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Nutritional profile of winged termite, *Macrotermes bellicosus* (Isoptera: Termitidae) consumed in Kontagora, Nigeria

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Abstract
Macrotermes bellicosus is considered a delicacy in Nigeria and many parts of Africa. The proximate, minerals, anti-nutrients and amino acids contents of the roasted termite were determined using standard methods. The crude protein was 36.16%, fats 23.36%, carbohydrates 13.16%, fibre 13.18% and ash 5.38%. Minerals like calcium, iron, phosphorus, potassium, zinc, and magnesium were abundant and had excellent mineral ratios. Consumption of 100g of termite as food will supply 37% of calcium, 40% of magnesium, 52% of potassium, and over 100% of iron and zinc required by humans. Anti-nutrients like cyanide and oxalate present in wing termites are of tolerable quantity for human consumption. The amino acid content was excellent with 69% of the indispensable amino acids satisfying the recommended benchmark for human diets. The quantity of branched amino acids (19.4%) was adequate and the consumption of 50.12g of termite will supply all the amino acids needed in adult humans. The results indicate that winged termite is a potentially rich source of macronutrients, minerals and essential amino acids that are necessary for combating protein-mineral malnutrition common in developing countries of the world. Therefore, the insect is recommended as an alternative to conventional sources of animal protein.

Keywords: *Macrotermes bellicosus*, amino acids, macronutrients, malnutrition, anti-nutrients

Introduction
Termites live in colonies and are morphologically or adaptively divided into five castes. Each caste has fundamental responsibilities towards the overall benefits and continuous sustainability of the population. One of these castes of termite colonies is the winged adults which are responsible for the dispersal and continuous perpetuation of the species. They are the potential kings and queens when new colonies are to be established. Winged termites are always available at the onset of the rainy season and are called various names by different ethnic groups in Nigeria such as 'Aku' by the Ibos, 'Chinge' by the Hausas and 'Esusu' by the Yoruba [1]. Winged termites attracted to light, emerge as swarms at night during their nuptial flight and are collected by humans for consumption [2].
Out of the three continents where termites are mostly used, Africa has the highest use of termite resources [3]. Termites are a threat to the human ecosystem because they are known for the damage they cause to plants and human furniture. However, they are important natural resources because of their roles in the decomposition of organic matter, usage in traditional medicine and as human and animal feed in many parts of the world. Out of the 48 species of termites consumed by man, the species *Microtermes bellicossus* and *Microtermes nigiriensis* are mostly eaten in different parts of Nigeria and several other African countries [4].
Hunting for winged termites for food by humans is a cultural practice dating back to time immemorial. Children and adults alike collect the alates (winged termites) at night during their swarming period. The collected termites are roasted, the wings removed and the finished product is either eaten or sold in the market as a snack [5]. Dried or roasted *Macrotermes bellicosus* has been reported to be a good source of dietary protein, fats, vitamins and minerals with insignificant levels of antinutrients [4, 6]. The inclusion of termites in complementary diet formulations has also been proven satisfactory [1, 7].
Edible insects such as winged termites have been recommended as a potential solution to human malnutrition and this has led to investigations into their nutritional and health benefits [6]. However, the nutritional potentials of edible insects are largely variable due to differences in geographical location, climate, stage of metamorphosis and methods of processing [8].

Therefore, the objectives of this study are to determine the proximate, macroelement, antinutrient and amino acids composition of winged termites, *Macrotermes bellicossus* collected from Kontagora Niger State Nigeria.

Materials and Methods

The sample, wing termites were collected in June 2024, during their nuptial flight two days after rainfall between 7.30 pm and 8.30 pm using the traditional method of attraction to light and handpicking from residential buildings in Kontagora town. The harvested insects were transported under the ice to the laboratory of the Department of Biology, Federal University of Education, Kontangora for processing. The sample was roasted for ten minutes in a frying pan over a gas cooker, dewinged, dried at 50 °C and stored in an airtight container pending when another analysis was done.

Proximate Analysis

The proximate analysis of the sample was carried out using the method described by the Association of Official Analytical Chemists [9]. The carbohydrate content was obtained by difference by adding the amount of crude protein, crude fat, moisture and ash of the samples and subtracted from 100 [10]. Gross energy was determined using Atwater factors by multiplying the value of protein content of the sample by 4, lipid multiplied by 9 and total carbohydrate by 4. The sum of these values was expressed as Kcal/100g. All analyses were conducted in triplicate for each measurement.

