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Assessment of the nutritional value and the quality of the oil of *Macrotermes bellicosus* insect collected during rain season in Togo

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Abstract
This work involves the assessment of the nutritional value of the insect *M. bellicosus* and a survey on the importance of this insect in the diet of local populations. A study was conducted among people in Lomé using questionnaires for data collection. The proximate composition and minerals contents were determined on the dried and roasted insect. The results on the knowledge and the frequency of consumption of the insect showed that 95% of the respondents knew the insect and 57% consumed it. Among consumers, 10.37% rarely, 22.22% often and 7.41% very often consumed. It turned out that the dried and roasted insects contained a low moisture value while the lipid values were 50.37% of dry matter for dried insect. The proteins contents were respectively 44.14% for dry insect and 39.71% for roasted insect ($p < 0.05$). Chemical analysis (mg/100g) of the insect revealed the following values for roasted insect 43.78 ± 0.38 (Mg), 52.75 ± 0.03 (Fe), 84.22 ± 0.13 (Ca), 123.72 ± 0.70 (Na), 331.46 ± 0.41 (K), 344.07 ± 1.04 (P) and 38.86 ± 0.03 (Mn). The insect oil contained 2.94 mg KOH/g lipid for the acid index, 1.48 meq O_2/kg lipids for the peroxide index, 134.29 g I_2/g lipids for the iodine index, 10.37% of unsaponifiable matter, 200.60 mg KOH/g lipids for saponification value and 14.84 mg/100g lipid for total cholesterol. Thus, the insect contains not only proteins and fat, but also major minerals. The quality of its oil has shown that it can be used as a seasoning oil. The insect *M. bellicosus* could be transformed into products for human consumption because of its nutritional properties.

Keywords: insect, *Macrotermes bellicosus*, nutritional value, consumption, Togo

1. Introduction
In Africa, in spite of substantial efforts to increase foodstuffs, malnutrition persists and the food insecurity is the main problem of most housekeeping [1]. Although the causes of malnutrition are many and diverse, inadequate intake of foods and essential nutrients has been reported to be a major contributory factor to under-five malnutrition [2]. About 10.7% (815 million) of the world's population currently suffer from chronic undernourishment [3]. More than one thousand millions of young people and children suffer from the malnutrition in the world including 20 million of children of less than 5 years old are suffering from chronic malnutrition [4, 5]. In Togo, a study reported 14.3% of malnutrition rates for children aged less than 5 years [5]. This prompts the need for more balanced and environmentally friendly methods for producing nutritious foods. The use of insect as food is among the many approaches that have been thought to provide a long-lasting solution to this foreseen future deficit in animal protein supply. The adequacy of a diet is determined by the amount of nutrients it contains and provide to meet the needs dictated by an individual's physiological state and genetic make-up.
In Africa, entomophagy is a traditional and culturally acceptable way through which low-income persons supplement the meager protein content of their high carbohydrate diets. The interest in using insect as food has been expressed in several reports [6, 7, 8]. These insects are usually eaten as part of a meal or complete meal. Insect are traditional foods in most cultures, playing an important role in the history of human nutrition in Africa, Asia and Latin America [9]. They are an important resource for the native population, who like other indigenous groups, deploy much effort in their collection and utilisation as food. It is demonstrated that 100 g of insect could cover nutritional need in minerals, vitamins and it contains proteins 3 to 4 time higher than the one of chicken and pig [4]. In Africa tropical, insect represent a food source that is well appreciate by some population [10]. Some series of studies were performed for the evaluation of the nutritional value of insect and larvae [11, 12]. So, at the workshop in Douala (Cameroun) in 1992 on promotion of non-conventional food resources, it was recognised that the valorisation of insect and larvae represents the principal way to fight against proteins malnutrition [13], because edible insect have played a nutritional role in the diet of people in many parts of the world [14]. They are currently being promoted as an inexpensive alternative source of protein in underdeveloped countries due to the rising cost of conventional animal protein and the foreseen future deficit in its supply.
Insect constitute quality food and feed, have high feed conversion ratios, and emit low level of greenhouse gases [15]. In certain regions of Togo, the consumption of the insect it has become a traditional habit in some ethnic groups. The *M. bellicosus* insect have been well appreciated by people. Studies reported that the nutritional health can be enhanced by the consumption of novel source of food among including insect, mushrooms, snails and larvae [13, 16].

