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Proximate and Mineral Composition of Edible Alate Termites (*Macrotermes subhyalinus*)(Rambur) in Nasarawa State, Nigeria

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Abstract

This study was aimed at evaluating the proximate and mineral composition of *Macrotermes subhyalinus*, an edible termite species, with a view to revealing any possibility of its use as a base for the formulation of new food/feed products as a possible means of combating malnutrition. A minimum size of 2 kg of adult winged termites was collected, oven-dried at 40°C to a constant weight and analysed according to official methods of analysis recommended by the Association of Official and Analytical Chemists (AOAC). The analysis revealed high protein (3.5 - 5.0 + 0.12%), fat (33.3 + 0.29%) and carbohydrate (24.1 + 0.12%) contents, yielding a calculated energy value of 560.1 kcal/100 g. Mineral analysis showed significant levels of 361.41 mg/g and 230.60 mg/g for phosphorus and calcium, respectively. The low moisture content (3.10 ± 0.02%) enhanced self-stability. These results indicated that this delicacy is a potentially rich source of nutrients that may be necessary for combating protein-related disease conditions prevalent in developing countries of the world.

Keywords: *Macrotermes subhyalinus;* edible insects; proximate analysis; mineral analysis; Nigeria.

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INTRODUCTION

In recent years, entomophagy, the eating of insects by humans, has attracted great interest worldwide from business companies and consumers (Van Huis and Timberlin, 2017). The commonly consumed insects in Nigeria include winged adult termites (*Macrotermes subhyalinus/Macrotermes bellicosus),* adult crickets (*Brachytrypes spp.),* adult short-horned grasshoppers (*Cytacanthacris naeruginosus unicolor*), rhinoceros beetle larvae (*Oryctes boas*) and larvae of butterflies and moths (*Anaphe spp.).*

In Nigeria, the food situation is worsening owing to increasing population and restrictions on the importation of food items among several other factors. This has resulted in a high incidence of hunger and malnutrition, a situation in which children and women are most vulnerable. Apart from the incidence of hunger posed by the worsening food situation, the widespread prevalence of protein-energy malnutrition (PEM) has resulted in high morbidity and mortality rates, especially among infants and children in developing countries, including Nigeria. While every measure is being taken to boost food production by conventional agriculture, including current interest focused on the possibilities of exploring the vast number of less familiar plant resources existing in the field (Ojiako and Igwe, 2008), almost zero interest has been shown in the consumption of insects, a traditionally recognised and available source of protein and fats.

The Food and Agriculture Organization of the United Nations (2013) suggests that edible insects have a high nutritional value, and their farming is environmentally friendlier compared to other animal protein sources (Ooninct et al. 2010). However, it is important to note that

entomophagy has limited acceptance due to its unfamiliarity to almost all Western cultures and is even considered a cultural taboo, which has limited its incorporation into the current Western diet.

Termites, particularly in their winged alate form, are traditionally harvested at the onset of the rainy season and relished as a delicacy across various Nigerian communities due to their nutty flavour and rich oil content (Ayotunde-Ojo and Omoyeni, 2024; Chesto et al., 2024). With the increasing burden of food insecurity, hunger and protein-energy malnutrition, especially among children and women in sub-Saharan Africa, alternative food sources are urgently needed (Aigbedion-Atalor et al. 2024; Hlongwane et al. 2020). The worsening food crisis, exacerbated by rapid population growth, climate variability and economic challenges, has prompted renewed interest in the nutritional exploitation of edible insects, which are often more accessible and affordable than conventional animal protein sources (Babirye et al., 2024; Makore et al., 2025).

In Nigeria, larvae of palm weevils and silkworms, grasshoppers, locusts, termites (alates), and crickets are used as food. Termites are the most widely accepted food in Nigeria (Fasoranti and Ajiboye, 1993).

Termites are social insects with colonies divided into "castes", which include workers, soldiers, winged adults, a queen and a king, and they are the most widely consumed insects in Africa. Winged termites are highly attracted to light and are collected for consumption as they emerge in swarms during the rainy seasons (Food Info Net, 1999-2009). Once roasted, the wings are removed either by sifting or rubbing them between palms. The finished product is either eaten or sold in the markets in Western and Eastern Nigeria as snacks (Banjo et al. 2006). Roasted termites can be sun-dried for future use.

