

Nutritional potential of the caterpillar *Imbrasia obscura* (Butler, 1878) consumed in the Kara region of Togo

ABSTRACT

Lepidopteran larvae, which constitute unconventional food resources in many parts of the world, are consumed by aboriginal populations in Togo without any study being carried out on their nutritional value. The aim of this study was to assess the nutritional composition of the caterpillar *Imbrasia obscura* (Butler, 1878) consumed by populations in the Kara Region of Togo. To this end, 9 *I. obscura* samples were taken from three localities in this region. Ash, protein, vitamin and lipid contents were determined using AOAC (Association of Official Analytical Chemists) methods, and fiber content using the AFNOR (Association française de normalisation) method. Minerals were analyzed spectrophotometrically and colorimetrically. Fatty acid composition was determined by chromatography. This caterpillar is made up of $10.41 \pm 0.33\%$ moisture, $53.36 \pm 0.05\%$ protein, $14.22 \pm 0.62\%$ lipids, $10.67 \pm 0.62\%$ fiber and $1.04 \pm 0.54\%$ carbohydrates. Lipids contain monounsaturated (oleic ($30.57 \pm 0.03\%$) and elaidic ($0.46 \pm 0.02\%$) acids) and polyunsaturated fatty acids (linoleic ($4.82 \pm 0.02\%$), α -linolenic ($1.872 \pm 0.02\%$), γ -linolenic ($1.57 \pm 0.01\%$) and arachidonic ($2.33 \pm 0.01\%$) acids). With regard to micronutrient composition, the average mineral content is 10.3%, and varies according to the nature of each mineral. *I. obscura* also contains variable levels of fat-soluble vitamins (retinol: 0.02 ± 0.01 mg/100g and tocopherol 4.10 ± 0.07 mg/100g) and water-soluble vitamins (thiamine: 1.35 ± 0.16 mg/100g, riboflavin: 2.12 ± 0.11 mg/100g and niacin: 4.10 ± 0.07 mg/100g). These data show the quantitative and qualitative richness of *I. obscura* in nutrients. This species could therefore contribute to the nutritional balance of consumers, and deserves to be given greater prominence on our plates.

Keywords: caterpillar, *Imbrasia obscura*, nutritional value, Kara region, Togo.

1. INTRODUCTION

Forests and trees outside forests, with free access to resources, attract aboriginal populations [1]. According to FAO [2], 60 million aboriginal peoples are almost entirely dependent on forests, and over 1.6 billion people worldwide depend to varying degrees on forests for their livelihoods. Household dependence on forest resources can be direct, through the harvesting of food and medicinal products, materials used for handicrafts and cultural ceremonies, as well as fuelwood or timber [3]. It can also be indirect through the marketing of these products in order to obtain financial means for subsistence or even social fulfillment [4]. In developing countries, household dependence on forest resources has increased as a result of poverty and food insecurity [5]. Moreover, the outlook for the world's population is for continued growth over the coming decades, especially in developing countries, where almost all of this increase will occur [6]. Adding value to forest products, which have been exploited since time immemorial, is therefore essential for the survival of these ever-growing populations. Several studies have been carried out in this direction [7, 8, 9]. According to this work, forests offer interesting potential in terms of non-timber forest products (NTFPs) harvested to ensure the food and economic security of dependent

populations. Insects in particular are envisaged as a possible alternative or complementary food to conventional meat in order to mitigate the environmental impact of conventional livestock farming [10, 11]. However, to date, the nutritional value of many consumed insect species remains unknown. This knowledge is needed to enhance the value of edible insects and improve the living conditions of dependent populations. In Togo, very little work has been done on the nutritional value of this fauna. Ethnic communities (Kabyè and Nawdba) in the Kara region of Togo consume and appreciate the caterpillar *Imbrasia obscura* (Butler, 1878) (Lepidoptera: Saturniidae), but no studies have been carried out on its nutritional composition. This is justified by the lack of scientific knowledge of the latter. The aim of this study was to assess the nutritional potential of the *I. obscura* consumed by populations in the Kara region of Togo, with a view to improving its value.

2. MATERIAL AND METHODS

2.1 Biological material studied and harvesting method

The biological material used in this study was the *I. obscura* caterpillar. It is consumed by the Kabyè and Nawdba ethnic groups in the Kara region of Togo. It is known by the following vernacular names: Kpankpatoulé (Kabyè) and Kpakpaï (Nawdba). The caterpillar's host plant is *Parkia biglobosa* (Fabaceae) (figure 1).