However, it is necessary to investigate the nutritional value of insect in order to make a scientific recommendation to encourage their consumption [11, 12]. Evaluation of the nutritive value of *M. bellicosus* insect becomes important as the insect larva could form a base for new food products. This work was performed to investigate the nutritional value of *M. bellicosus* insect.

2. Materials and Methods

2.1 Area study, data and samples collection

The analysis of biochemical composition and minerals content were carried out in the laboratory of Food control and normalisation of Institut Togolais de Recherche Agronomique (ITRA) and in the laboratory of Food Sciences and Technology of Ecole Supérieure des Techniques Biologiques *et al*imentaires (ESTBA) of University of Lomé. The extraction of oils from the *M. bellicosus* insect was done in the laboratory of soil and vegetables analysis of Ecole Supérieure d'Agronomie of University of Lomé (Togo).

An investigation was performed to collect information concerning the importance of *M. bellicosus* insect. Base on questionnaires, local names, information related to cooking methods and consumption of *M. bellicosus* insect were collected in Lomé. Data were collected from a total of 100 people in different area of Agoè, Agbalépédo, Djagblé, Kégué, Adéwui, Totsi and at University of Lomé.

M. bellicosus insect were collected after the rain during their nuptial flight under the light using a back containing water. *M. bellicosus* insect collected were assembled to one sample and dry under air conditioning at 25°C in the laboratory. The sample was then divided into two parts. One part was dried in the oven at 65°C for 48 hours. The second part was roasted using oven at 105°C for 30 minutes. Each dried and roasted sample was ground and the flour was packaged in aluminium paper and sachet and stored at ambient temperature of the laboratory. The oil was extracted based on the Soxhlet method using n-hexane solvent. The photography of *M. bellicosus* insect was presented in Figure 1.

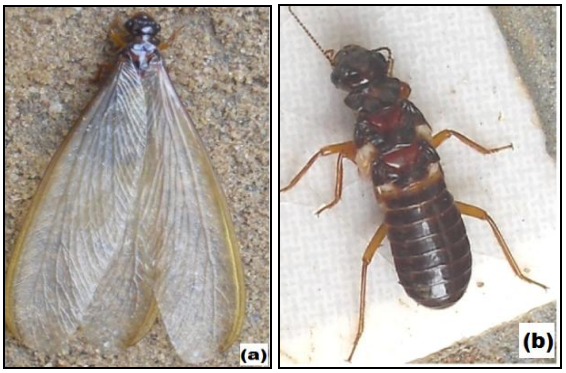

Fig 1: Photography of winged insect (a) and non-winged insect (b) of *M. bellicosus* (Author photography)

2.2 Determination of proximate composition

The moisture content was estimated by gravity method using 5 g of insect sample which have been placed in the oven BINDER at 105°C for 4 hours according to NF T60-201 (1984). The ash content was determined by complete incineration of 5 g of samples in the oven mark VULCAN^{TM}3-550 at 550°C during 6 hours according to NF ISO 6884 (1986). The total protein content was carried out by Kjeldahl method using TECATOR KJELTEC System 1002 Tecator apparatus according to NF V18-100 (1977). The crude protein content was calculated by multiplying the percentage of total nitrogen by the conversion factor 6.25. The lipid content was determined based on the Soxhlet method according to NF V 03-904 (1973). Briefly, 5 g of each sample was putted into a Soxhlet extraction cartridge. The assembly was placed in the extractor (RAFATEC II, 1050 Extractor). The n-hexane was used as the solvent for the extraction for 6 hours. At the end of the extraction, the glasses containing the fat were removed and placed in an oven at 105°C for 15 minutes. All determination were carried out in duplicate. The carbohydrate content was determined by the differential method according to AOAC [17]. According to the principle of this method, the sample consists essentially of water, minerals, proteins, fats and carbohydrates. The content of carbohydrates was determined by deduction according to the following expression:

$$\%\text{Carbohydrates} = 100\% - (\%\text{Water} + \%\text{Ash} + \%\text{Proteins} + \%\text{Lipids}) \quad (1)$$

