

East African Journal of Agriculture and Biotechnology

eajab.eanso.org

Volume 9, Issue 2, 2026

p-ISSN: 2707-4293 | e-ISSN: 2707-4307

Title DOI: <https://doi.org/10.37284/2707-4307>



EAST AFRICAN
NATURE &
SCIENCE
ORGANIZATION

Original Article

Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions

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Article DOI: <https://doi.org/10.37284/eajab.9.2.5031>

Date Published: ABSTRACT

26 May 2026

Keywords:

Subterranean
Termites,
Termitidae,
Mangifera indica,
Saccharum
officinarium,
Zea mays and
Wood Substrates.

Termites are the most important invertebrates in terms of wood degradation and nutrient recycling, and they are important economically as a sustainable food source, especially in malnourished populations, since they provide high nutrients and minerals that are more bioavailable than those found in plant diets. This study aimed at determining appropriate and sustainable feed resources for artificial rearing of termites under natural ecological conditions and to evaluate the relative feed preference of termites between the selected feed substrates. The study was conducted using termite mounds in Sakwa, located within Bondo sub-county of Siaya County in Kenya. Termite mounds were selected for the study using random purposive sampling, the three specific study sites being designated as Bondo, Koyucho and Siaya. A Randomised Complete Block Design (RCBD) was used with the feed substrates sugar cane (variety KEN 82-216), maize cob (variety KH 500-33A), and mango wood (variety Dodo) being the treatments. Each treatment (substrate) was replicated three times within each site, the sites forming the blocks. The feed substrates were dried for 72 hours at 300C under a shade and subsequently chopped into 20 cm by 5 cm pieces. The dried pieces were then inserted according to the design into 45 cm by 30 cm rectangular holes excavated on the termite mounds at the rate of 900 g per hole. After 30 days, the mounds were opened/dug to remove the remaining feed substrates, which were then weighed. The termites (workers and soldiers) were removed and collected in a transparent bucket of 1000 ml. The collected termites were dried under room temperature for about 72 hours and finally oven-dried in the laboratory and ground into powder form, ready for proximate analysis. The leftover substrates were also removed and dried under room temperature (300C) and ground into powder form, ready for proximate analysis. The data was subjected to the analysis of variance (ANOVA) for Post-Hoc results with significant difference tests (LSD) and relevant correlation tests. The results of the study show that, based on the amount of wood substrate consumed by the termites, there was a higher relative preference for sugar cane (*Saccharum officinarum*) with a mean of $835.00 \pm 21.64g$, followed by maize cob (*Zea mays*) at $323.8 \pm 31.6g$, with Mango wood (*Mangifera indica*)

being the least preferred at $110.2 \pm 50\text{g}$. Relatively high levels were recorded for Protein and Energy contents in the termites, ranging from 320.8 ± 4.3 to $109.3 \pm 0.6\%$ calories for energy, 70.8 ± 0.3 to $38.3 \pm 0.2\%$ for protein. There was a positive correlation between the termites' wood consumption rates and the known wood preference determinants such as moisture ($r = 0.99$, $P < 0.001$), fat ($R = 0.98$, $P < 0.001$), and energy ($r = 0.81$, $P < 0.001$). Mineral content analysis of termites showed the highest amounts of iron (809.75 ppm) and manganese (311.56 ppm) in Mango wood. Maize cob, on the other hand, had the highest concentrations of copper (3.89 ppm). Iron is essential in transporting oxygen throughout the body via haemoglobin in red blood cells, while Copper is essential for energy production, iron metabolism and the formation of connective tissue. The study shows that termites had a higher relative preference for sugar cane wood over other maize cob and mango wood.

APA CITATION

Edwar, M. A., Watako, A., & Otieno, K. (2026). Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions. *East African Journal of Agriculture and Biotechnology*, 9(2), 121-138. <https://doi.org/10.37284/eajab.9.2.5031>

CHICAGO CITATION

Edwar, Modi Andrew, Arnold Watako and Kenneth Otieno. 2026. "Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions" *East African Journal of Agriculture and Biotechnology* 9 (2), 121-138. <https://doi.org/10.37284/eajab.9.2.5031>.

HARVARD CITATION

Edwar, M. A., Watako, A., & Otieno, K. (2026), "Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions", *East African Journal of Agriculture and Biotechnology*, 9(2), pp. 121-138. doi: 10.37284/eajab.9.2.5031.

IEEE CITATION

Edwar, M. A., Watako, A., & Otieno, K., "Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions", *EAJAB*, vol. 9, no. 1, pp. 121-138, May. 2026.

