



Research Article

Assessment of the Nutritional Value of Winged Termites (*Macrotermes bellicosus*) in the City of Man

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Abstract

This study, conducted on winged termites (*Macrotermes bellicosus*) collected in the Man region, assessed their mineral, lipid and protein composition in order to highlight their nutritional value. The results showed a high content of essential minerals, notably iron, calcium, potassium, magnesium and phosphorus, confirming the nutritional potential of these insects in combating dietary deficiencies and iron-deficiency anaemia. Trace elements such as zinc, copper, manganese and iodine were also detected in low concentrations but remain important for the body's physiological functions. Lipid analysis of the extracted oil revealed a predominance of monounsaturated and saturated fatty acids, with a notable presence of polyunsaturated fatty acids and omega-3s, which are beneficial for cardiovascular health and neurological development. Analysis of the amino acid profile highlighted the presence of several essential amino acids, notably lysine, threonine, leucine and tryptophan, demonstrating the high biological value of the proteins in winged termites. These results confirm that *Macrotermes bellicosus* constitutes an alternative food resource of high nutritional value that can contribute to dietary diversification and improved food security for populations in West Africa, particularly in areas affected by malnutrition.

Keywords

Macrotermes bellicosus, Mineral Composition, Essential Amino Acids, Human Nutrition

1. Introduction

Insects represent the most species-rich group of animals on the planet. They constitute one of the most diverse groups of animals, as a single class contains far more species than all other animal groups combined [1]. They are of extraordinary value as they play several roles that are essential to the functioning of the ecosystem. For example, insects are involved in

plant pollination, soil enrichment and the decomposition of organic matter. More recently, their use has extended to biological control, where they help manage pests. Finally, insects have long been a food source for humans. According to Ponzetta [2], insects form part of the dietary habits of traditional populations, highlighting the importance of the various species of edible insects consumed over time. This dietary

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practice should be encouraged, particularly as insects form part of the traditional diets of at least 2 billion people worldwide [3]. Moreover, the number of edible species recorded worldwide varies significantly depending on the author, reaching as many as 2,000 [4].

In French-speaking West Africa, despite varying levels of knowledge about edible insects from country to country [5], they are consumed as an alternative food source to combat malnutrition [6]. Thus, insects play a role in food security worldwide. Indeed, sales of edible insects rose from 33 million in 2015 to 55 million USD in 2019 [6]. Indeed, edible insects constitute a sustainable alternative source of proteins, lipids, essential amino acids, vitamins, and minerals such as calcium, iron, phosphorus, manganese and zinc for human nutrition [7-8]. The nutrient composition of edible insects depends on the insect's stage of development and its habitat [9]. Furthermore, the edible portion of insects accounts for over 80%, compared to 55% for beef and 55% for chicken [10].

In Côte d'Ivoire, people eat insects. Surveys conducted by Boko [11] in the town of Man revealed that the rate of insect consumption stands at 63.7%. During periods of food scarcity in these regions, these insects generally provide an alternative source of animal protein for the local population. In fact, these insects are rich in protein and contain iron as well as vitamin A. For this reason, these insects, consisting mainly of *Macrotermes bellicosus*, could therefore provide a solution to the nutritional deficiencies faced by certain populations. However, the numerous studies conducted by researchers on *Macrotermes bellicosus* have been limited to determining protein, lipid and mineral content [12]. Yet the quality of proteins and even lipids depends on the quality of fatty acids and amino acids, particularly essential ones. Knowledge of the amino acid profile of *Macrotermes bellicosus* winged termites would help to correct unbalanced diets and combat malnutrition, particularly in children. The aim of this study is therefore to assess the nutritional value of winged termites by determining their mineral, fatty acid and amino acid profiles.

2. Introduction to the Town of Man

2.1. Geographical Location

With an area of 4,140.7 km² the town of Man is one of the largest in western Côte d'Ivoire. It is situated at 7°24'0''N and 7°33'0''W in DMS (degrees, minutes, seconds) (GPS coordinates), in a basin formed by mountain ranges that surround it. Man is the administrative centre of the Tonkpi region and the capital of the Montagnes district, which comprises not only the Tonkpi region but also the Guemon and Cavally regions (Figure 1). The Tonkpi region comprises five (5) departments: Man, Sipilou, Danané, Biankouma and Zouan-Hounien. Man borders the departments of Biankouma and Danané. It comprises eleven (11) sub-prefectures, namely: Bogouiné, Fagnampléu, Gbangbéguiné-Yati, Logoualé-Man (administrative centre), Podiaguiné, Sabdougué-Soba, Sangouiné