Mineral analysis

The potassium and sodium content of the sample was evaluated by first digesting the ash with perchloric acid and nitric acid after which the reading was taken on a photometer [11]. Phosphorus was determined by vandomolybdate colourimetric method [12]. Calcium, magnesium, iron, zinc and manganese contents were determined from the digested ash using an absorption spectrophotometer [13] and compared with the absorption of standards of these minerals. All analyses were conducted in triplicate for each sample.

Phytochemicals or anti-nutrients determination

Phytochemical analysis for the presence of tannins was determined by the method described by [14, 15] method was used for pythin determination. Oxalate was assayed as described by [16] while alkaloids and saponin were measured by method described by [17]. All analyses were conducted in triplicate for each sample.

Amino acids analysis

Amino acid content was determined by ion exchange HPLC chromatography [18], using the Applied PTH Amino Acid Analyzer (Model 120A). 2g of each of the samples was defatted using chloroform/methanol (2:1) (AOAC, 2006) and then hydrolyzed at 110oC under a nitrogen atmosphere for 22hrs with 6M hydrochloric acid. For the determination of tryptophan, 2g of each of the samples were separately hydrolyzed with 4.2M sodium hydroxide for 22 hours and were neutralized to PH 7.0 with 6N of hydrochloric acid. The hydrolysates were injected into the amino acid analyzer for separation and characterization. Quantification was obtained by using an external amino acid standard and the results were corrected for the recoveries. All analyses were conducted in triplicate for each sample.

Quality of the amino Acids

The total amino acid (TAA), total essential amino acid (TEAA), total acid amino acid (TAAA), total sulphur amino acid (TSAA), total aromatic amino acid (TArAA) and total branched amino acids (BCAA) were determined. The Predicted Protein Efficiency Ratio (P-PER) was determined using the equation developed by [19].

P-PER = -0.468 + 0.454 (Leu) - 0.105 (Tyr)

The amino acid score for essential amino acids was calculated according to FAO/WHO (1973).

AAscore = AAAsp/AAARp

Where AAAsp is the amount of limited amino acid in the sample protein (mg/g) while AAARp is the amount of the same amino acid in the reference protein (mg/g)

Results

Table 1 shows the macronutrient composition of *M. bellicosus*. The sample contains high protein (36.15 ± 1.45), lipid (23.36 ± 1.37), carbohydrate (13.18 ± 1.31) and fibre (13.16 ± 0.96). The moisture, ash and energy were 8.43 ± 0.90, 5.38 ± 1.03 and 407.32 ± 6.13 Kcal respectively.

Table 1: Proximate composition of *M. bellicosus* (%)

Minerals	*M. nigeriensis*
Moisture	8.43 ± 0.90
Ash	5.38 ± 1.03
Crude protein	36.15 ± 1.43
Fiber	13.16 ± 0.96
Crude fats	23.36 ± 1.37
Carbohydrate	13.18 ± 1.31
Energy (Kcal)	407.32 ± 6.13

Values are mean of triplicate measurements

Table 2 shows the macro elemental composition of *M. bellicosus*. The sample has a high content of calcium (368.60 ± 1.08), potassium (214.00 ± 2.45), phosphorus (147.10 ± 1.53), magnesium (124.40 ± 1.19) and sodium (93.66 ± 2.05), while zinc and iron were (48.30 ± 0.79) and (11.10 ± 1.47) respectively. The mineral ratio of the sample shows K+/Na+ (2.28), Ca2+/P (2.50), Ca2+/Mg2+ (2.96), Ca2+/K+ (1.72) and Na+/Mg2+ (0.75)

Table 2: Elemental composition of *M. bellicosus* (mg/100g)

Minerals	*M. nigeriensis*
Iron	11.10 ± 1.47
Phosphorus	147.10 ± 1.53
Calcium	368.60 ± 1.08
Sodium	93.66 ± 2.05
Potassium	214.00 ± 2.45
Zinc	48.30 ± 0.79
Magnesium	124.40 ± 1.19
K^+/Na^+	2.28
Ca^{2+}/P	2.50
Ca^{2+}/Mg^{2+}	2.96
Ca^{2+}/K^+	1.72
Na^+/Mg^{2+}	0.75

Values are mean of triplicate measurements

Table 3 shows the antinutrient content of *M. bellicosus*.

