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THE NUTRITIONAL PROPERTIES OF THE EDIBLE TERMITE *MACROTERMES BELLICOSUS* (ISOPTERA: TERMITIDAE) IN BAYELSA STATE COASTAL REGION OF SOUTH-SOUTH NIGERIA

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ABSTRACT
The study aimed at ascertaining by proximate analyses, the nutrient composition and mineral content of winged adults and soldiers of the edible termite specie *Macrotermes bellicosus* as a healthy food supplement was carried out using methods spelt by Association of Official Analytical Chemists (A.O.A.C) in the Postgraduate laboratory of the Niger Delta University Wilberforce Island, Bayelsa State. The result obtained showed significant difference between the samples for all the tested parameters. Nutrient composition was moisture content (86.6%; 62.3%), crude protein (29.9%; 28.7%) and carbohydrate obtained by NFE (68.0%; 64.4%) and DM (14.4%; 37.6%). The results also showed low contents of ash (1.1%; 1.3%), crude lipid (2.8%; 3.8%) and crude fibre (0.2%; 1.6%) respectively for winged adults and soldiers. Mineral content of the termites *was* high for calcium (64.7 and 8.3 mg/100 g), magnesium (128.5 and 13.3 mg/100 g), sodium (112.6 and 11.8 mg/100 g), potassium (194.5 and 22.4 mg/100g), manganese (132.5 and 14.7mg/100g) and phosphorus (68.4 and 8.3 mg/100 g), iron (16. 7 and 1.1 mg/100 g), zinc (4.9 and 3.9 mg/100 g) and copper (1.8 and 0.2 mg/100 g) for winged adults and soldiers. Proximate moisture composition indicated that the termites have low shelf-life and are indeed a good source of protein and other micro- and macronutrients. Thus, *M. bellicosus* should be cultivated with modern techniques in order to increase their commercial value and availability. The nutritional content of *M. bellicosus* has proven that its consumption can supplement the daily dietary requirements of the nutrient intake in humans and livestock, hence should be included in the sustainable development goals of agricultural practices.

Key words: *Macrotermes bellicosus*, Proximate analyses, nutrient, mineral, food supplement

INTRODUCTION
The contribution of edible forest insects to human nutrition and to forest management cannot be overemphasized[1-4]. Entomophagy, as the practice of using insects as a part of the human diet[5], has played an important role in the history of human nutrition in Africa, Asia and Latin America[6-10]. Termites are significant detritovores particularly in the subtropical and tropical regions and their recycling of plant matter is of considerable ecological importance[2,11]. The negative view that most people have of termites prevails in many places, and it often masks the ecological role of these insects as mediators of the process of decomposition of plant organic matter and as agents with influence on the formation of soils and energy and nutrient flows, especially in tropical forests[12,13]. Termites though important in the decomposition of organic matter in the tropical regions, are also important food and medicinal sources across sub-Saharan Africa and India where they are consumed as delicacies both in rural and urban areas[14] owing to their nutrient composition[15,16]. Several species of termites are eaten as food by humans. Studies reveal that about 48 species are consumed by humans but the genus *Macrotermes* is the most eaten, especially the species *Macrotermes bellicosus*[17] which is eaten as a delicacy in different parts of Nigeria and several other African countries and also used for rituals and medicinal purposes[18]. Another important use of insects by humans is medicinal use, featuring a practice known as Entomotherapy[19-21]. It should be emphasized that, from a utilitarian perspective, termites are commonly used insects in traditional popular medicine[22-25]. They are used in the treatment of various diseases that affect humans, such as influenza, asthma, bronchitis, whooping cough, sinusitis, tonsillitis and hoarseness[26,27]. In India termites and even its termitarium have medicinal importance. Also in East Africa, termite mounds are considered so important that they are owned by an individual and form part of his inheritance upon demise[14,28].