Other than proximate analysis, it is paramount that nutritional research is geared towards micronutrients because the deficiency of these nutrients remains a public health concern, especially in undeveloped and developing countries. To this end, termite species with high micronutrient density can be screened and the mass rearing of these termite species encouraged to address lingering nutritional deficiencies (Kinyuru et al., 2013). Similarly, several studies highlight the presence of high zinc (Zn) and iron (Fe) content in edible termites (Verpoor et al. 2020). Termites can thus be used as dietary supplements during pregnancy to satisfy the high Zn and Fe demands in pregnant mothers (Kinyuru et al. 2013).

MATERIALS AND METHODS

Location and Period of the Experiment

The experiment was carried out in the entomology laboratory, College of Agriculture, Science and Technology, Lafia (COASTL), Nasarawa State (08°0' - 33°0' N and 080° - 320° E) of Nigeria, between January and May 2026.

Sample Collection and Preparation

A sample of *Macrotermes sunhyalinus* was collected around COASTL and environs during their swarming flights. The collected sample was divided into two portions. One fresh sample which was used to determine moisture content and fresh sample analysis, while the second sample was roasted for ten minutes over a gas cooker, de-winged, labelled as “Roasted Sample” and kept in a freezer at -40°C until ready for use.

Proximate Composition Analysis

Proximate analysis (moisture, crude fat, crude protein, ash, crude fibre and carbohydrate) was conducted following standard procedures outlined in the official methods of analysis of the Association of Official Analytical Chemists (AOAC International, 2016).

- Moisture content was determined by drying approximately 2 g of fresh sample at 105°C for 4 hours.
- Crude fat was extracted with petroleum using a Soxhlet apparatus.
- Crude protein was measured using the Kjeldahl method and converted by multiplying the nitrogen content by 6.25.
- Ash content was determined by incinerating samples in a muffle furnace at 550°C for 4 hours.
- Crude fibre was analysed through sequential acid and alkaline digestion.
- Carbohydrate Content was calculated by difference:

% carbohydrate = 100 - (% moisture + % protein + % fat + % ash + % fibre).

2.4 Mineral Composition Analysis

Minerals including sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and iron (Fe) were determined using atomic absorption spectrophotometry (AAS) (PinAAcle 900T, PerkinElmer, USA). Approximately 0.5 g of powdered sample was digested using a mixture of nitric acid and perchloric acid (3:1 v/v), filtered and diluted to 50 ml with deionised water. The concentrations of elements were measured against calibration curves prepared from certified standard solutions. Analytical quality assurance was performed using a standard reference material (NIST 1547 Peach Leaves).

RESULTS

Figure 1 presents the proximate composition of fresh and roasted *Macrotermes subhyalinus* expressed in grams per 100 grams of sample. The results reveal notable differences in the nutritional composition of the

