnic group

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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).

Table 3. Dytic consumption frequencies by the Moba ethnic group

Locations surveyed	Dytic consumption frequencies (%)	183
Lotogou	32.5	184
Nanergou	42.5	185
Bogou	37.5	186
Total	37.5	187
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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%).

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

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3.4 Chemical composition of *C. tripunctatus*

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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± 0.46g proteins, 26.98± 1.62 g lipids, 12.60 ± 0.14g fibers, 4.94 ± 1.46g carbohydrates, and 8.62±0.33g ashes (**table 5**). It is a high-energy food, with calorific values of 1804.19 ± 33.25kJ/100g.

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	216
Ashes	8.62 ± 0.33	217
Proteins	36.52 ± 0.46	218
Lipids	26.98 ± 1,62	219
Fibers	12.60 ± 0.14	220
Carbohydrates	4.94 ± 1.46	221
Energy	1804.19 ± 33.25	222
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3.4.2 Mineral composition

The mineral composition of *C. tripunctatus* is rich in macronutrients like calcium (82.88 ± 0.46mg/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 ± 0.00mg/100g), zinc (6.07 ± 0.00mg/100g) and manganese (3.64 mg/100g) (**table 6**).

231 **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

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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.

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

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3.4.3 Amino acid composition

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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.

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
Methionine	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

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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 [13].

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

Amino acids	Reference WHO/ FAO/ONU (1985)	Index values for <i>C. tripunctatus</i>
*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

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*Limiting amino acid

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3.4.4Lipid characteristics

262 **3.4.4.1 Fatty acid composition of *C. tripunctatus***

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

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

Fatty acids	Percentage(\pm SD)
Myristic acid (C14:0)	1.09 \pm 0.00
Isopalmitic acid (C16:0)	36.61 \pm 0.01
Stearic acid(C18:0)	7.17 \pm 0.01
Oleic acid <i>cis</i> (C18 :1)	34.13 \pm 0.01
Elaidic acid <i>trans</i> (C18 :1)	2.77 \pm 0.01
Linoleic acid (C18 :2n 6)	6.54 \pm 0.00
Acide α -linolénique (C18:3)	1.63 \pm 0.02

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273 **3.4.4.2 Degree of lipid saturation**

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

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281 **Table 11. Lipid saturation (%) and Omega6/Omega3 ratio for *C. tripunctatus***

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

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284 **3.5.5 Vitamin composition**

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286 The specie studied has variable vitamin contents (table 12) per 100g: retinol ($0.04 \pm$
287 0.00 mg), thiamin (1.89 ± 0.01 mg), riboflavin (2.2 ± 0.01 mg), niacin (7.17 ± 0.06 mg) and
288 tocopherol (3.29 ± 0.16 mg).

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

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Vitamin	Average vitamin contents(\pm SD)
Retinol (A)	0.04 \pm 0.00
Thiamin (B ₁)	1.89 \pm 0.1
Riboflavin (B ₂)	2.2 \pm 0.1
Niacin (B ₃)	7.17 \pm 0.06

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4. DISCUSSION

3.1 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 [15], the number is small. Edible aquatic insects account for just 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 [16]. Seventy-eight (78) belonging to 22 genera and are consumed in 27 countries, mainly Mexico and Asia (China, Japan). The most widely consumed aquatic insect families in the world are the Dytiscidae and Hydrophilidae, which are the most diverse and largest in size [17]. 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 [18]. 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.

According to Johnson [19], 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 [20]. 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 [21].

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 [22]. Indeed, several authors [23, 24, 25] 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.