Yapleu, Zagoué and Zionguiné

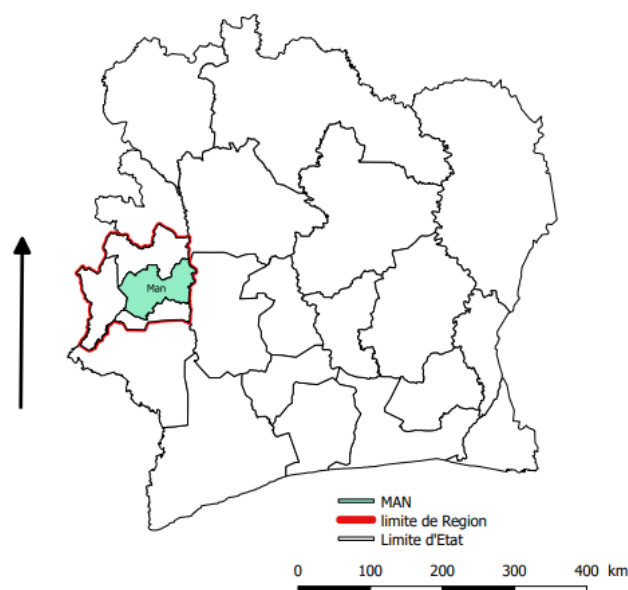


Figure 1. Geographical and administrative location of the Department of Man [13].

2.2. Population, Climate and Vegetation

The population of the Department of Man is estimated at 1,387,909 inhabitants according to the General Population and Housing Census [14]. The indigenous peoples are the Dan, also known as the Yacouba. In addition to the indigenous peoples, there are non-indigenous groups such as the Gobé Gueré Toura, Mahoka, Senoufo, Malinké and Baoulé amongst others. There are also nationals from neighbouring countries, namely Guineans, Liberians, Malians, Burkinabés and Nigeriens.

The climate of Man, and by extension that of our study site, is a mountain climate where temperatures decrease with altitude (down to 8 °C in January) and rainfall reaches up to 1,770 mm [15]. It is characterised by two seasons, including a rainy season that runs from November to January, with a month and a half of the Harmattan (December to mid-January).

The vegetation of the Department of Man consists of 80% tropical rainforest, part of which has been converted into fallow land planted with *Chromolaena odorata* (Sekou Toure), whilst another part is used for agro-industrial plantations of coffee, cocoa or rubber, not to mention food crops such as cassava, rice and yams [15].

2.3. Topography

The topography of Man District, as in the whole of the western part of the country, consists of a series of low plateaus which, in places, give way to very rugged terrain, ranging from gentle slopes to elevations sometimes exceeding 1,000

m, such as Mount Nimba (1,752 m) and Mount Tonkpi (1,293 m). This terrain, whose mountainous character is accentuated by Mount Dan and Mount Toura, consists of a succession of domes and hills separated by deep valleys. It is rugged across one-third of its area [15].

3. Materials and Methods

3.1. Biological Material

The biological material consists of fresh (Figure 2) and dried (Figure 3) winged termites (*Macrotermes bellicosus*).



Figure 2. *Macrotermes bellicosus* fresh.



Figure 3. *Macrotermes bellicosus* dried.

3.2. Methods

3.2.1. Study Area and Period

Winged termites were collected in March 2025 in four (4) villages (Tiakoupleu, Kagui, Kouitongouie I and Seipleu) and at the Polytechnic University of Man (UMAN). To capture the termites, containers were filled with water and then placed under floodlights between 1 am and 2 am. As the termites are attracted to the light, they eventually fall into the water container and are trapped there.

3.2.2. Sample Preparation and Packaging

The captured winged termites (*Macrotermes bellicosus*) were kept at 4 °C in a cool box containing ice to preserve their freshness and then transported to the laboratory. At the laboratory, the termites were cleaned with tap water and rinsed. They were then stripped of their wings and ground in a blender. Part of this ground material was used for a number of analyses, including moisture, protein and ash content, whilst another part was placed on trays and dried in an oven at 65 °C for 72 hours, then sieved to obtain *Macrotermes bellicosus* flour, which was used for lipid extraction.