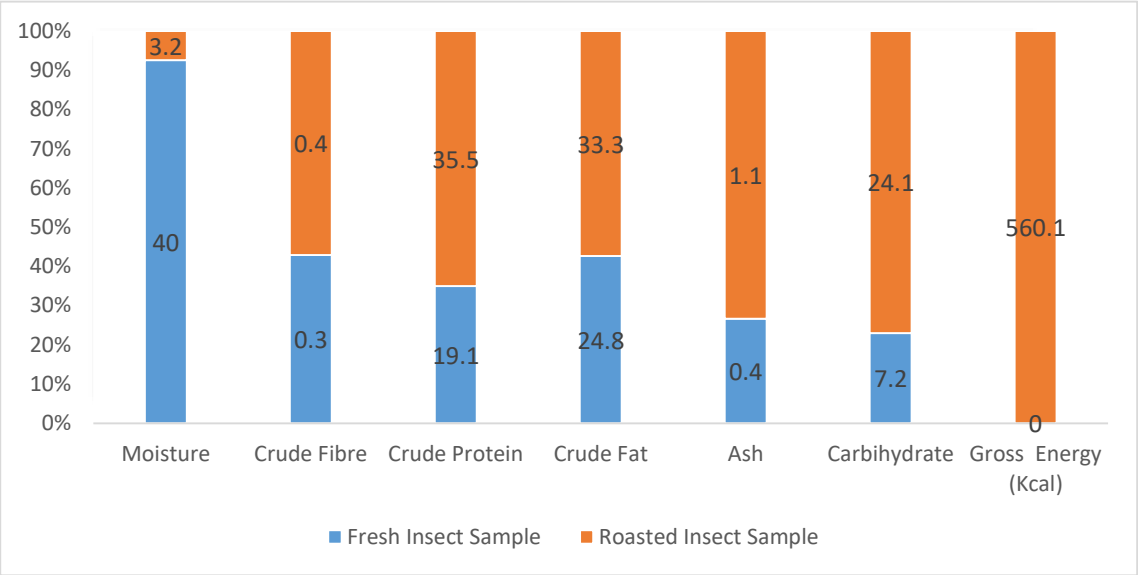

Figure 1: Proximate Composition of Fresh and Roasted *M. subhayalinus* (g / 100 g)

termite following roasting, indicating the significant influence of processing on its nutrient profile.

The fresh sample was characterised by a relatively high moisture content, reflecting the natural water composition of the insect. It also contained appreciable amounts of crude protein and crude fat, demonstrating its potential as a rich source of essential macronutrients. In contrast, the levels of crude fibre and ash were comparatively low, while carbohydrate content was present in moderate quantities. These findings suggest that fresh *M. subhyalinus* can serve as a valuable dietary source of energy and nutrients necessary for growth, tissue maintenance, and metabolic functions.

Roasting resulted in a highly significant reduction in moisture content ($P < 0.05$), which can be attributed to the evaporation of water during the heating process. The reduction in moisture led to a concentration effect on the remaining nutrients, resulting in significantly higher values of crude protein, crude fat, and carbohydrates in the roasted sample compared to the fresh sample. This increase does not necessarily imply the formation of additional nutrients but rather reflects the greater proportion of nutrients present after moisture loss.

Furthermore, the roasted sample exhibited a remarkably high gross energy value, which is likely due to its elevated fat and protein contents. Since fats provide more energy per gram than proteins and carbohydrates, the increased fat concentration following roasting contributed substantially to the overall caloric value of the insect. The enhanced energy density of the roasted termite highlights its potential importance as a nutrient-rich food source, particularly in regions where energy and protein deficiencies are prevalent.

The findings further demonstrate that roasting is an effective processing method for improving the storage stability and nutritional density of *M. subhyalinus*. By reducing moisture content, roasting may help prolong shelf life and reduce the risk of microbial spoilage while simultaneously enhancing the concentration of essential nutrients. Therefore, roasted *M. subhyalinus* may represent a highly nutritious and sustainable food resource capable of contributing to improved dietary quality and food security.

Figure 2 illustrates the mineral composition of fresh and roasted *Macrotermes subhyalinus*, expressed in milligrams per 100 grams of sample. The results indicate that both fresh and roasted termite samples contain a variety of essential minerals required for normal physiological functions, growth, and overall health. However, roasting significantly influenced the concentration of these minerals, resulting in generally higher mineral levels in the roasted sample than in the fresh sample.

Among the minerals analysed, phosphorus was the most abundant in both fresh and roasted samples. The roasted sample recorded the highest phosphorus concentration (361.49 mg/100 g), compared with 150.20 mg/100 g in the fresh sample. Phosphorus is an essential mineral involved in bone and teeth formation, energy metabolism, and cellular function. The high phosphorus content observed suggests that *M. subhyalinus* may serve as an important dietary source of this mineral.

Calcium was also present in substantial amounts, particularly in the roasted sample, where a concentration of 230.60 mg/100 g was recorded compared with 28.90 mg/100 g in the fresh sample. Calcium plays a critical role in skeletal development, muscle contraction, blood clotting, and nerve transmission. The elevated calcium content of the roasted termites highlights their potential contribution to maintaining healthy bones and teeth,