3.2 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 [5] on the same species (38.03%). However, these contents are all lower than the moisture contents of conventional meat products such as

344 beef, chicken, pork and fish, which have moisture contents in the 40-70% range [11]. The
345 low moisture content of *C. tripunctatus* raises the relative concentrations of other food
346 components. The ash from the incineration of *C. tripunctatus* has been used to quantify a
347 number of minerals (calcium, phosphates, sodium, potassium, iron, zinc) essential to the
348 organism and contained in the insect. The levels of the minerals obtained in during this work
349 confirm that this beetle provides the populations that consume it with a sufficient quantity of
350 minerals. The value of minerals content is relatively high for the beetle studied (8.62%), like
351 many edible insects. [21,26] Indeed, compared to the values reported for meat products [11],
352 insects are known to be rich sources of different macro and trace elements. Sodium and
353 potassium regulate the water content of the human body and help maintain the acid-base
354 balance. These two elements have been found in significant quantities in *C. tripunctatus*.
355 Considering the Na/K ratio, which is equal to 0.34 and therefore less than 1, we deduce that
356 consumption of *C. tripunctatus* would have a positive effect combating cardiovascular
357 disease [27,28]. Calcium and phosphorus are necessary for bone growth. Calcium
358 deficiency causes growth retardation, rickets in children, spasmophilia in adults and
359 osteoporosis in the elderly. As intestinal absorption of calcium is favorable when the Ca/P
360 ratio is balanced, as is the case for *C. tripunctatus*, the intake of these elements by *C.*
361 *tripunctatus* is beneficial. The Calcium/Magnesium ratio of *C. tripunctatus* is close to 2, which
362 favours significant calcium fixation in the organism [29]. Oligominerals like zinc, copper and
363 maganese have also been found in *C. tripunctatus*. Zinc is essential for cell growth and
364 wound healing. It enables the proper utilization of group B vitamins and vitamin A. Copper
365 promotes intestinal absorption of iron, is involved in the formation of red blood cells, plays a
366 role in energy production and contributes to the synthesis of many vital substances. It is also
367 necessary for hemoglobin formation and red blood cell maturation [30,31]. *C. tripunctatus*
368 consumed by the Moba ethnic group in Togo constitutes an important source of animal
369 protein (36.52%), a value higher than that obtained in India by Shantibala et al[5] in the
370 same species (22.64%). Comparison of this content with that of adults of other aquatic
371 insects consumed, or with fish or meat shows that *C. tripunctatus* consumed in Togo is
372 richer in protein than *Lethocerus indicus* (Lepelletier et Serville, 1825) (Hemiptera :
373 Belostomatidae) (22.08%), *Hydrophilus olivaceous* Fabricius, 1781 (Coleoptera :Dytiscidae)
374 (25.08%), beef (18.2%) and fish (18.3%) [5,11], however, *C. tripunctatus* is less protein-rich
375 than adults of other aquatic insects like *Laccotrephes maculatus* (Fabricius, 1775)
376 (Hemiptera : Nepidae) (66.5%) and *Crocothemis servila* (Drury, 1770) (Libellulidae)
377 (70.48%) that are also consumed [5]. Protein quality in food is determined by its essential
378 amino acid content. All essential amino acids are present in the protein portion of *C.*
379 *tripunctatus*. Comparison of the protein composition of this insect with the WHO/FAO/ONU
380 Reference [13] shows that the valine, leucine, isoleucine, tyrosine, histidine and
381 phenylalanine values obtained for this dytic exceed the reference recommendation,
382 however, in decreasing order, threonine, lysine, tryptophan, methionine and cystine are
383 limiting amino acids for *C. tripunctatus*. These results are in line with those of Mabossy-
384 Mobouna et al. [32], who noted low concentrations of tryptophan and sulfur amino acids
385 (methionine and cystine) in the caterpillar *Imbrasia truncata* Aurivillius, 1909 (*Lepidoptera* :
386 *Saturniidae*). A diet based on *C. tripunctatus* needs to be supplemented with foods rich in
387 these essential amino acids. The high protein content of *C. tripunctatus* is suggestive of its
388 potential in combating protein deficiency in developing countries. This insect can provide a
389 cheaper source of essential nutrients that is readily available and affordable to aborigines in
390 the localities where it is consumed.