MLA CITATION

Edwar, Modi Andrew, Arnold Watako & Kenneth Otieno. Evaluation of Nutritionally Suitable Feed Resources for Rearing Subterranean Termites (*Termitidae*) Under Natural Conditions. *East African Journal of Agriculture and Biotechnology*, Vol. 9, no. 2, May. 2026, pp. 121-138, doi:10.37284/eajab.9.2.5031

INTRODUCTION

Termites are the most important invertebrates in terms of wood degradation, global carbon cycling and nutrient recycling, and they have amazing ecological consequences. Approximately 3,000 termite species have been identified in the tropics, subtropics and temperate zones. Termites can be classified into three main groups according to their habitat: subterranean, damp-wood and dry-wood termites (Baker & Marchosky, 2005; Paul & Rueben, 2005) Subterranean termites are closely associated with the soil habitat where they tunnel to locate food and water, such as wood, fallen logs and other cellulose-containing materials, and they have a tendency to migrate by forming networks in the

ground (Suiter et al., 2009). According to (Maynard et al., 2015), the name "subterranean" (*Macrotermes michaelseni*) refers to the fact that they nest inside or close to the earth in order to satisfy their significant need for moisture in their surroundings. Termites have a wide range of ecological, economic and societal roles (Govorushko, 2019), and methane (CH_4) produced by their associated methanogenic prokaryotes is among the most poorly constrained natural sources contributing to the global CH_4 budget (Saunois et al., 2019).

Ecological Role of Termites

Termites contribute significantly to the population of soil invertebrates and offer a range of ecosystem services as they maintain soil aeration, water

infiltration, water storage and transference at various sizes, and temperature management by conserving carbon through their activities (Jouquet et al., 2016). Termites affect the productivity and makeup of plant communities by soil translocation, tunnelling, and the decomposition and deposition of organic matter (faeces and saliva) (Maynard et al., 2015). Termites help recycle waste materials since they are adept scavengers and decomposers. According to (Freyman et al., 2008), termites eat a variety of items such as dung, live, dead, or decomposing plant materials, and soil that is high in organic matter. By recycling waste materials, including dead wood, excrement, plants and dead tissues at every stage of decomposition, termites contribute significantly to the environment (Bignell et al., 2011). In tropical regions, termites are known to decompose 50–100% of decomposing biomass and dead plants. Soil-based feeding is carried out by subterranean termites, which feed on soil particles and organic matter present in that environment (Boulogne et al., 2017). Termites are the most abundant insect group in all tropical terrestrial ecosystems, and their estimated total biomass (ca. 100 million tons) represents approximately 40% of the global biomass of soil arthropods (Rosenberg et al., 2023). Termites primarily consume cellulose and lignocellulose (Bignell & Eggleton, 2000). Termites may produce up to two litres of hydrogen from the breakdown of a single sheet of paper, making them one of the most efficient bioreactors in the world (Ibrahim & Adebote, 2012). Termites alone are responsible for at least 80% of termite-related losses. The term "subterranean" describes how termites build their nests inside or close to the ground to satisfy their significant need for moisture in their surroundings (Maynard et al., 2015). Termites are a major issue in both urban and rural settings worldwide because termites cause enormous financial losses by damaging numerous crops, plants, buildings and woodwork. Termites' ability to eat wood is influenced by a variety of conditions, and these factors have intricate interactions with one another. The type and

hardness of the wood, the presence of hazardous materials in other substrates, feeding inhibitors or deterrents, the degree of fungal degradation and the presence or absence of fungi, and the moisture levels of the soil and wood are the most significant of these factors (Nagnan & Clement, 1990). Depending on the features of the wood species in question, termites may begin, continue, or stop eating. The interdependence of the wood's mechanical, chemical, and physical qualities likely results in variations in its termite resistance. Moisture content (MC), the quantity and chemical makeup of wood extracts, physical hardness, the distinction between sapwood and heartwood, and the kind and severity of prior fungal assault are some of the variables that affect termites' choice of wood in the wild (McManamy et al., 2008). However, feeding is greatly impacted by a number of meteorological parameters, including the cellulose content, hardness, and relative humidity (RH) of the plant substrate. The dry-wood termite *Cryptotermes brevis* favored poplar and maple woods over other woods that the colony typically rejected, according to a study published in (McMahan, 1966) publication. However, a range of environmental parameters, including cellulose and hardness, have been studied in relation to termites' eating and foraging preferences (Gautam & Henderson, 2011).

Termites have a close mutualistic interaction with a range of endomicrobes that reside in the hind intestine, such as flagellates, bacteria, and archaea, to help with the digestion and preparation of cellulose for assimilation. In certain species, protozoans in a specialised midgut help break down cellulose (Tokuda et al., 1997). Termites' ability to eat wood is influenced by a variety of conditions, and these factors have intricate interactions with one another. The type and hardness of the wood, the presence of hazardous materials in other substrates, feeding inhibitors or deterrents, the degree of fungal degradation and the presence or absence of fungi, and the moisture levels of the soil and wood are the

most significant of these factors (Nagnan & Clement, 1990).