Figure 1: Image of *I. obscura* caterpillars on *P. biglobosa* leaves in Kpenzindé

Nine samples of about ten live caterpillars per sampling were collected under the host plant in August 2021 in the three localities namely Kpenzindé, Kémériada and Siou (figure 2) in the Kara region (three sample sites per locality) where it is widely consumed.

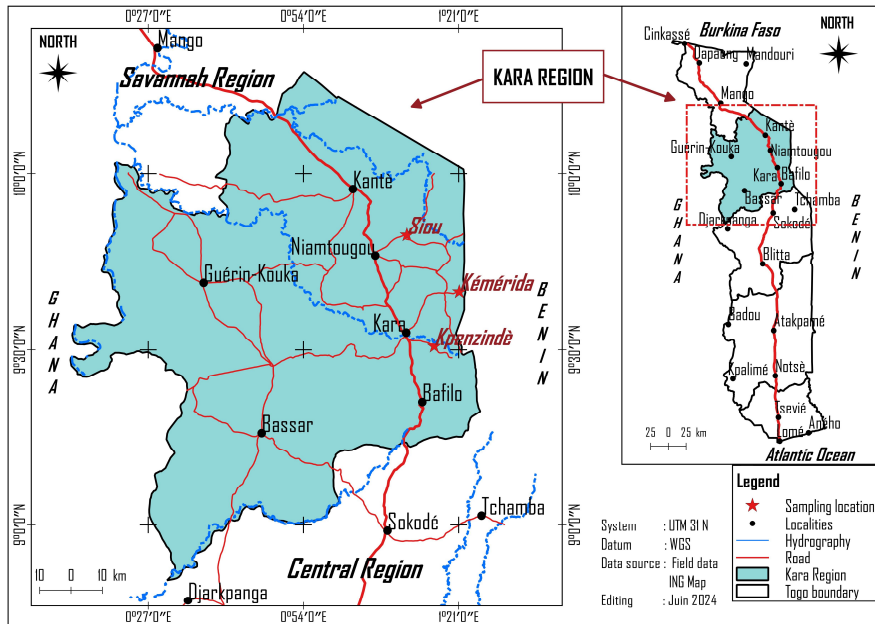


Figure 2: Sample collection locations

Samples were preserved in 70° alcohol and transported to the Applied Entomology Laboratory in the University of Lomé for identification using determination keys. Caterpillars for chemical analysis were collected at each site during the same period. These live-captured insects were cold-killed and preserved by placing them in an icebox [12]. They were then transported to the Laboratory of Biochemistry Applied to Nutrition at the University of Lomé.

2.2 Chemical analysis

2.2.1 Determining moisture content

It was performed on fresh *I. obscura* caterpillar samples using the SCALTEC brand desiccator (SM01 Instrument GmbH, Germany) [12]. One gram of untreated wet insect sample is placed on a tared dish and introduced into an electronic moisture analyzer (automatic analysis) according to the manufacturer's recommendations. A beep signals the end of dehydration, and the moisture content is displayed as a percentage on the instrument's screen.

2.2.2 Processing samples in the laboratory

Five grams of fresh caterpillars from each sample site were weighed and mixed to obtain an average sample. The average samples from each locality were placed in an ISUZU type AS vacuum oven at 40° C for 7 days for dry. The dried caterpillars were ground in a General Electric Interlabs Moulinex. The ground samples were then sieved through a 1 mm mesh Fischer Scientific stainless-steel sieve for the different assays. Samples were analyzed in 2021 and 2022.

2.2.3 Determination of proximate composition and energy

Total fiber content was determined using the Weende method [13]. 200ml of 12.5g/l sulfuric acid was introduced in an Erlenmeyer flask containing 3g of sample. The resulting mixture was boiled for 30 minutes. The mixture was then filtered through a 500 µm Fischer Scientific stainless-steel sieve and rinsed 3 times with the same quantity of distilled water (200ml) while hot. The resulting insolubles were added to another Erlenmeyer flask containing 200ml of 12.5g/l sodium hydroxide. The new mixture was treated in the same way as before. The residues contained in the sieve were transferred to a crucible of known mass. The contents were dried in a SCALTEC desiccator (SM01 Instrument GmbH, Germany) at 150°C for one hour, weighed and then incinerated in a Nabertherm LE 14/11 muffle furnace at 550°C for 6 hours. After cooling in a desiccator, the crucible was weighed. The percentage of total fiber (F) in the sample was obtained using the following formula [13]:

$$F = \frac{\text{Mass of residue after drying} - \text{Mass of ash after incineration}}{\text{mass of test sample}} \times 100(1)$$

Ashes were obtained by incinerating the samples in a Nabertherm LE 14/1 muffle furnace at 550°C for 6 hours [14].