391
392 The lipid content of *C. tripunctatus* is quite high. On a fresh insect mass basis, the lipid
393 content of *C. tripunctatus* (26.98%) is higher than the amount found in most conventional
394 foods like beef, chicken, egg and milk [11]. The lipid saturation values show that the species
395 studied contain saturated fatty acid levels of 50.95%. This is higher than recommended by
396 the French Food Safety Agency (AFSSA), which advises a maximum dietary intake of 33%

397 saturated fatty acids [33].Indeed, high levels of saturated fatty acids in the diet are
398 considered to be risk factors for cardiovascular disease. Saturated fatty acids are excellent
399 energy nutrients, but their consumption in high proportions can increase the risk of
400 cardiovascular disease and promote the formation of thrombosis, leading to cardiovascular
401 disease [34]. Monounsaturated fatty acids are also present in this species.These are oleic
402 acid (34.13%) and elaidic acid (2.77%), which is the trans isomer of oleic acid.The high oleic
403 acid content is a nutritional advantage, as lipids with high levels of unsaturated fatty acids
404 are good for human consumption. With the exception of elaidic acid (2.77%), which is trans-
405 configured, all the other fatty acids in the lipids of the insect studied are cis-configured.
406 Fortunately, the quantity found in this insect is low, as excessive consumption of trans fatty
407 acids is likely to have a negative impact on health, just like saturated fatty acids [35]. At very
408 high doses, these “trans” fatty acids, like saturated fatty acids, are capable of increasing
409 levels of LDL-cholesterol, or bad cholesterol, while lowering levels of HDL-cholesterol, or
410 good cholesterol [36]. The polyunsaturated fatty acids contained in these lipids are linoleic a
411 (6.54%) and α -linolenic (1.63%) acids. The level of polyunsaturated fatty acid unsaturation
412 observed in the insect studied is low (8.17%), since their content is less than 15% of fatty
413 acids [33]. Their presence in food is beneficial to health, as they have the potential to lower
414 LDL cholesterol levels in the blood [37].This species contains the two essential fatty acids
415 (linoleic acid and α -linolenic acid) that are the precursors of the two fatty acid families
416 Omega6 and Omega3.The species studied has an Omega6/Omega3 ratio of less than
417 5.This underlines the nutritional quality of this insect's oil, as such a ratio reduces the risk of
418 cardiovascular disease [38]. Linoleic and α -linolenic acids are essential to the functioning of
419 the human body. In fact, linoleic acid is involved in the formation of phospholipids in cell
420 membranes and molecules regulating cellular functions, reproductive functions and platelet
421 functions [35]. α -Linolenic acid plays specific roles in the development and physiology of the
422 retina, brain and nervous system [39]. Futhermore, as the species studied is rich in both
423 proteins and lipids, its energy value is very high. A comparison of the total energy supplied
424 by the insect studied with that of conventional foods in West Africa [11] shows that it is more
425 energetic than most of the conventional foods, notably tubers (manioc, yam), cereals (maize,
426 sorghum, rice), meats (beef, chicken) and legumes (beans, soya), whose the energy values
427 fall within the range of energy supplied by insects for the same food mass.

428
429 *C. tripunctatus* also contains appreciable quantities of all the vitamins required. It contains
430 appreciable quantities of retinol, thiamine, riboflavin, niacin and tocopherol making it a
431 species of good nutritional quality. The presence of vitamins in *C. tripunctatus* confirms the
432 conclusion of several authors [40,41,42] that insects are an important source of vitamins.
433 These vitamins have several functions in the body. Vitamins A and E are antioxidants, while
434 the B vitamins are co-enzymes [33].

435
436 The fiber content of the species studied is high compared to conventional meat products
437 [11]. This species can therefore contribute to better digestion for people of all ages. Indeed,
438 fiber in the diet can improve intestinal health [43]. In addition, fiber has a positive effect on
439 accelerating satiety, thus limiting the risk of overeating. This helps prevent obesity [44]. On
440 the other hand, insects are not a great source of carbohydrates according to several authors
441 [15,18,45]. The content obtained in this study for the species studied is also low, confirming
442 the findings of these authors. Carbohydrates represent the primary source of energy
443 available to the human organism [46]. However, an excess of carbohydrates contributes to a
444 number of adverse effects on the body, including obesity. As insects are low in
445 carbohydrates and high in fiber, their consumption is beneficial in avoiding obesity, a risk
446 factor for a number of pathologies, notably cardiovascular disease and diabetes.

447
448

449 5. CONCLUSION

450

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

464

465

466 Disclaimer (Artificial intelligence)

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

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