The theoretical energetic value was calculated using the Merrill and Watt coefficients as described by FAO [18], where 1 g of lipids correspond to 9 kcal, 1 g of proteins and carbohydrate correspond each to 4 kcal. The calorific value per 100 g of dried matter sample was obtained as follows:

$$\text{Calorific value (kcal/ 100g)} = (\%\text{Lipids} \times 9) + 4 \times (\%\text{Proteins} + \%\text{Carbohydrates}) \quad (2)$$

2.3 Determination of minerals content

The determination of the content of potassium (K), sodium (Na), nickel (Ni), magnesium (Mg), iron (Fe), calcium (Ca), zinc (Zn) and copper (Cu) were carried out by flame atomic absorption spectrometry (ASA) while cadmium (Cd) and lead (Pb) content were evaluated using electrothermic absorption spectrometry (ASA) mark VARIAN according to the method described in standard NF EN 14082 [19]. Phosphorus (P) content was carried out using molecular absorption spectrometry according to NFT90-023 (1982). Each mineral in samples was quantified by using the standard solution of each mineral from which standard curve was plotted out. Briefly, 2 mL of oxygen water, 2 mL of concentrate nitric acid and 1.5 mL of concentrate sulfuric acid were added to the sample and kept at 80°C for 3 hours in bain-marie for mineralisation. After that, the solution obtained was filtered in glass phial of 50 mL and completed with distilled water. All determination were carried out in triple.

2.4 Determination of physical characteristics of oils and cholesterol content

Total cholesterol was determined by colorimetric method of Liebermann-Burchard according to Sperry [20]. Determination of unsaponifiable matter was carried out according to NF EN ISO 3596 T60-205 (2001). Index acid value was determined according to NF EN ISO 660, T60-204 (1999). Index iodine estimation was carried out according to NF EN ISO 3961, T60-203 (1999). Index saponification was determined using the method of AFNOR NF T60-206. The index peroxide was determined according to ISO 3960. All determination were carried out in triple.

2.5 Statistical analysis
Results were expressed as mean ± Standard error. Means, standard deviations were calculated using Microsoft Excel 2013. Sphinx Plus²-V5 was used for investigation data collection and calculation of percentages. Significance threshold was defined at $p < 5\%$.

3. Results and Discussion
3.2 Results
3.1.1 Local names of *M. bellicosus* insect in Togo
The results from the investigation on local name of *M. bellicosus* insect according to the ethnic groups are presented in Table 1. The local names of *M. bellicosus* insect are related to the different ethnic group.

Table 1: Local names of *M. bellicosus* insect in Togo

Ethnic group	Local names
Bassar	Inankiitchan
Ewé	Ayamé-kanami, Dzipo-kanami, Dami-dami, Konvi, Konvi-konvi, Baba-konvi, Konflé, Ekoè
Kabyè	Adjemlé, Adjomlé, Adjomda, Atchimdè, Atsédé, Kakpankparsi
Kotokoli	Gnon'ni
Losso	Atchamta

3.1.2 Knowledge and frequency of consumption of *M. bellicosus* insect
The results on the knowledge and the frequency of consumption of *Macrotermes bellicosus* insect were summirized in table 2. The results showed that 95% of the respondent's knowed the *Macrotermes bellicosus* insect and 57% of them have consumed the insect. Among the the consumers, only 47.37% still eat the insect. However, only 10.37% of people consume rarely, 22.22% often and 7.41% very often. Drying and roasting were the most widespread cooking method of *Macrotermes bellicosus* insect.

Table 2: Knowledge and frequency of consumption of *M. bellicosus* insect

	Responses		Number of people	Percentage (%)	Total
Knowledge	Yes		95	95	100 (100%)
	No		5	5	
Consumption	Yes		57	57	100 (100%)
	No		43	43	
Frequency of consumption	Continual	Yes	27	47.37	57 (57%)
		No	30	52.63	
	Rarely		19	10.37	27 (47.37%)
	Often		6	22.22	
	Very often		2	7.41	

3.1.3 Biochemical contents of *Macrotermes bellicosus* insect
Results obtained showed that the dried and roasted *M. bellicosus* insect contained low moisture value while the lipid values were 35.63 ± 1.96% of dry matter (roasted insect) and 50.37 ± 0.40% of dry matter for dry insect. The proteins contents were respectively 44.14 ± 0.01% for dry insect and 39.71 ± 0.66% for roasted insect. No significant difference was obtained between samples ($p < 0.05$). The carbohydrates contents were respectively 0.33 ± 0.14% for dry insect and 21.68 ± 1.87% for roasted insect with calorific value of 631.21 ± 2.14 kcal/100 g (dry insect) and 566.23 ± 5.23 kcal/100 g (roasted insect).