Total protein in caterpillar samples was estimated by determining total nitrogen using the Kjeldahl method [15]. Total protein content was then calculated by multiplying total nitrogen by the conversion factor 6.25 [16].

Lipids from caterpillar samples were extracted continuously in a Soxhlet after hexane action on ground caterpillar samples. Weighed *I. obscura* was introduced into a lipid-free white cartridge. These were then passed through a column of hexane to extract the lipids. Extraction lasted 10 hours per day and was repeated over three successive days. The device was adjusted to obtain 5 siphonings per hour. The extract obtained at the end of the operation was filtered and transferred to a dry flask, then evaporated under vacuum at 35°C using a Buchi R114 rotavapor. The lipids obtained after evaporation were weighed. The total carbohydrate content of caterpillar samples was calculated by difference with the percentages of other total constituents according to the following formula [16]:

$$\text{Carbohydrate} = 100 - (\text{Moisture} + \text{Protein} + \text{Fat} + \text{Ash} + \text{Fiber})(2)$$

The energy value of 100 grams of samples was determined by multiplying the percentage content of each of the macronutrients measured by its energy value, i.e. 17 kJ.g⁻¹, 38 kJ.g⁻¹, 17 kJ.g⁻¹ and 8 kJ.g⁻¹ for proteins, lipids, carbohydrates and fibers respectively, then summing [16]:

$$EM = 17 \times \text{Protein} + 37 \times \text{Fat} + 17 \times \text{Carbohydrate} + 8 \times \text{Fiber}(3)$$

2.2.4 Mineral analysis

The mineral profile was determined by solubilizing the crushed material by acid etching using two concentrated solutions (nitric acid and hydrogen peroxide). The product obtained after solubilization was assayed for calcium, magnesium, sodium, potassium, iron, copper and manganese, using a flame ionization spectrophotometer, model AA Solaar (Thermo Electron Corporation), according to the wavelength of each mineral. Phosphorus content was determined using the phosphovanado molybdate method, and absorbance was assessed using a colorimeter (Jenway model 6300) [17].

2.2.5 Vitamin analysis

The determination of vitamins in the samples was carried out according to the methods described by AOAC [14]. The principles of these methods are based on the staining

of vitamin molecules. The absorbance of colored solutions was measured using a colorimeter (Jenway model 6300).

For retinol, one gram of sample was introduced in a 250 ml flask. After the addition of 5 ml of pyrogallol solution, 35 ml ethanol and 10 ml potassium hydroxide solution, the mixture was heated for 30 min at 70-80°C under a reflux condenser and then left to cool under a stream of water. After cooling, 40 ml distilled water and 100 ml petroleum ether were added. Extraction was performed by stirring for 3 min. The resulting product was then left to settle, and the upper phase transferred to a separating funnel. The ethereal phase was washed to neutrality with a triple fraction of 50 ml water and filtered through filter paper. A 5 ml sample of the ethereal phase was introduced in a 50 ml flask and made up with petroleum ether. The retinol concentration of this solution was determined by measuring its optical density at 325 nm.

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 min, with frequent stirring. Five milliliters of 2.5 N sodium acetate solution was added to the contents of the flask and left to cool. After cooling, the flask was capped and placed in a water bath at 45-50°C for 2 hours. The resulting product was made up to 100 ml with distilled water and filtered through filter paper. 10 ml of the filtrate was added to 5 ml of potassium chloride solution. Absorbance was measured on this solution at a wavelength of 285 nm.