3.2.3. Mineral Analysis

(i). Analysis of Calcium, Potassium and Sodium

The calcium, potassium and sodium contents were determined using the AOAC method [16]. Five (5) grams of winged termites, incinerated at 550 °C for 8 hours in a muffle furnace, were dissolved in 20 mL of a 0.5 N hydrochloric acid solution. After standing for one hour, the mixture was filtered and made up to 100 mL with distilled water in a flask. Subsequently, 1 mL of this 1: 100 diluted solution was used for the determination of these minerals. The flame photometer was calibrated with a standard solution of calcium, sodium and potassium for the respective determination of calcium ions, sodium ions and potassium ions. An optical density (OD) value for each element was obtained for wavelengths between 279.5 and 321.7 nm. The analyses were carried out in triplicate.

The content of the analysed mineral is given by the following formula:

$$\text{Mineral content} = M \times \frac{DO \times V}{a \times Pe}$$

Where,

OD: Optical Density

a: Slope of the calibration curve

M: Molar mass of calcium/potassium/sodium (g/mol)

Pe: Sample volume (mL)

V: Volume of distilled water (mL)

(ii). Determination of Magnesium and Iron

The magnesium and iron contents were measured by atomic absorption spectrometry (Perkin-Elmer, Model 1100, France) on the ash dissolved in a 37% concentrated HCl solution (diluted 1: 100) for the iron determination. For the magnesium analysis, 1 g of ash was dissolved in a solution containing 10% lanthanum chloride (LaCl₃) as an interaction corrector. The mineral analysis required the prior establishment of a calibration curve.

(iii). Phosphorus Determination

The phosphorus determination was carried out according to

the method of Tausky and Shorr [17]. Ten millilitres of distilled water were added to five (5) grams of ash. Subsequently, 0.1 mL of this solution was transferred to various tubes and made up to 1 mL with distilled water. Three (3) mL of the molybdate-vanadate reagent were added to each tube. The optical densities were read on a spectrophotometer at 430 nm against the blank. The calibration curve was prepared under the same conditions using a hydrogen phosphate solution (2 mM). The analyses were carried out in triplicate.

The phosphorus concentration is calculated using the following formula:

$$\text{Phosphorus content} = Mp \times \frac{DO \times V}{a \times Pe}$$

Mp: molar mass of phosphorus (g/mol);

OD: optical density;

a: slope of the calibration line;

Pe: sample volume (mL);

V: volume of distilled water (mL)

3.2.4. Analysis of the Oil's Fatty Acid Profile

(i). Preparation of Methyl Esters

Fatty acid methyl esters were prepared using boron trifluoride reagent at a concentration of 8% in methanol (BF₃ / MeOH). One hundred (100) mg of sample was weighed into a 10 mL screw-cap test tube. To this were added 1.5 mL of hexane and 1.5 mL of BF₃ / MeOH. The tube was sealed tightly under nitrogen, shaken vigorously, then heated to 100 °C for 1 hour. After cooling to room temperature, 1 mL of hexane and 2 mL of distilled water were added, followed by shaking under nitrogen. Two phases separated after standing. The upper phase was collected in another tube and placed under nitrogen. The lower phase was extracted twice with 1 mL of hexane. All the collected phases (methyl esters) were washed with 2 mL of distilled water, then dried over anhydrous sodium sulphate. The solvent was evaporated under nitrogen. Hexane was added to adjust the concentration of the methyl esters for analysis by gas chromatography.

(ii). Gas Chromatography Analysis

The analysis of methyl esters is carried out on a Peri 2000 chromatograph (Perichrom, Saulx-le-Chartreux, France) fitted with a flame ionisation detector. They are separated on a capillary column (0.25 m long, 250 µm in diameter, with a film thickness of 0.5 µm) packed with polyethylene glycol doped with terephthalic acid (Perichrom). The detector and injector temperatures are set at 260 °C. The programme used for the analysis is as follows: initially held at 70 °C for 2 min, the column was raised to 180 °C (39.9 °C/min) and held at this temperature for 8 min, then underwent a second heating phase up to 220 °C (3 °C/min) for 45 min. Cooling was carried out at 39.9 °C/min. Peak identification was performed using two fatty acid standards supplied by Supelco (Bellefonte, USA):

PUFA 1 (marine source) and PUFA 2 (animal source).