Table 3: Proximate composition of dried and roasted insect of *Macrotermes bellicosus*

Parameters	*M. bellicosus* insect	
	Dried insect	Roasted insect
Moisture (%)	2.94 ± 0.10	1.62 ± 0.08
Ash (%)	5.23 ± 0.14	2.98 ± 0.05
Proteins (%)	44.14 ± 0.01	39.71 ± 0.66
Lipids (%)	50.37 ± 0.40	35.63 ± 1.96
Carbohydrates (%)	0.33 ± 0.14	21.68 ± 1.87
Calorific value (kcal/ 100 g)	631.21 ± 3.34	566.23 ± 6.45

The values represent the mean ± standard error of three determinations

3.1.4 Minerals contents of larvae of *Macrotermes bellicosus* insect
The *M. bellicosus* insect contained significant amount of important minerals (Table 4). The results showed that the potassium content was 636.07 ± 0.79 mg/100 g for dry insect and 331.46 ± 0.41 mg/100 g for roasted insect. It is observed that the roasting has signicantly affected the potassium content. The same result was obtained for sodium 155.09 ± 0.49 mg/100g (dry insect), 123.72 ± 0.70 mg/100g (roasted insect), calcium 94.06 ± 0.19 mg/100g (dry insect), 84.22 ± 0.13 mg/100g (roasted insect) and manganese 48.96 ± 0.04 mg/100g (dry insect), 38.86 ± 0.03 mg/100g (roasted insect). There was a significant difference between dried and roasted insect samples ($p > 0.05$). The cadmium and lead were not detected in dried and roasted insect.

Table 4: Minerals contents of dried and roasted insect of *Macrotermes bellicosus*

Parameters	*M. bellicosus* insect	
	Dried insect	Roasted insect
Magnesium (mg/100 g)	44.12 ± 0.01	43.78 ± 0.38
Iron (mg/100 g)	53.00 ± 0.07	52.75 ± 0.03
Calcium (mg/100 g)	94.06 ± 0.19	84.22 ± 0.13
Sodium (mg/100 g)	155.09 ± 0.49	123.72 ± 0.70
Potassium (mg/100 g)	636.07 ± 0.79	331.46 ± 0.41
Zinc (mg/100 g)	6.53 ± 0.02	5.69 ± 0.01
Copper (mg/100 g)	6.05 ± 0.05	4.60 ± 0.06
Phosphorus (mg/100 g)	344.13 ± 2.05	344.07 ± 1.04
Manganese (mg/100 g)	48.96 ± 0.04	38.86 ± 0.03
Cadmium (mg/100 g)	ND	ND
Lead (mg/100 g)	ND	ND

ND: Not determined. The values represent the mean ± standard error of three determinations.

3.1.5 Physical characteristics and cholesterol content of *M. bellicosus* oils
The physical characteristic and cholesterol content were presented in table 5. The result showed that saponification value was 200.60 ± 1.30 mg KOH/g lipid for the dried insect and 193.43 ± 0.96 mg KOH/g lipid for the roasted insect, with 10.37 ± 0.99 and 8.11 ± 0.55 % of unsaponification value were respectively for dried and roasted insect. The acid value were respectively 2.94 ± 0.15 mg KOH/g lipid and 1.68 ± 0.18 mg KOH/g lipid for dried and roasted insect ($p < 0.05$). *M. bellicosus* oils present a high level of instauration acid gras with index iodine of 134.29 ± 1.56 g d'I_2/g lipids and 127.23 ± 0.44 g d'I_2/g lipids

Respectively for dried and roasted insect ($p < 0.05$). The index peroxide was 1.48 ± 0.07 meq d'O_2/kg lipid for dried insect and 2.73 ± 0.17 meq d'O_2/kg lipids for the roasted one ($p < 0.05$). The total cholesterol content was 14.84 ± 0.27 mg/100g lipids (dried insect) and 7.20 ± 0.45 mg/100g (roasted insect). No significant difference was obtained ($p = 0.08$).