For riboflavin, one gram of each sample was weighed into a 250 ml volumetric flask, 5 ml of 0.1 N sulfuric acid and 5 ml of dichloroethene were added, followed by 90 ml of distilled water. The mixture was stirred and heated on a sand bath for 30 min to extract all the riboflavin. The mixture was then cooled and made up to 250 ml with distilled water. It was then filtered through filter paper. A 2 ml volume of the filtrate obtained was introduced into another 250 ml volumetric flask and topped up with distilled water. By measuring the absorbance of the colored solution at 460 nm, the riboflavin concentration of the solution could be determined. For niacin, five grams of sample were extracted with 50 ml of distilled water. Extraction was performed by repeated stirring for 30 min. The product was then left to settle and the upper phase was recovered and filtered. This operation was repeated 3 times each time with the same quantity of distilled water (100 ml). Five milliliters of the mixed filtrates were introduced into a 100 ml volumetric flask and topped up with distilled water. The absorbance of the colored solution obtained, measured at a wavelength of 385 nm, was used to determine the nicotinic acid content of the sample.

For tocopherol, one gram of sample was weighed and placed in a 250 ml flat-bottomed flask. Solution of 10 ml ethanol and 20 ml of 1 N sulfuric acid were added. The flask was wrapped in aluminum foil and heated with reflux for 45 min. The resulting solution was cooled for 5 min, followed by the addition of 50 ml distilled water and transferred to a separating funnel covered with aluminum foil. The unsaponifiable matter in the mixture was extracted 5 times with 50 ml 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 ethanol, 1 ml concentrated sulfuric acid and 1 ml concentrated nitric acid. The resulting product was placed in a water bath at 90°C for 30 min. After cooling, the tocopherol content of the extract was measured by ultraviolet absorption at 470 nm.

2.2.6 Lipid analysis

The fatty acid composition of the caterpillar lipids studied was obtained by separating the methyl esters from the lipids using gas chromatography. The transformation of fatty acids into methyl esters by transesterification of the crude lipids using a methanolic solution of

borontrifluoride (BF₃-Methanol) in accordance with AOCS [18] was the preparatory step for chromatographic analysis.

The methanolic trifluoride solution was prepared with 8% boron trifluoride reagent in methanol prior to the start of transesterification. For transesterification, 100mg of sample was introduced in a 10ml screw-tube. 1.5ml of hexane and 1.5 ml of methanolic boron trifluoride solution were added. The tube was sealed under nitrogen, shaken vigorously, then heated to 100°C for one hour. After cooling to room temperature, 1 ml hexane and 2 ml distilled water were added and the mixture stirred under nitrogen. Two phases were obtained at rest. The upper phase was recovered and put in another tube under nitrogen. The lower phase was extracted twice with hexane. The collected phases (methyl esters) were washed with distilled water, then dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo. Hexane was added to concentrate methyl esters suitable for gas chromatography analysis. An HP 6890 series GC System gas chromatograph was used for the analysis. The instrument is equipped with a flame ionization detector and an HP-5 (Crosslinked 5% ME Siloxane) capillary column (length 30 m; film thickness 0.25 µm; internal diameter 0.32 mm). The oven temperature is programmed to increase from -60 to +325°C at a rate of 1°C/min. The injector temperature is set at 275°C and the detector at 325°C. The inlet nitrogen pressure used as carrier gas varies from 6.90 to 47.6 kPa. The flow rate is maintained at 1 cm³/min and the dead time is 1 min 15 s (hydrogen 40 cm/sec). Representative methyl ester peaks were identified using reference substances (methyl esters) by comparing the retention times of each chromatogram peak with those obtained for the standards. The percentages of saturated and unsaturated fatty acids (monounsaturated and polyunsaturated) in caterpillar lipids were obtained by summing the contents of the fatty acids concerned.

2.3 Statistical analysis

All trials were repeated three times. Averages were calculated on the basis of the three repetitions. Standard deviations (SD) were considered.

3. RESULTS

3.1 Proximate composition of *I. obscura* compared with other protein foods

The results obtained in this study show that 100 g of fresh *I. obscura* caterpillars contain 10.41 ± 0.33 g of moisture, 53.36 ± 0.05g of protein, 14.22 ± 0.62g of lipids, 10.67 ± 0.62 g of fiber, 1.04 ± 0.54 g of carbohydrate and 10.3 ± 0.27g of ash and an energy value of 1478.54 ± 23.2 kJ/100g (table 1).