Termites are highly nutritious with high levels of proteins, fats, vitamins and minerals with very little or no anti – nutrient, noxious chemical and microbial concerns, they seem a great food source, their inclusion in complementary food formulations have proved very satisfactory[29]. These insects are particularly important in countries where food sources are scarce, as the protein from termites can help improve the human diet. Termites are also used as food for non-human primates such as wild chimpanzees, Japanese monkeys and baboons in cites of Tanzania[30,31]. Termites are hemimetabolous isopterous insects that under incomplete metamorphosis[32,33]. They are eusocial insects that exhibit polyphenism in nature[34]. Termite castes eaten have been differentiated into alate (winged adults), soldier and queen[35]. The alates are the most consumed stage of termites in Africa due to their swarming behavior during "nuptial flight" to establish new colonies, especially after rainfalls[33,36]. The soldiers are also eaten, but they are mostly harvested from the mound itself by making holes and sending in twigs or sticks to get them out. The queen is the least eaten stage, as it is the most difficult to harvest since it entails damaging an entire termite mound to locate them[8]. The queen has longevity and has been proven to possess antioxidant property that help protects the human body from cell damage caused by free radicals (unstable molecules)[37]. The study is aimed at ascertaining by proximate analysis, the nutrient composition of the edible termite specie *Macrotermes bellicosus* as a healthy food supplement with the objectives of evaluating the nutrient and mineral contents of the termite.

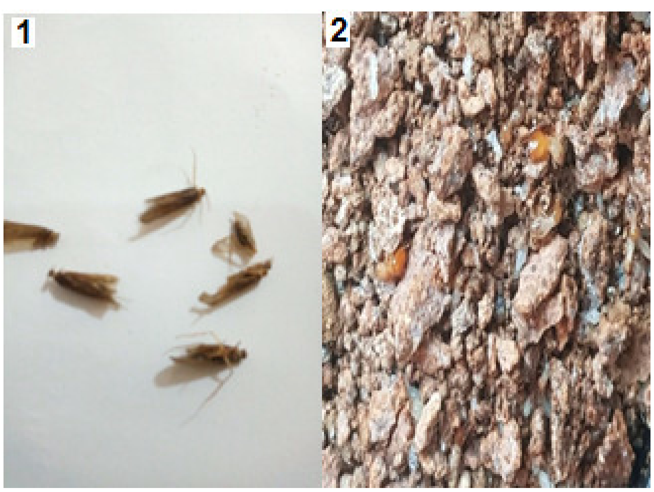

Plate 1-2: *Macrotermes bellicosus* winged adults and soldiers

MATERIALS AND METHOD

Adopting the methodology of[8,38], the winged adult termites (*M. bellicosus*) were collected during swarm flight under a light source in Azikoro village in Yenagoa Local Government Area while the soldiers were collected from a mound in Amassoma in Southern Ijaw Local Government area all of Bayelsa State. The samples were taken to the Postgraduate laboratory of the Niger Delta University, Wilberforce Island, Bayelsa State for identification and chemical analysis.

2.2 Methodology

Using the procedure of[38], the adults were dewinged and washed in water to remove dirt and soil particles and later oven dried at 40ºC for 8 hours. The dried termites were ground into powder, weighed and refrigerated at 4ºC for later use in the bioassay.

Proximate analyses of the nutrient content of the termites were determined using standard procedures spelt out by the Association of Official Analytical Chemists[39]. The content of the followings were determined: moisture, ash, crude protein, crude carbohydrate, crude fat and crude fibre.

2.2.1. Moisture content:

A clean porcelain crucible was dried in an oven to obtain a constant weight (a). Five grams (5g) of the sample was introduced into the crucible, the lid replaced and weighed to obtain the weight (b). The crucibles with contents were placed in the oven and the temperature set at 60ºC for 24 hours. This was allowed to cool in a constant weight (c) [39].

$$\% \, Moisture = \frac{b-c}{b-a} x \frac{100}{1}$$

.2.2 Ash content:

Two grams (2 g) of oven-dried sample was weighed in a crucible of known weight. The Crucible and content were placed in a muffle furnace and ignited at 550ºC for 15 hours and later cooled to room temperature in a desiccated desiccator. The ash and crucible were then weighed [39].