Table 5: Physical characteristics and cholesterol content of *M. bellicosus* oils

Parameters	*M. bellicosus* insect	
	Dried insect	Roasted insect
Acid value (mg KOH/g lipids)	2.94 ± 0.15	1.68 ± 0.18
Index peroxide (meq O_2/kg lipids)	1.48 ± 0.07	2.73 ± 0.17
Index iodine value (g I_2/g lipids)	134.29 ± 1.56	127.23 ± 0.44
Unsaponifiables matter (%)	10.37 ± 0.99	8.11 ± 0.55
Saponification value (mg KOH/g lipid)	200.60 ± 1.30	193.43 ± 0.96
Total cholesterol (mg/100g lipids)	14.84 ± 0.27	13.48 ± 0.86

Each data is the mean ± standard error of three determinations

3.2 Discussion

The results on the knowledge and the frequency of consumption of *M. bellicosus* insect showed that 95% of the respondents knowed the insect and 57% of people have consumed it. From 57% of people who have consumed it, only 47.37% of them continue to eat. However, 10.37% of people consume rarely, 22.22% often and 7.41% very often. Drying and roasting were the most widespread cooking methods of *M. bellicosus* insect.

Generally, the insect is rich in protein, lipid, ash, total carbohydrates and high energy. The results of the proximate composition of *M. bellicosus* insect showed that the moisture was 2.94 ± 0.10% for dried insect and 1.62 % for the roasted one ($p = 0.0004$). These values are less than 12.60 % reported by Ekpo [21] for *M. bellicosus* insect and 92.0 % was reported for *M. subhyalinus* insect [22]. The value of moisture content for *M. bellicosus* insect in this study is comparable to one previously reported by Adepoju [23]. The ash content of *M. bellicosus* insect is 5.23% (dry insect) and 2.98 % (roasted insect). The ash content is less than 11.26 % reported by Ekpo [21] for *M. bellicosus* insect and 12.49 % was reported for *M. subhyalinus* insect [22]. This may thus suggest that the larva is riche in mineral content. The proteins contents of insect were between 45.6 to 79.6% of dry matter [10]. In this study, the content of proteins in dried insect of *M. bellicosus* is 44.14 % and 39.71 % for the roasted one. The high protein content of the *M. bellicosus* is suggests that the insect could be used in combating protein deficiency. Nevertheless, this result is higher than 38.36 % reported by Ekpo [21] for *M. bellicosus* insect and 38.2 % was reported for *M. subhyalinus* insect [22]. The *M. bellicosus* insect are a good source of digestive proteins which can cover food imbalances [24]. Malnutrition in developing countries is more a problem of caloric and protein deficiency [25]. The value obtained for the macronutrients of *M. bellicosus* insect was related to that reported by Adepoju [26]. This result shows that *M. bellicosus* insect could be used to resolve proteins needs which is between 23 to 56 g/kg [27]. The fat content of insect is between 8.1 to 35.0% of dry matter [10]. In this study, the fat content of *M. bellicosus* insect obtained is respectively 50.37 % for dry insect and 35.63 % for the roasted one ($p < 0.05$). This values are higher than 36.12 % reported by Ekpo [21] for *M. bellicosus* insect and 46.3 % reported by Niaba [22] for *M. subhyalinus* insect. The carbohydrates contents obtained is 0.33 ± 0.14% for dried insect and 21.68 % for the roasted one with 631.21 kcal/100 g of dry matter. These values are lower than 14.25 % reported by Ekpo [21] for *M. bellicosus* insect and 3.0 % was reported for *M. subhyalinus* insect [22]. The high values of the macronutrients of the insect can contribute significantly to macronutrients of infant complementary foods. So, adding *M. bellicosus* to local complementary foods is safe and improved their nutritional quality, hence its use is recommended among mothers [28].