3.2.5. Amino Acid Analysis

The amino acids in the initial proteins of winged termites were analysed using reverse-phase high-performance liquid chromatography (PTC RP-18 column, 220 mm long, 2.1 mm internal diameter, and a precolumn, Applied Biosystems, Applera Corp, Foster City, CA, USA). The samples were then diluted in deionised water to a concentration of approximately 0.8 g/L, and subsequently filtered through a 0.22 µm Millipore filter. The samples were hydrolysed under vacuum at 150 °C for 60 min in a Pico-Tag station (Waters, Milford, MA, USA) in the presence of 6 N HCl containing 1% phenol. They were then transferred to ultrapure water and automatically derivatised using an Auto Derivatiser-Analyser 420a (Applied Biosystems, Applera Corp, Foster City, CA, USA). The amino acid derivatives in the form of phenyl isothiocyanates (PITC) were separated using buffer A (45 mM sodium acetate at pH 5.9) and buffer B (30% 105 mM sodium acetate, pH 4.6; 70% acetonitrile) under an elution gradient. Detection was set at 254 nm and the total run time was 31 minutes. Data acquisition and analysis were performed using the 'Model 600 Data Analysis System' software (Applied Biosystems, Applera Corp, Foster City, CA, USA).

4. Results

4.1. Mineral Composition of *Macrotermes bellicosus* Flour

The Table 1 summarises the mineral content of *Macrotermes bellicosus* flour. Analysis of the ash from dried winged termites shows that it contains minerals such as potassium, calcium, magnesium and phosphorus, which constitute the macronutrients, as well as micronutrients such as iron, copper, zinc, iodine and manganese. There is significant variability in the levels of the minerals studied, ranging from 109.30 mg/100g to 191.78 mg/100g for macronutrients and from 0.02 to 3.00 mg/100g for micronutrients.

Table 1. Mineral content of dried *Macrotermes bellicosus*.

Minerals	Content (mg/100g of dry matter (DM))
Potassium (K)	169.88 ±0.001
Sodium (Na)	109.3 ±0.001
Magnesium (Mg)	159.28 ±0.001
Calcium (Ca)	191.78 ±0.002
Phosphorus (P)	127.08 ±0.001
Iron (Fe)	297.1 ±0.001

Minerals	Content (mg/100g of dry matter (DM))
Copper (Cu)	2.00±0.001
Zinc (Zn)	3.00±0.001
Manganese (Mn)	0.02±0.001
Iodine (I)	0.46±0.001

The values are the average of three sample tests (n=3) / DM = Dry Matter. JASP 0.19

4.2. Fatty Acid Profile of Oil Extracted From Winged Termites (*Macrotermes Bellicosus*)

The fatty acid profile determined by chromatography shows that the oil from winged termites captured in the city of Man consists of saturated fatty acids (42.38±0.02%), monounsaturated fatty acids (49.52±0.04%) and polyunsaturated fatty acids (8.10±0.05%). Furthermore, the saturated fatty acid composition is dominated to a greater extent by palmitic acid (30.98±0.01%) and to a lesser extent by stearic acid (9.86±0.05%). As for the monounsaturated fatty acid composition, it is richer in oleic acid, with a content of 46.95±0.08%. The oil from winged termites also consists of linoleic and linolenic fatty acids, with respective values of 7.55±0.02% and 0.55±0.01%. All this data is set out in Table 2.

Table 2. Fatty acid profile of oil from winged termites captured in Man's town.

Fatty acids	Content (%)
Palmitic acid (C16: 0)	30.98±0.01
Lauric acid (C12: 0)	0.2±0.01
Pentadecanoic acid (C15: 0)	0.18±0.07
Myristic acid (C14: 0)	0.89±0.02
Heptadecanoic acid (C17: 0)	0.27±0.03
Stearic acid (C18: 0)	9.86±0.05
Σ Saturated Fatty Acids (SFA)	42.38±0.02
Oleic acid (C18: 1n9)	46.95±0.08
Gadoleic acid (C20: 1n9)	0.32±0.01
Hexadecenoic acid (C16: 1n9)	0.17±0.06
Palmitoleic acid (C16: 1n7)	1.9±0.04
Heptadecenoic acid (C17: 1n10)	0.18±0.01
Σ Monounsaturated fatty acids (AGMI)	49.52±0.04
Linoleic acid (C18: 2n6)	7.55±0.02
Linolenic acid (C18: 3n3)	0.55±0.01
Total polyunsaturated fatty acids (PUFAs)	8.10±0.05