$$\%Ash = \frac{Weight \; of \; Ash}{Weight \; of \; Sample} x \frac{100}{1}$$

2.2.3. Crude protein content:

0.5g of each sample was weighed into a standard 500 ml Kjeldahl flask containing the Kjeldahl catalysts 1.5 g of copper sulphate ($CuSO_4$) and 1.5 g of sodium sulphate ($NaSO_4$), some anti bumbs chips and 5ml of Concentration hydrogen tetraoxosulphate (vi) acid (H_2SO_4). The digestion flask was placed on the digestion rack and heated gently for one hour to prevent charring and frothing. The heating was then increased about 4-5 hours until a clear bluish digest was observed. The digest was cooled and quantitatively transferred into a 50 ml standard flask and made up to the mark with distilled water. 10 ml of this solution was transferred in a kjeldahl distillation flask, treated with 10 ml

of 40% sodium hydroxide (NaOH) and heated. The gas ammonia is collected in a conical flask containing 10 ml of 5% boric acid into which 2 drops of the mixed indicator was added. The tip of the distillation condenser is positioned in a way that the tip is immersed into the conical flask and the distillation continued until about 3 times, the original volume was obtained. The boric acid, mixed indicator solution turned green as ammonia was distilled into it [39].
A 50ml burette was then filled with 0.1M HCl solution and the distillated was titrated.

$$\% \, Nitrogen = ml \, HCl \, (sample) - ml \, HCl \, (blank) x \, \frac{14}{1000} x \frac{50}{10} x \frac{100}{0.5}$$

$$\% \, Protein = \% \, N \, x \, 6.25$$

2.2.4. Crude lipid of extract:

0.5g of the oven-dried sample were accurately weighed into a thimble. About 200ml of petroleum ether was poured into a previously weighed round bottom flask containing weighed anti bumping granules. A blank deformation was also done without the 0.5g sample. The soxhlet extractor and the thimble with its contents were filled into the flask and the set up was placed on a heating mantle. The flask was heated slowly on the heating mantle until the solvent in the extraction was complete. The thimble was removed and air-dried. The extracted lipid in the flask was concentrated using rotary evaporator which was further dried in a desiccator and then weighed. The amou nt of lipid extracted was obtained from the difference between the weight of the flask before and after extraction[39].

$$\% \, Lipid = \frac{Weight \, of \, Extract}{Weight \, of \, Sample} x \, \frac{100}{1}$$

2.2.5 Crude fibre:

The procedure involved acid digestion, filtration and base digestion. Two grams (2g) of fat free sample was weighed and quantitatively transferred into a 400ml beaker which has a mark at the 200ml line. 50ml of 1.25% H_2SO_4 was added and the mixture made up to 200ml mark with distilled water.
The beaker was then boiled for 30 minutes. The contents of the beaker were filtered through a funnel with the end of a suction pump. The residue was washed severally with hot water until it was acid free.
The residue was then transferred into the 400ml beaker and 50ml of 1.25% NaOH solution was added and made up to the 200ml level, with distilled water. The mixture was brought to boiling for 30mm with stirring. The contents were filtered through a funnel and washed severally with hot water until it was free from NaOH. Finally the residue was washed with 95% ethanol twice and transferred into a porcelain crucible and dried at 100°C [39].

$$\% \, Fibre = \frac{Weight \, of \, dried \, fibre}{Weight \, of \, fat \, free \, sample} \, x \, \frac{100}{1}$$

Mineral contents such as calcium, magnesium, sodium, potassium, iron, manganese, copper, zinc and phosphorus were also evaluated using standard atomic absorption method of Association of Official Analytical Chemists[40]. Two grams (2g) of each sample was ash at 550 °C for 15 hours in a muffle furnace. The resulting ash was then acid digested in 15ml of concentrated Nitric acid (HNO_3). 20 ml of distilled water was added to the acid digest to dilute the solution. The solutions were filtered into 100 ml volumetric flask and made up to the mark with the distilled water. The samples were then aspirated on the Atomic Absorption Spectrophotometers for the variation of elements.

2.3 Data analysis

Proximate composition of the samples was done using three experimental evaluations. Statistical analysis and significant difference tested at alpha level $p< 0.05$ was done using Microsoft excel version for window 2010 while results were presented in tables as mean and standard deviation of three replicates. Mean differences in mineral composition and nutrient contents between the winged adults and soldiers were determined by one way ANOVA (two-factor with replication). Confirmation of significant difference was done using software staplus.