Phytate (4997.13 ± 12.03), saponin (1351.21 ± 2.88) and cyanide (255.67 ± 0.20) were generally high, while oxalate (0.47 ± 0.01) and tannin (12.67 ± 0.15) were low.

Table 3: Anti-nutrient composition of *M. bellicosus* (mg/100g)

Anti-nutrient	*M. nigeriensis*
Cyanide	255.67 ± 0.20
Oxalate	0.47 ± 0.01
Phytate	4997.13 ± 12.03
Tannins	12.67 ± 0.15
Saponnins	1351.21 ± 2.86

Values are mean of triplicate measurements

Table 4 shows the amino acid profile of *M. bellicosus*. 66.7% of the essential amino acids satisfied the FAO requirement for the human diet. The protein Efficiency Ratio (P-PER) was 2.36, the amino acid score was 0.63 and the essential to non-essential amino acid ratio was 0.69. The total branched amino acids (BCAA) was 17.59 while the percentage of branched amino acids was 19.40%.

Table 4: Amino acid Composition of *M. bellicosus* (g/100g protein)

Amino acid	*M. bellicosus*	*FAO/WHO (RDA)
Leucine	7.07 ± 0.04	6.60
Lysine	4.19 ± 0.03	5.80
Isoleucine	5.19 ± 0.04	2.80
Phenylalanine	4.98 ± 0.03	6.30
Tryptophan	0.69 ± 0.03	1.10
Valine	5.33 ± 0.04	3.50
Methionine	2.67 ± 0.02	2.50
Proline	8.94 ± 0.03	9.13
Arginine	7.05 ± 0.02	8.00
Tyrosine	3.65 ± 0.03	6.30
Histidine	2.56 ± 0.04	1.90
Cysteine	1.46 ± 0.02	2.50
Alanine	5.56 ± 0.02	3.11
Glutamic acid	9.52 ± 0.02	5.60
Glycine	6.23 ± 0.03	7.12
Threonine	4.16 ± 0.03	3.40
Aspartic acid	6.34 ± 0.03	5.30
Serine	5.03 ± 0.04	9.93
∑TAA	90.60	
%TEAA	36.84 (40.7%)	
%TNEAA	53.76 (59.3%)	
∑TEAA/∑TNEAA	0.69	
P-PER	2.36	
AA_{score}	0.63	
∑TBCAA	17.59	
∑BCAA/TAA	0.194 (19.4)	
Leu/iso/val	1.38:1.01:1.00	

Values are mean of triplicate measurements, *FAO/WHO [20]

Table 5 presents the amount of the sample in grams that will satisfy the daily human essential amino acids requirement. The result shows that a minimum consumption of 50.12g of the sample is enough to meet the daily amino acid requirement in humans.

Table 5: Daily recommended intake of protein samples which satisfy the body amino acids requirements

	*Recommended Daily Intake		g/100g of protein
Amino acid	mg/Kg body weight	g/70kg body weight	*M. bellicosus*
Leucine	39.0	2.70	7.07 (35.06)
Lysine	30.0	2.10	4.19 (50.12)
Isoleucine	20.0	1.40	5.19 (26.97)
Phe + Tyr	25.0	1.75	8.63 (20.28)
Theonine	15.0	1.05	4.16 (25.24)
Met + Cys	15.0	1.05	4.13 (25.42)
Valine	26.0	1.82	5.33 (34.16)
Tryptophan	4.0	0.28	0.69 (40.57)
Histidine	10.0	0.70	2.56 (27.34)
∑Essential	184.0	12.58	

*RDI Standard WHO [21]

Value in bold parentheses represent minimum recommended daily intake in grams of samples for adults' humans

Discussion

The moisture content of 8.34% in *M. bellicosus* is appropriate for a good shelf life because it reduces proteolytic, lipolytic and microbial proliferation when stored [22]. A similar result was reported for oven-dried winged termites, *M. bellicosus* by [7]. The crude protein of 36.15% in this sample is similar to the 37.7% obtained for roasted *M. bellicosus* [2]. It was however higher than the 20.94% and 29.94% reported by Igwe *et al* [23] and [4] respectively. The crude protein in this sample satisfies the 23-60% benchmark recommended for human foodstuffs [24]. The consumption of this insect could contribute to improved quality of dietary protein and the replacement of the unaffordable conventional animal proteins among rural dwellers in developing countries like Nigeria [5]. The fat content in the sample was lower than the range of 41.2-49.1&% obtained for winged termites by [6]. Our observation was however similar to the 22.5% reported for *M. notalensis* [25]. Fat is vital in the structural and biological functioning of cells. Fat helps in the retention and absorption of food flavour which contributes to its palatability and acceptability [23].