Table 1: Proximate composition (% of total weight) and energy content (kJ/100g) of *I. obscura* compared with other protein foods

Species or food	Moisture	Ash	Protein	Lipid	Fiber	Carbohydrate	Energy	Reference
<i>I. obscura</i>	10.41 ± 0.33	10.3 ± 0.27	53.36 ± 0.05	14.2 ± 0.62	10.6 ± 0.62	1.04 ± 0.54	1478.5 ± 23.2	
<i>C. forda</i>	10.06 ± 0.12	18.4 ± 1.25	51.43 ± 3.8	9.25 ± 1.59	8.42 ± 0.45	2.39 ± 1.2	1324.7 ± 21.50	[12]
Beef	71.4	1.0	21.7	4.3	0	0	978	[16]
Chicken	72.8	1.0	20.4	5.9	0	0	563	[16]
Fish	78.7	1.2	17.1	1.2	0	0	335	[16]

Goatmeat	74.6	1.1	17.5	10.6	0	0	689	[16]
Pork	48	1.1	16.8	22.0	0	0	1100	[16]
Soybean	7.9	3.9	34.7	15.9	9.4	28.3	1730	[16]
Beans	8.9	3.9	22.1	1.5	10.3	53.2	1420	[16]

3.2 Mineral composition of *I. obscura* compared with other protein foods

The mineral composition of the caterpillars studied shows that they are rich in macroelements like calcium (132.03 ± 0.37 mg/100g), magnesium (84.42 ± 2.40 mg/100g), phosphorus (112.02 ± 2.1 mg/100g), potassium (130.50 ± 2.1 mg/100g), sodium (26.96 ± 0.14 mg/100g) and trace elements like iron (27.15 ± 0.61 mg/100g), copper (0.17 ± 0.03 mg/100g) and zinc (1.07 ± 0.61) (table 2).

Table 2: mineral composition (mg/100g) of *I. obscura* compared with other protein foods

Species or food	Ca	Mg	P	K	Na	Fe	Cu	Zn	Reference
<i>I. obscura</i>	132.03 ± 0.37	84.42 ± 2.40	112.02 ± 2.1	130.50 ± 0.63	26.96 ± 0.14	27.15 ± 0.61	0.17 ± 0.03	1.07 ± 0.61	
<i>C. forda</i>	206.19 ± 4.74	97.3 ± 0.66	233.09 ± 0.19	67.38 ± 0.22	35.03 ± 0.38	6.92 ± 0.12	3.55 ± 0.34	19.65 ± 0.16	[12]
Beef	5	22	170	327	50	2.1	0.09	3.6	[16]
Chicken	11	24	194	276	84	1.1	0.05	1.36	[16]
Fish	61	28	197	320	51	1.2	0.06	0.64	[16]
Goatmeat	11	27	150	385	82	2.4	0.16	3.45	[16]
Pork	10	20	170	301	47	1.4	0.10	3.6	[16]
Soybean	206	249	536	1770	5	6.5	1.5	4.8	[16]
Beans	50	185	309	1370	28	3.3	0.82	2.39	[16]

3.3 Vitamin composition of *I. obscura* compared with other protein foods

The insect species studied have variable vitamin contents (100g of sample dry weight)(table 3): vitamin A (0.02 ± 0.01 mg), vitamin B₁ (1.35 ± 0.16 mg), vitamin B₂ (2.12 ± 0.11 mg), vitamin B₃ (8.32 ± 0.15 mg) and vitamin E (4.10 ± 0.07 mg).

Table 3: Average vitamin content (mg/100g dry weight) of *I. obscura* compared with other protein foods

Species or food	Retinol (A)	Thiamine (B ₁)	Riboflavin (B ₂)	Niacin (B ₃)	Tocopherol (E)	References
<i>I. obscura</i>	0.02 \pm 0	1.35 \pm 0.16	2.12 \pm 0.11	8.32 \pm 0.15	4.10 \pm 0.07	
<i>C. forda</i>	0.02 \pm 0	1.33 \pm 0.02	2.56 \pm 0.01	7.64 \pm 0.15	4.55 \pm 0.05	[27]
Beef	0	0.06	0.19	6.2	0.35	[16]
Chicken	17	0.09	0.16	7.0	0.26	[16]
Fish	2	0.06	0.19	6.2	0.23	[16]
Goatmeat	0	0.18	0.29	6.1	0.18	[16]
Pork	0	0.72	0.22	3.8	0.1	[16]
Soybean	0	0.72	0.28	2	0.68	[16]
Beans	0	0.39	0.12	1.9	0	[16]