RESULTS AND DISCUSSION

Table 1 below gives the result for proximate analysis of the nutrient contents of *M. bellicosus* adult and soldier which was proven to be high in moisture content (86.6% and 62.3%), in crude protein (29.9% and 28.7%) and carbohydrate, analyzed in two ways: nitrogen free extract (NFE) (65.98% and 64.38%) and difference method (DM) (14.38% and 37.65%). The results also showed low contents of the followings: ash (1.1% and 1.5%), crude lipid (2.8% and 3.8%) and crude fibre (0.26% and 1.6%) respectively.
The results of this study further reveals the mineral content of *M. bellicosus* winged adult and soldier termites as follows: calcium (64.7 mg/100g and 8.3 mg/100g), magnesium (128.5 mg/100g and 13.3 mg/100g), sodium (112.6 mg/100g and 11.8 mg/100g), potassium (194.5 mg/100g and 22.4 mg/100g), manganese (132.5 mg/100g and 14.7 mg/100g) and phosphorus (68.4 mg/100g and 8.6 mg/100g) but showed low contents for iron (16.7 mg/100g

and 1.1 mg/100g), zinc (4.9 mg/100g and 3.9 mg/100g) and copper (1.8 mg/100g and 0.2 mg/100g) with the lowest content as presented on table 2.

As the practice of entomophagy is gradually gaining acceptance all over the world by which people can

Table 1: Proximate analysis of the nutrient contents of *M. bellicosus* winged adults and soldiers

Nutrient	Composition (%)	
	Adult	Soldier
Moisture Content	86.6±1.0b	62.3±0.6a
Ash content	1.1±0.6a	1.5±0.7a
Crude protein	29.9±3.2b	28.7±3.1b
Crude lipid	2.8±1.0c	3.8±1.1c
Crude fibre	2.8±0.3c	1.6±0.7c
Carbohydrate (Difference Method)	14.4±2.2b	37.6±3.5a
Carbohydrate (Nitrogen Free Extract method)	68.0±4.7a	64.4±4.6a

Results are presented as mean percentages of three experimental evaluations. There was significant difference recorded. Different letters used showed significant differences along rows or samples at p<0.05

supplement the meager protein content of their high carbohydrate diets, termites have been found to be highly nutritious and insects that possesses high levels of proteins, fats, and minerals. Like nutrient composition of other edible insects, the nutritional values for termites are highly variable, these variations have been attributed to the origin of species, insect food substrates as well as measuring methods employed [10,41].

The moisture content of the winged termite was high measuring 86.8% and soldier 62.3% and is in agreement with that of [42]: 62.6-69.1%. This is indicative of the fact that the termites possess a shorter shelf life and cannot be stored for a long period of time, hence should be consumed earlier upon preparation. This result varies significantly with those of other authors such as [43]: 6% and [44,45]: 43%. The reason for the variable is largely dependent on the drying technique used.

Ash content value of winged termite and soldier was 1.1% and 1.5% respectively. This is in comparison with that obtained by[43]. The low ash content of the termite is indicative of the absence of contaminants and can retard the growth of microorganisms. This value is also in line with the recommended ash content value for meat and dairy products (0.1-0.2%).

Crude fibre content for the adult was 2.8% and 1.6% for the soldier. This compares favorably with that of [43] and also aligns with the result of[40] who reported 2.0% and 1.8% respectively. This is as a result of feeding habit of the termites and the presence of different compounds such as protein and lipids that are bound to the chitinous exoskeleton[46].

The crude lipid content of the termite (*M. bellicosus*) winged adult and soldier was (2.8%, 3.8%) and is in agreement with the reported mean of crude lipid content (2.9%, 2.52%) for *M. bellicosus* as by [42] but was higher in *M. falciger* (46.5) as reported by [43]. Fat is also vital in the structural and biological functioning of cells. The implication of the low fat content in the termites is that it decreases the chances of insect fat content to storage deterioration by lipid oxidation which is usually on the increase in insects with high fat content[43].