The ash content of 5.38% was higher than the 4.96% reported for *M. bellicosus* [7] (Akullo et, 1.20% reported by [2] and 4.10% by [26]. This was however lower than the 6.2-7.2% range reported by [27] and 7.6% reported for *M. nigeriensis* [23]. Ash represents the quantity of minerals in a food and helps in the metabolism of organic compounds like carbohydrates and fats [28]. *M. bellicosus* in our study has higher fibre compared to 0.20% and 1.60% reported by [2] and [4] respectively. Dietary fibre is very important in promoting peristalsis movement in the gut during digestion and a sense of satiety ideal for weight control [29]. Insects' fibre, a product of chitin is known for the establishment of beneficial probiotic bacteria which improve gut health, and confer anti-inflammatory, antimicrobial, antitumor and antioxidant properties [30, 31]. Generally, insects are regarded as low carbohydrate-high protein food which is recommended for the control of cardiovascular diseases and gain loss [32]. This accounted for the low carbohydrate content in our sample.

The mineral contents detected in this study are similar to those previously reported for termites [4]. The sample has an appreciable amount of iron, phosphorus, calcium, sodium, potassium, zinc and magnesium. Consumption of 100g of this termite would satisfy 37% of the 1000mg recommended daily intake (RDI) of calcium, 40% of 310mg RDI magnesium, over 100% RDI iron, 100% of 3-8% RDI zinc, 52% of RDI potassium [33, 34]. Iron is important in energy metabolism; improves the immune system, cognition and physical performance [32], magnesium and zinc prevent cardiomyopathy, muscle degeneration, impaired spermatogenesis, immune dysfunction and bleeding disorder [35]. Phosphorus is a co-factor for many enzymes, activates B-complex vitamins and is involved in the production of ATP [36, 37].

High amounts of phytate, saponin and cyanide were found to be present in our studied sample, while oxalate and tannin were relatively lower in quantity. This value was higher than the quantity reported for *M. bellicosus* [2]. Termites are herbivores and so they sequestrate these bioactive compounds from plants for subsequent modification into protective metabolites [38]. The variation in concentrations of these phytochemicals in insects may be due to the availability and distribution of specific plant species they feed on [39]. Antinutrient complexes with micro and macronutrients reduce their absorption and availability to the body [40]. However, their consumption has been proven to be of immense benefit to humans. For instance, consumption of moderate oxalate and saponin could reduce plasma and liver cholesterol [41, 42]. Minute alkaloids in diets are anticancer and antitumors with many other pharmacological benefits [43, 44]. This suggests that humans can improve their therapeutic arsenals against inflammatory infections by consuming winged termites [6].

Overall, leucine, isoleucine, valine, methionine, histidine and threonine were the most abundant indispensable amino acids, while glutamic acid and arginine were the most abundant dispensable amino acids in this sample. This is similar to the result presented for termites from three regions in Kenya [6]. Histidine, lysine and leucine are important amino acids for growth [45] while arginine is known to enhance calcium absorption [46]. The ratio of essential to non-essential amino acids of 0.69 satisfies the recommended value of 0.60 for human diets [25]. The percentage of branched amino acids (BCAA) of 19.4% in this termite satisfies the 10% recommended for the synthesis, repair and maintenance of muscle tissues [47]. Cysteine was the limiting sulphur amino acid while tryptophan was the limiting indispensable amino acid. The presence of lysine in *M. bellicosus* made it a complementary food for the enrichment of lysine-deficient cereals and low-protein diets in many developing countries. Despite the limiting status of tryptophan and cysteine, the consumption of at least 50.12g of this termite will provide the necessary daily requirement of all amino acids required in human adults.

Conclusion

The study showed that winged termite *Marcrotermes bellicosis* is rich in essential nutrient like protein, fats, minerals; amino acids with tolerable amount of anti-nutrients which when consumed can mitigate malnutrition in humans. They are therefore recommended as an alternative source of animal protein.

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Availability of data and Materials

Data and materials used during the study are available from the corresponding author on reasonable request

Conflict of interests

The authors have not declared any conflict of interests.

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