3.4 Lipid characteristics of *I. obscura*

The results of the chemical screening carried out on the lipids are shown in Table 4. The lipids of this species contain saturated fatty acids like palmitic acid ($25.51 \pm 23.2\%$) and stearic acid ($32.37 \pm 0.06\%$). Lipid saturation values show that the species studied contains saturated fatty acids at $58.88 \pm 0.01\%$ (table 4). Monounsaturated fatty acids are also present in this species. These are oleic acid ($30.57 \pm 0.03\%$) and elaidic acid ($0.46 \pm 0.02\%$), the trans isomer of oleic acid. The polyunsaturated fatty acids contained in the lipids of this caterpillar are linoleic acid ($4.82 \pm 0.02\%$), α -linolenic acid ($1.87 \pm 0.02\%$), γ -linolenic acid ($1.57 \pm 0.01\%$) and arachidonic acid ($2.33 \pm 0.01\%$). The percentage of polyunsaturated fatty acids observed in the insect studied was $10.60 \pm 0.02\%$.

Table 4: Average fatty acid composition (%) of *I. obscura*

Fatty acids	Percentage
Palmitic acid (C16:0)	25.51 ± 0.04
Stearic acid (C18:0)	32.37 ± 0.06
Total saturated fatty acids	58.88 ± 0.01
Oleic acid cis (C18 : n-9)	30.57 ± 0.03
Elaidic acid trans (18 : n-9)	0.46 ± 0.02
Total monounsaturated fatty acids	31.03 ± 0.02
Linoleic acid (C18:2n-12)	4.82 ± 0.02
α -Linolenic acid (C18:2n-6)	1.87 ± 0.02
γ - Linolenic acid (C18:2n-12)	1.57 ± 0.01
Arachidonic acid (C20:4n-24)	2.33 ± 0.01
Total unsaturated fatty acids	10.60 ± 0.02
Omega6/Omega3	4.66

4. DISCUSSION

The water content of the *I. obscura* ($10.41 \pm 0.33\%$) is higher than that of the caterpillar *Imbrasia oyemensis* (Rougeot, 1955) (Lepidoptera: Saturniidae) which is $4.60 \pm 0.58\%$ [19] but similar to that of the caterpillar *Cirina forda* (Westwood, 1849) (Lepidoptera: Saturniidae) which ranges from $10.06 \pm 0.12\%$ [12] and $10.85 \pm 0.38\%$ [20], and that of legume seeds such as beans (10.5%) and soybeans (9.3%) [16]. It is low compared to conventional meat products commonly consumed in West Africa (beef :71.4%, chicken :73.8%, goat :74.6%, pork :48% and fish :78.7%) [16]. This low water content enables better physical preservation by simply drying the caterpillar, thus avoiding decomposition, and better conservation of most of the caterpillar's nutrients [21].

The results of this study show that the protein and lipid contents of this caterpillar are within the range of protein (14 and 68%) and lipid (5 and 49.5%) contents generally found in edible Lepidoptera [21] on a fresh mass basis. Comparing the results of this investigation with those obtained by Badanaro et al [12] on *C. forda* also consumed in Togo, *I. obscura* was found to be richer in protein ($53.36 \pm 0.05\%$ vs $51.43 \pm 3.8\%$) and lipids ($14.22 \pm 0.62\%$ vs $9.25 \pm 0.62\%$) than *C. forda* (table 1). It was also richer in protein than beef (17.5%), chicken (17.6%), goat (19.2%), pork (12.5%), fish (16.5%), bean (21.3%) and soybean (31.3%) [16]. Protein levels (72%) obtained for the same caterpillar in Central Africa exceed those obtained in this study [21]. This shows that *I. obscura* caterpillars rank among the most protein-rich foods. Generally speaking, most caterpillars consumed have a high protein content (14 and 68%) [22]. For this reason, the FAO [23] promotes their incorporation into low-protein flours to combat infant malnutrition.

The energy value per 100 g of *I. obscura* is high (1478.54 ± 23.2 kJ). This high calorific value could be explained by its richness in energy components (proteins, carbohydrates, lipids and fibers). This value was higher than that of *C. forda*. Consumption of *I. obscura* could therefore reduce the effects of energy deficiencies in consumer populations. Compared to conventional meat products such as beef, chicken, goat, pork and fish, which do not contain dietary fiber [16], *I. obscura* studied and *C. forda* [12] showed appreciable amounts of fiber (table 1). This caterpillar could therefore contribute to better dietary digestion for people of all ages. Indeed, a lack of fiber in the diet can lead to gastric and intestinal disorders. Moreover, fiber has a positive effect on accelerating satiety, thus limiting the risk of overeating. This helps prevent obesity [23].