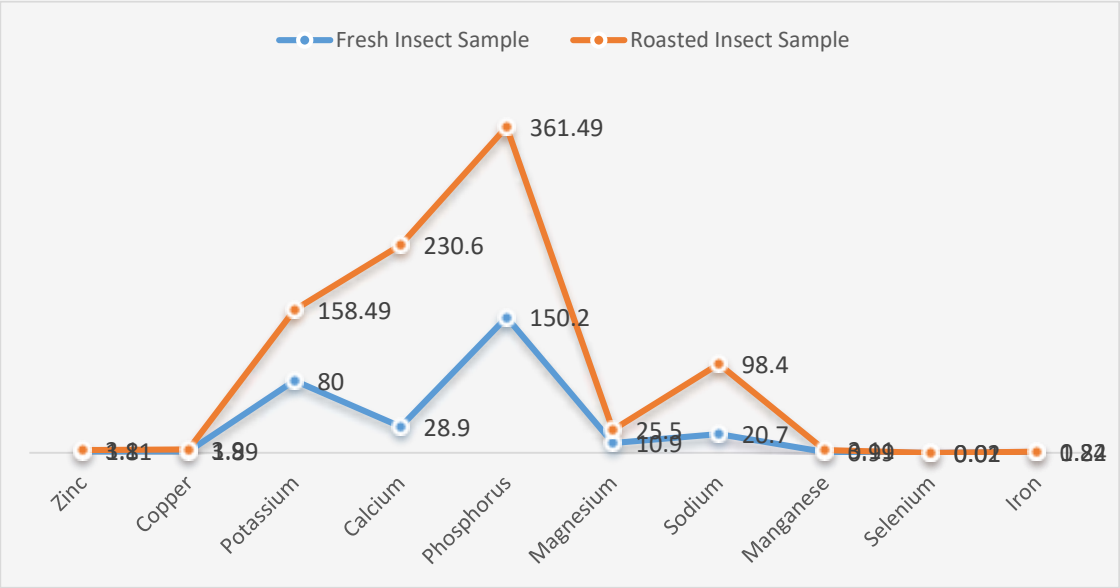

Figure 2: Mineral Composition of Fresh and Roasted M. sunhyalinus (mg/100 g)

especially in populations at risk of calcium deficiency.

Potassium was another major mineral identified in the samples. The roasted termites contained 158.49 mg/100 g, while the fresh sample contained 80.00 mg/100 g. Potassium is essential for maintaining fluid balance, regulating blood pressure, supporting nerve impulse transmission, and ensuring proper muscle function. The appreciable potassium content further enhances the nutritional significance of *M. subhyalinus* as a functional food resource.

Moderate concentrations of sodium and magnesium were also detected. Sodium levels increased from 20.70 mg/100 g in the fresh sample to 98.40 mg/100 g in the roasted sample, while magnesium increased from lower levels in the fresh sample to 25.50 mg/100 g after roasting. These minerals are vital for maintaining electrolyte balance, enzyme activity, nerve function, and muscle performance. Their presence contributes to the overall nutritional value of the insect.

Trace minerals, including zinc, copper, manganese, selenium, and iron, were found in relatively low concentrations in both fresh and roasted samples, with values generally below 4 mg/100 g in the roasted sample and below 2 mg/100 g in the fresh sample. Although present in smaller amounts, these micronutrients are biologically important because they participate in numerous metabolic processes, immune system functions, antioxidant defence mechanisms, and blood formation. Even at low concentrations, regular consumption of *M. subhyalinus* may contribute to meeting daily micronutrient requirements.

The generally higher mineral concentrations observed in the roasted sample can be attributed primarily to moisture loss during roasting, which concentrates the nutrients within the remaining dry matter. This finding demonstrates that roasting not only improves the shelf stability of the insect but may also enhance its nutritional density. Overall, the results indicate that *M. subhyalinus* is a valuable source of essential macro- and micro-minerals and has considerable potential to contribute to improved nutrition, food security, and the prevention of mineral deficiency disorders, particularly in regions where access to conventional animal protein sources is limited.

DISCUSSION

In Nigeria, caterpillars, grasshoppers and winged termites constitute an important part of the diets of the locals. *M. subhyalinus* is a delicious insect and highly relished food item in Nigeria among the rural populace but is also currently available in most urban markets in the country. The seasons when these insects are available are usually short-lived. However, the processed insects can be stored for 2-3 months, which increases the period of availability for consumption and income generation.

The observed high moisture content of fresh *M. subhyalinus,* as shown in table 1, was in agreement with the findings of Hlongwane et al. (2020), who reported a high moisture value for fresh animal products with 75% water content. The roasted *M. subhyalinus,* on the other hand, showed a highly significant reduction in moisture content, with a corresponding increase in its crude protein, fat and carbohydrate value ($P < 0.05$).

The high protein and fat contents (35.3 and 33.3%, respectively) in the roasted termite of this experiment align with the value characteristics of the *Macrotermes* genus (Cheseto et al. 2024; Makore et al. 2025). More so,

the high energy content of 560.1 kcal/100 g underscores the potential of *M. subhyalinus* as a high-energy food source, which is crucial for addressing calorie deficits in vulnerable populations.