The crude protein (29.9%) was also in agreement with that of[42]: (29.75%);[18]: (20.94%) and[43-45]: (23.1%) and was higher in the adults than the soldiers (28.7%). This also aligns with the statement of [46, 47] that the type of feed consumed and the stage of metamorphosis are major derivatives of the protein content of insects which are reportedly more in adults than other developmental stages. The mean total protein level of the termite is higher and differs significantly from those of cow milk (3.8%), hen's egg (12. 4%) and beef (18.0%)[48] and those of raw beef (19-26%), cooked reptiles (11-27%) and raw fish/sea food (13-28%)[40,47], therefore can adequately supplement for the daily protein requirement of 23.56% of human. This can be substantially augmented by incorporating processed termite meat into children, pregnant and lactating mother's diets or even adults who are malnourished. If an adult male of about 70 kg body weight requires 35g of protein daily. Only about 113 g of the termite food would be required to provide an average adult man's minimum daily protein need[43]. It is therefore reasonable and economical to supplement diets with edible termite or be eaten as dessert, delicacy or appetizer to meet up with the protein demand of the body.

The result of the study also showed that the termites had appreciable content of carbohydrate be it winged adult or soldier (14.4%, 37.6%). This finding is also in agreement with the reported mean of carbohydrate content for *M. bellicosus* (36.7%, 34.8%) as reported by[42] which is also in comparison with that reported for *M. nigeriensis* (20.74%) by[18] and (16.5%) by[43] for *M. falciger*. Carbohydrates are important nutritive elements in the human body. They are the main energy source, can reduce consumption of protein and help in detoxification.

The levels of minerals present in the insects indicate that they are good sources of both macro and micro minerals for young, pregnant and lactating mothers. Calcium is a major mineral nutrient required in the diet of humans. The calcium content of the termite is 64.7 mg/100g which can complement the daily intake requirement of 100-120mg of human adult. The mineral calcium is essential for the building of bones and teeth, helps in muscle contraction and relaxation, nerve function, blood pressure regulation, immune system health and as a messenger in cell signaling[49]. It is extremely important to avoid loss of bone[50,51].

Magnesium is also a macro nutrient required daily in high amount in human diet (400-420 for men and 310-320 for women). It was revealed by the study to be present in the termite dry weight as 128.5 mg/100g. This value is in agreement with that obtained by[41] for *M. falciger* and can also complement for the daily requirement value needed by humans as magnesium is essential in making protein, muscle construction, nerve transmission, immune system health, metabolic processes and energy production synthesis of biomolecules[51]. It is also a structural component of cell membrane and chromosomes and is used in ion transport and cell migration.

TABLE 2: Mineral content of M*acrotermes bellicosus* adult and soldier

Mineral	Composition (mg/100g)	
	Adult	Soldier
Calcium	64.7±4.6a	8.3±1.7a
Magnesium	128.5±6.5b	13.3±2.1a
Sodium	112.6±6.1b	11.8±2.0a
Potassium	194.5±8.1c	22.4±2.7b
Iron	16.7±2.4a	1.1±0.6a
Manganese	132.5±6.6b	14.7±2.2a
Cupper	1.8±0.8a	0.2±0.3a
Zinc	4.9±1.3a	3.9±1.1a
Phosphorus	68.4±4.8b	8.6±1.7a

Results are presented as mean and standard deviation of three experimental evaluations. There was significant difference recorded. Different letters used showed significant differences along rows or samples at $p<0.05$.

Sodium as a macro nutrient is needed for proper fluid balance, nerve transmission and muscle contraction[31] with the recommended daily intake given as 1.5- 3.8 g of sodium chloride per day. The quantity found present in the dry weight of the winged adult and soldier (112.6 mg/100g and 11.8 mg/100g) termites respectively, far exceed the above recommended daily requirement by humans and thus can adequately supplement the sodium chloride daily intake. This result is in conformity with those obtained by[18]: (112.0mg/100g) and[43]: (118.7 mg/100g) for different Macrotermes species.

Potassium is another major mineral required in large quantity by humans for proper fluid balance, nerve transmission and muscle contraction[51]. It also acts as electrolyte in the body and functions as a cofactor for a number of enzymes. Its deficiency leads to fatigue, muscle cramps and abdominal pains[52]. It was found to be high in the termite (194.5 mg/100g) far exceeding the recommended daily requirement of 4.7g as reported by[53].