Insect are known to be rich sources of various macro and trace elements. These elements are probably accumulated for future use in adult exoskeletal and connective tissue. Results of the mineral composition show that 100g of *M. bellicosus* insect will meet the RDA values for iron, zinc, copper, manganese and magnesium in most developing countries. Iron deficiency is a major problem in women diets in the developing world, particularly among pregnant women, and especially in Africa [29]. *M. bellicosus* insect contained substantial amount of minerals such as potassium (636.07 mg/100 g for dried insect and 331.46 mg/100 g for roasted insect). It is observed that the roasting has affected significantly the potassium content. Similar results were obtained for sodium (155.09 mg/100g for dry insect and 123.72 mg/100g for roasted insect), calcium (94.06 mg/100g for dried insect and 84.22 mg/100g for roasted insect) and manganese (48.96 mg/100g for dried insect and 38.86 mg/100g for roasted insect). Cadmium and lead not detected in the samples. Potassium content for the dry insect, manganese and copper are higher than 497.96 mg/100g; 325.01 mg/100g and 04.70 mg/100g of dry matter was reported [22]. Nevertheless, the contents of sodium, calcium, magnesium, iron, zinc and phosphorus are lower than those reported by Niaba [22]. The mineral need of a man of 70 kg is estimated to 1 to 3 mg of copper, 0.5 to 1.2 for calcium, 0.35 for magnesium and 0.010 to 0.020 for iron per day [30]. These results showed that the consumption of the *M. bellicosus* insect could cover the minerals need for humans [7]. The *M. bellicosus* insect may constitute a cheaper source of essential nutrients that is easily available and affordable to the natives within the localities where the larvae are found.

The acid value was 2.94 mg KOH/g lipid and 1.68 mg KOH/g lipid respectively for dry and roasted insect ($p < 0.05$). These value is lower than the limit dose of 4.0 mg KOH/g lipid set by Codex [31]. These values are also lower than 3.6 mg KOH/g lipid reported by Ekpo [21] for *M. bellicosus* insect oil and 3.89 mg KOH/g lipid reported by Niaba [22] for *M. subhyalinus* insect oil. The fewer level of acid value was related to the fewer level of index peroxide which was 1.48 meq d'O_2/kg lipid for dry insect and 2.73 meq d'O_2/kg lipids for the roasted one ($p < 0.05$). The index peroxide results are higher than 0.81 meq d'0_2/kg lipid reported by Niaba [22] for *M. Subhyalinus* insect oil. These values are less than the limit dose of 10 meq d'0_2/kg lipid set by Codex [31]. Saponification value was 200.60 mg KOH/g lipid for the dry insect and 193.43 mg KOH/g lipid for the roasted insect. These values are similar to the 193.40 mg KOH/g lipids reported by Ekpo [21] for *M. bellicosus* insect oil but lower than 250.47 mg KOH/g lipid was reported [22]. The unsaponification value were 10.37 and 8.11%

respectively for dry and roasted insect. *M. bellicosus* oils present a high level of index iodine of 134.29 g d'I_2/g lipids and 127.23 g d'I_2/g lipids respectively for driedy and roasted insect. The *M. bellicosus* insect lipids gave a high iodine number from the results reported [21, 22] indicating a relatively high level of instauration of acid gras of the insect oils [32]. Their saponification values were high, suggesting the presence of a fair amount of fatty acids but their acid values were low likely due to the fact that these fatty acids were not free but esterified acids. The total cholesterol content was 14.84 mg/100g lipids (dried insect) and 7.20 mg/100g (roasted insect) suggesting that the oil from *M. bellicosus* insect contains good lipids.

4. Conclusion

This work was performed to evaluate the knowledge, the frequency of consumption and the nutritional value of *M. bellicosus* insect through an investigation and the determination of the proximate biochemical composition. Though *M. bellicosus* insect are known, they are less consumed. The most widespread cooking methods for consumption were drying and roasting. It arises from the biochemical analyses that the contents of proteins, lipids and minerals of the *M. bellicosus* insect are rather interesting. The high percentages of proteins, lipids and major minerals such as iron, calcium and magnesium showed that the *M. bellicosus* insect can be used to compensate food imbalances in some diets. The quality of *M. bellicosus* insect oils showed that it can be used as seasoning oil.

5. Authors' contributions

This work was carried out in collaboration between authors. Authors read and approved the final manuscript.

6. Conflict of interest

Authors have declared that no competing interests exist.

7. References

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