Fatty acids	Content (%)
n-6/n-3 ratio	13.73
PUFAs/SFAs	0.20

4.3. Amino Acid Profile of the Protein From Winged Termites (*Macrotermes Bellicosus*)

The results of the amino acid profile analysis of the termite meal are presented in Table 3. They show that the proteins from *Macrotermes bellicosus* contain 20 amino acids, with a protein content of 1,022 mg/g. Of these 20 amino acids, 510 mg/g are so-called essential amino acids. The essential amino acids (essential AAs) have levels ranging from 19 mg/g (tryptophan) to 101.7 mg/g (phenylalanine + tyrosine). Essential amino acids such as phenylalanine + tyrosine (101.7 mg/g), lysine (79.9 mg/g), threonine (77.5 mg/g), leucine (62.5 mg/g), valine (58.9 mg/g) and isoleucine (56.8%) are present in greater quantities than histidine (29.8 mg/g), methionine + cysteine and tryptophan (19 mg/g). The other amino acids are aspartic acid + asparagine, glutamic acid + glutamine, glycine, arginine, serine, proline and alanine, with levels ranging from 51 to 100.8 mg/g.

Table 3. Amino Acid profile (mg/g of protein) of *Macrotermes bellicosus*.

Amino acids (AA)	mg/g of protein
Threonine	77.5
Phenylalanine + Tyrosine	101.7
Tryptophan	19
Lysine	79.9
Isoleucine	56.8
Leucine	62.5
Methionine + Cysteine	23.9
Valine	58.9
Histidine	29.8
Σ Essential amino acids (essential AA)	510
Aspartic acid + Asparagine	100.8
Glutamic acid + Glutamine	102.3
Glycine	73.6
Arginine	51.4
Serine	59.1
Proline	58.6
Alanine	66.2

Amino acids (AA)	mg/g of protein
Total Amino Acids	1022

5. Discussion

The results obtained for the powder of winged termites collected in Man reveal a mineral composition dominated by iron (297.1 mg/100 g), calcium (191.78 mg/100 g), potassium (169.88 mg/100 g) and magnesium (159.28 mg/100 g), followed by phosphorus (127.08 mg/100 g) and sodium (109.3 mg/100 g). Trace elements such as zinc, copper, manganese and iodine are present in lower concentrations. This nutritional profile is consistent with data in the literature describing edible termites as excellent source of essential micronutrients, particularly in tropical regions where nutritional deficiencies remain common.

5.1. Mineral Composition and Nutritional Value

The high calcium and phosphorus contents observed in this study suggest that powdered winged termites could contribute to bone mineralisation and the maintenance of skeletal health. Research by Van Huis et al. [18], published by the Food and Agriculture Organization of the United Nations (FAO), indicate that several species of edible insects have calcium contents comparable to, or even higher than, those of certain conventional animal proteins. More recent studies also confirm the nutritional value of edible insects as alternative sources of essential minerals in sustainable food systems [19, 20]. The high concentrations of potassium and magnesium also confirm the nutritional potential of winged termites in regulating neuromuscular functions, electrolyte balance and energy metabolism. According to Anankware et al. [21], edible insects represent a promising nutritional resource, providing high-quality proteins and essential micronutrients that may contribute to improving food and nutrition security in West Africa.

The particularly high iron content is one of the key findings of this study. Termites of the genus *Macrotermes* are recognised as being among the insects richest in bioavailable iron. Christensen et al. [22] had already shown that several insects consumed in Africa contribute significantly to the prevention of iron-deficiency anaemia. This observation was reinforced by the work of Mwangi et al. [23], who demonstrated that edible insects can represent a sustainable source of iron for vulnerable populations. In Côte d'Ivoire, where iron deficiency remains a public health problem, the use of winged termites could thus contribute to improving the nutritional quality of diets.

However, the bioavailability of iron depends on numerous factors, notably the presence of compounds that inhibit or facilitate intestinal absorption [24]. Recent research also indi-

cates that the technological processing of insects can positively influence the absorption of micronutrients [25].

The low concentrations of zinc, copper, manganese and iodine observed in this study are consistent with the mineral profiles generally reported for edible insects. Although present in relatively small amounts, these elements play essential physiological roles in enzymatic, immune and endocrine functions. Zinc is particularly involved in immune function, while copper contributes to iron metabolism. Iodine, even at low concentrations, is essential for the synthesis of thyroid hormones. These findings are consistent with previous reports highlighting edible insects as potential sources of a wide range of essential micronutrients [26-27].