The ash from the incineration of *I. obscura* was used to quantify the mineral content of this species, which was found to be high ($10.3 \pm 0.27\%$). This high mineral content suggests that this caterpillar provides the populations that consume them with sufficient quantities of minerals. The results obtained for calcium, magnesium, phosphorus, iron and copper during our work were similar to those obtained for *C. forda* [12, 21] and legumes (beans and soybeans), but higher than those for conventional meat products commonly consumed in West Africa [16], as shown in table 2. On the other hand, potassium levels were higher in meat products (beef ($327\text{mg}/100\text{g}$), chicken ($276\text{mg}/100\text{g}$), goat ($385\text{mg}/100\text{g}$), pork ($301\text{mg}/100\text{g}$) and fish ($320\text{mg}/100\text{g}$)) than in caterpillars (*I. obscura*: $130.50 \pm 0.63\text{mg}/100\text{g}$ and *C. forda*: $67.38 \pm 0.22\text{mg}/100\text{g}$) and legumes (soybeans: $1770\text{mg}/100\text{g}$ and beans: $1370\text{mg}/100\text{g}$). The presence of minerals in insects is advantageous, as they are known to be involved in numerous biological functions. Calcium, potassium and magnesium are involved in the regulation of blood pressure [25]. Zinc is essential for cellular metabolism. It plays an important role in cell renewal and protein synthesis [26].

All vitamin levels were higher in *I. obscura* (0.02 ± 0 mg/100g) than in conventional protein species. However, retinol levels in *I. obscura* were lower than those in chicken ($5\text{mg}/100\text{g}$) and fish (141 mg/100g) [16]. The same applies to vitamin levels in *C. forda* (0.02 ± 0 mg/100g) [27]. Retinol could be supplemented in an insect diet by other sources of micronutrients like orange and unrefined palm oil, generally known as sources of retinol [28]. Since vitamins are essential for the body to function properly, their presence in appreciable quantities in the caterpillars studied enhances their nutritional value.

Lipid saturation values show that the species studied contained $58.88 \pm 0.01\%$ saturated fatty acids. This is higher than recommended by the French Food Safety Agency (AFSSA), which recommends a maximum dietary intake of 33% saturated fatty acids [29]. 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 [30]. Monounsaturated fatty acids such as oleic and elaidic acids are also found in this species. With the exception of elaidic acid, 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 too high an intake of trans fatty acids is likely to have a negative impact on health, as saturated fatty acids [31]. This caterpillar's lipids also contained linoleic ($4.82 \pm 0.02\%$), α -linolenic ($1.87 \pm 0.02\%$), γ -linolenic ($1.57 \pm 0.01\%$) and arachidonic ($2.33 \pm 0.01\%$) acids, like polyunsaturated fatty acids. The level of polyunsaturated fatty acid unsaturation observed in the insect studied is low ($10.60 \pm 0.02\%$), since their content is less than 15% [29]. Their presence in food in high quantities is beneficial to health, as they have the potential to lower LDL (Low Density Lipoprotein) cholesterol levels in the blood [32]. However, this species contains the two essential fatty acids (linoleic acid and α -linolenic acid) that are the precursors of the two fatty acid families (Omega 6 and Omega 3). The species studied had an Omega 6/Omega 3 ratio of

less than 5, also attested by the work of Mabossy-Mobouna et al [21] on this caterpillar. This highlights the nutritional quality of this insect's oils, as such a ratio reduces the risk of cardiovascular disease [33]. There are, however, some notable limitations to this study. Because the analyses were not carried out on a site-by-site basis, we were unable to carry out comparative statistical tests to confirm the good nutritional qualities of this caterpillar, and to identify variations in the caterpillar's composition as a function of growing environment.

5. CONCLUSION

The aim of this study was to contribute to the development of a non-conventional food resource, the *I. obscura* caterpillar, by determining its nutritional qualities compared with other conventional protein foods. The results of this study show that this caterpillar is rich in macronutrients, micronutrients and essential fatty acids. These parameters provide ample evidence that integrating *I. obscura* in food recipes in Togo could significantly improve on the prevalence of malnutrition among local populations in general, and particularly among children and pregnant women in particular, who are the most vulnerable. It is important to consider appropriate management and conservation measures to ensure the sustainability of this resource. Proper management of this resource will involve regulating its exploitation, as well as protecting the *P. biglobosa* host tree, which is threatened by the manufacture of charcoal.

Data availability: All data are included in the document content.

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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