Iron and zinc deficiency are wide spread in developing countries, especially in children and women of reproductive age. According to[53], iron is a critical component of many metabolic proteins and enzymes. The iron content of the termite (16.7mg/100g) is in conformity which that reported by[53] as the recommended daily requirement of men: 8mg/100g, women: 18mg/100g and pregnant women: 27mg/100g in United States of America. It is also in line with that of[43] for *M. falciger* (18.6mg/100g). Iron contains the molecules haemoglobin found in red blood cells and myoglobin which carry oxygen in the body of animals to the tissues and also function as cofactor of various enzymes[44,51,52]. Iron deficiency leads to anemia, reduced physical activity and increased maternal morbidity and mortality. The iron content of the termite exceeds that contained in beef (6mg/100g) as reported by[54] and thus can supplement the daily requirement for men, women and children so as to combat anemia which stands as a major health issue in most countries all over the world.

Zinc is the micro mineral functioning as essential component of many enzymes which catalyze activation, cell division and immune system health action [53,55]. Its presence is needed for making protein and genetic material. It also functions in taste perception, wound healing, normal fetal development, sperm production, growth, development and sexual maturation, reproduction and neurological function[51]. It functions in cellular metabolic processes as structural part of cell membrane and transcription factor [53]. Zinc deficiency causes impaired growth and contributes considerably to the high infectious disease burden. From the result, zinc content is 4.9 mg/100g which can be complementary in infant feeds that could receive a boost with the addition of processed termites to the diets given that the recommended daily intake is 11 and 8 mg/100g respectively for men and women [51]. This composition also agrees with those reported by [43]: (5.3mg/100g) and [42]: (5.9mg/100g). Minerals are known to play important metabolic and physiological roles in the living system. Iron, zinc, copper and manganese strengthen the immune system as antioxidant enzyme cofactors. Likewise, magnesium and zinc prevent cardiomyopathy, muscle degeneration, growth retardation, impaired spermatogenesis, immunological dysfunction and bleeding disorders [53].

Copper is a cofactor of many enzymes involved in energy production, connective tissue formation and iron metabolism [53]. It is a component of oxidizing enzymes which contribute to oxidation-reduction reaction [41,50]. It is found in negligible amounts in the termite under study of about 1.8 mg/100g.

The mineral manganese is present in very high amount in the termite (132.5 mg/100g) which is above the stipulated recommended value for men (2.3 mg/100g) and women (1.8 mg/100g) as stated by [53]. This result also aligns with that of [43] who reported 147.5 mg/100g. Manganese functions as part of many enzymes which contribute to activate antioxidant activity in the mitochondria and assist enzymes in metabolism, bone development and wound healing [56]. Its deficiency leads to osteoporosis, diabetes and epilepsy [52].

Phosphorus is a minor mineral also found in the termite at 68.4 mg/100g. This is also in corroboration of earlier report by [43] which gave 84 mg/100g. It is reportedly essential for healthy bones and teeth. It also maintains acid-base balance, used as cell membrane component and functions as part of the energy molecules Adenosine Triphosphate (ATP) and Adenosine Diphosphate (ADP) which contain phosphate [51,52].

Finally, just like the nutrient composition of other edible insects, the nutritional values for termites are highly variable which is attributed to the origin of species, different ecotypes and age of termite, insect food substrates as well as measuring methods employed [2,10,51,57]. According to the following authors [9,58,59,60], species type, environmental condition, geographical location, feeding habits and developmental stages of the insects play important role in the variability of nutrient level of edible insects. Furthermore, the nutritional value of edible insect is dependent on the species type, insect stage of life, habitat, diet of insect, preparation and processing methods applied before consumption [54,61,62].

CONCLUSION

This study revealed that the termite (*Macrotermes bellicosus*) have high nutritional qualities. Proximate nutrient composition indicated that termites have low shelf-life with the adults showing high nutrient content values for moisture, protein and carbohydrates as against the soldiers which were high for ash, lipid and fibre contents respectively. Furthermore, the adults proved higher for all the minerals tested. The result of this study confirmed the fact that termites are indeed a good source of protein and other micro- and macronutrients and can supplement for the daily requirement of these nutrients when incorporated in diets.

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DISCLOSURE STATEMENT

The authors declare the absence of conflict of interest. The study was sponsored by the authors with no financial obligation received from any organization.

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