The variations observed in mineral content may be linked to environmental conditions, the food substrate, and the ecological characteristics of the Man region. Forest soils rich in organic matter are thought to promote the accumulation of certain minerals, particularly iron and calcium, in *M. bellicosus* tissues. Several authors have shown that the nutritional composition of insects varies according to the environment, physiological stage, diet and harvesting season [28, 29].

Thus, powdered winged termites appear to be a food resource with great potential for combating nutritional deficiencies and improving food security in West Africa.

5.2. Lipid Composition and Nutritional Quality of the Oil

Analysis of the oil extracted from *Macrotermes bellicosus* reveals a predominance of monounsaturated fatty acids (49.52%) and saturated fatty acids (42.38%), whilst polyunsaturated fatty acids account for 8.10%. These results are similar to those reported by Badanaro et al. [12] in Togo, who observed a monounsaturated fatty acid content of 51.66% in the same species.

The proportion of polyunsaturated fatty acids obtained in this study is similar to that reported by Niaba et al. [30] for *Macrotermes subhyalinus* in Côte d'Ivoire, but higher than the values observed by John et al.; Badanaro et al. [12, 31]. These differences could be attributed to several factors, including environmental conditions, seasonal variations, the physiological stage of the insects, and the susceptibility of polyunsaturated fatty acids to oxidation [32, 33].

The n-6/n-3 ratio obtained (13.75) falls within the range reported in some nutritional guidelines, although the optimal ratio remains a subject of debate. Similarly, the PUFA/SFA ratio of 0.20 indicates a relatively low proportion of polyunsaturated relative to saturated fatty acids and should be interpreted cautiously in terms of lipid nutritional quality [34]. These observations are consistent with the findings of Oyarzun et al. [35] on termites of the genus *Nasutitermes*, which also reported appreciable levels of unsaturated fatty acids.

The presence of α -linolenic acid (omega-3) also confirms the nutritional value of *Macrotermes bellicosus* oil. Omega-3

fatty acids play a fundamental role in neurological development, immune function and the prevention of cardiovascular disease [36].

5.3. Protein Quality and Amino Acid Profile

Analysis of the amino acid profile reveals the presence of several essential amino acids, notably threonine, phenylalanine, tyrosine, tryptophan, lysine, isoleucine, leucine, methionine, cysteine, valine and histidine. The proteins in winged termites appear to be particularly rich in lysine and threonine, but relatively lower in methionine and cysteine.

These results corroborate the observations of DeFoliart [37], according to which insect proteins generally have high lysine and threonine contents. The high lysine content constitutes a significant nutritional advantage, particularly for fortifying cereal-based diets, which are often deficient in this essential amino acid [38]. Lysine also plays a role in protein synthesis and the assimilation of other amino acids [39].

Furthermore, the significant arginine content could promote children's growth and development, as arginine plays a key role in cellular growth mechanisms and immune functions [40]. Finally, the overall content of essential amino acids (510 mg/g of protein) meets the nutritional recommendations established for human consumption, thereby confirming the value of winged termites as an alternative protein source of high biological value.

6. Conclusion

Several scientific studies have addressed the utilisation of winged termites in general. This study examined the same topic, focusing specifically on winged termites from the Man departmental region. It also assessed the quality of the proteins and fats in these insects by analysing their respective profiles. Indeed, geographical location and climate are likely to be factors influencing variation. The results have indeed shown that *Macrotermes bellicosus* contains essential macro- and micronutrients, and is therefore of recognised nutritional value. These significant nutritional qualities may help to provide high-quality diets in areas affected by deficiency-related malnutrition. Furthermore, analysis of the amino acid and fatty acid profiles showed that these are present in significant proportions. *Macrotermes bellicosus* is therefore an unconventional food resource that could serve as a means of dietary diversification for local populations. It would therefore be necessary to investigate the form of consumption that would allow for the maximum benefit from the valuable nutrients they contain.

Abbreviations

AOAC	Association of Official Analytical Chemists
WHO	World Health Organization
PICI	Projet De Renaissance Des Infrastructures De

Côte d'Ivoire
INS Agence National De La Statistique

Author Contributions

Oulai Tokpa Louya: Conceptualization, data curation, Ressources

Yao N'guessan Firmin: Supervision, Validation

Akpro Lathro Anselme: Writing-original draft, Writing-review and editing

Ochou Germain Cynthia Epse L&kadou: Software

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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