The low moisture content (3.2%) in roasted termites is a favourable attribute that enhances the shelf-life and stability of the dried product by minimising the risk of microbial spoilage. The appreciable crude fibre of 0.4% may offer benefits for digestive health, while the ash content of 1.1% indicates a rich repository of essential minerals.

M. *Subhyalinus* is rich in essential minerals for healthy growth and development and normal physiological activities in the body. Phosphorus (361.49 mg/g) was the most abundant, followed by calcium (230.60 mg/g) and potassium (158.44 mg/g). Phosphorus and calcium are important for bone and teeth formation. Sodium, phosphorus and potassium maintain acid-base-water balance and nerve function in the body. Copper and iron are responsible for the formation of red blood cells and haemoglobin in the body, respectively (Marshall and Hughes, 1980). Electrolytes like phosphorus, calcium, magnesium, zinc, potassium and many more are essential for numerous physiological processes, including nerve transmission, muscle contraction and maintaining fluid balance. Results from this study revealed the presence of these elements in different volumes ranging from high to moderate and low in both fresh and roasted termite samples, with the roasted sample revealing significantly higher volumes of most essential elements over the fresh sample, except for moisture content, which is significantly higher in the fresh sample experiment. The detected levels of calcium (28.90 mg/g) and iron (0.84 mg/g) in this study were found to be relatively lower than those reported in some other termite studies (Chesto et al. 2024). However, they still make up a valuable dietary and medicinal source in that iron availability can contribute to the management of anaemia, an iron-deficient condition which is a prevalent health issue in this part of the world. Zinc deficiency causes impaired growth and contributes considerably to the high infectious disease burden. Complementary infant nutrition as well as pregnant mothers can receive a huge boost with the addition of naturally processed termite alates to their diets. These findings, therefore, reveal termites to be a good source of minerals for healthy foetal formation, infant growth enhancement, and sickle cell anaemia management, as well as the overall physiological balance in both humans and animals.

CONCLUSION

This study has demonstrated that *Macrotermes subhyalinus* is a valuable source of essential nutrients and minerals, particularly proteins and carbohydrates, which are critical for human growth, development, and overall health. The findings indicate that the termite possesses significant nutritional potential and can contribute meaningfully to addressing Protein-Energy Malnutrition (PEM), a persistent public health challenge in many developing regions of the world.

The high protein, fat, and carbohydrate contents observed in *M. subhyalinus* suggest that it can serve as an affordable and sustainable alternative source of nutrition. When properly harvested, processed, and incorporated into human diets, this edible insect could help alleviate nutritional deficiencies, especially among vulnerable populations such as infants, children, pregnant women, and low-income households. Protein-energy malnutrition remains a major cause of impaired growth, weakened immunity, poor cognitive development, and increased susceptibility to disease. Therefore, the promotion of nutrient-rich food sources such as edible termites may play a significant role in improving food security and public health outcomes.

Furthermore, the growing global interest in edible insects as sustainable food resources highlights the importance of exploring indigenous and underutilised species such as *M. subhyalinus*. Beyond their nutritional value, edible termites offer environmental and economic advantages due to their abundance, ease of collection, and relatively low production costs. Consequently, their inclusion in food systems could contribute not only to improved nutrition but also to sustainable livelihood opportunities and enhanced food sustainability.

RECOMMENDATIONS

Based on the findings of this study, nutritional, pharmaceutical, and food-processing industries should explore the incorporation of edible termites, particularly *M. subhyalinus*, into dietary supplements, fortified foods, and other nutrition-based products. Such initiatives could enhance the nutritional quality of food products while providing consumers with affordable and locally available sources of essential nutrients.

Additionally, governments, health organisations, and research institutions should support further studies on the nutritional composition, safety, processing methods, and potential therapeutic benefits of edible termites. Public awareness campaigns should also be implemented to promote the acceptance and consumption of edible insects, especially in regions where malnutrition remains prevalent.

Furthermore, investment in the commercial production, preservation, and value-added processing of edible termites could stimulate economic growth and create employment opportunities within local communities. Since termites are readily available and can be processed using relatively simple and cost-effective methods, their utilisation has the potential to improve both human and animal nutrition while enhancing the profitability and sustainability of food manufacturing enterprises.

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