Nutritional Potential and Cultural Uses

Termites are an important part of the food culture in the Lake Victoria region of East Africa (Ayieko et al., 2007). Due to their high-calorie and excellent protein content, termites are consumed throughout much of the world (Pearce, 1997). In various regions of Africa, Latin America, Asia, and Australia, they are frequently a part of people's diets (Gope & Prasad, 1983). In many households in western Kenya, termites are considered a delicacy by almost all ethnic groups. Edible termites are a significant, useful, economical and sustainable food source, especially in malnutrition interventions (Ordoñez-Araque & Egas-Montenegro, 2021). Termites are believed to provide high-quality nutrients, including well digested proteins (Kinyuru et al., 2013) and minerals that are more bioavailable than those found in plant diets (Khan & Ahmad, 2018). In less developed countries where malnutrition is common, (Katayama et al., 2008) found 43 species of termites that are used as food for people because termite proteins are believed to improve diet. Their protein, fat (lipid), and essential amino acid content gives them a noteworthy nutritional benefit (Harris, 1970). Several studies have found that edible termites have a high Zn and Fe content (Verspoor et al., 2020). Termites can therefore be used as dietary supplements to satisfy the increased Zn and Fe requirements of pregnant women (Kinyuru et al., 2013). Additionally, termites can be used to improve and strengthen a variety of foods, including bread, hamburgers, meat loaves, crisps and more (Ordoñez-Araque & Egas-Montenegro, 2021).

Edible termites can produce a range of industrial goods and bioactive chemicals, including peptides, enzymes, polyunsaturated and monounsaturated fatty acids, antioxidants, and antimicrobial compounds, in addition to food (Siddiqui et al., 2023). Because of their great nutritional content, termites are used as food by humans and as feed by

many animals in many civilisations (Harris, 1970). From a utilitarian perspective, termites are commonly used insects in traditional popular medicine (Alves et al., 2014). Termites are used to treat a variety of conditions, including whooping cough, sinusitis, tonsillitis, asthma, bronchitis, influenza, and hoarseness (Alves et al., 2014). According to Su & Scheffrahn (2000), subterranean termites are significant structural pests that result in significant damage.

Limitations in Current Utilisation

Farmers collect termites by breaking their mounds or by trapping them using various methods. (Kenis et al., 2014). However, harvesting termites becomes challenging when high quantities are needed for food or to feed a larger flock or to increase the proportion of protein food or feed in the diet. The abundance of termites varies with seasons and regions, and in recent years, especially in western Kenya, termite populations have decreased, forcing harvesters to walk increasingly long distances to collect the necessary number of termites for food and to feed their poultry. Consequently, many farmers in the Western stop feeding their poultry with termites, without finding alternative protein sources (Sankara et al., 2018). Termites are eusocial and live in large colonies of up to several million individuals; they are herbivores, and either plant-dwelling (one-piece termites), wood feeding, or soil-feeding and nest on, in or adjacent to the substrate they consume, often within trees or directly in the soil (Staunton et al., 2008). Termites can feed on dead wood, grass litter or soil organic matter (Donovan et al., 2001), and are thus prime examples of animals that rely on nitrogen-poor food sources (McManamy et al., 2008). Termites often prefer early wood, i.e. the wood that develops in spring with an abundance of rain and nutrients, which is generally softer and less dense, and is preferably consumed (Neoh et al., 2012). A variety of substances have also been discovered to be present in *Mangifera indica* (Barreto et al., 2008), primarily polyphenolic compounds (flavonoids,

xanthenes, and phenolic acids) that are present in the plant's fruits, leaves, bark, and kernels (stone) (Dorta et al., 2012).

Need for Controlled Rearing

In view of the current challenges in field harvesting of termites, there is a need to develop simple, sustainable methods to harvest and store termites for use as needed without affecting the environment and local biodiversity (Sankara et al., 2018). However, the ongoing need for non-food and feed-based sources led to the use of less expensive and sustainable resources for their bioconversion through fundamental pathways of microbial bioconversion into value-added products of commercial interest (Hatti-Kaul et al., 2007). This study aimed at determining appropriate and sustainable feed resources for artificial rearing of termites under natural ecological conditions and to evaluate the relative feed preference of termites between the selected feed substrates.

MATERIALS AND METHODS

Study Site

The study was conducted in Sakwa, located within Bondo sub-county of Siaya County in Kenya. Termite mounds were selected for the study using random purposive sampling. The three specific study sites were Bondo, Koyucho and Siaya. The region is situated approximately 0.053°N and 34.284°E. The area has an average annual temperature of 21.4°C and an average annual rainfall of approximately 1000mm to 1500mm.

Experimental Design

The experiment employed a Randomised Complete Block Design (RCBD). The treatments sugar cane, a variety (KEN 82-216), maize cob, a variety (KH 500-33A) and mango wood variety (Dodo), commonly produced by local farmers and majorly found in Western Kenya, were randomly assigned to plots within each of the selected sites, which served as blocks. Each treatment (substrate) was replicated three times within every block for site-specific

variability in each chosen termite's mound. 45 cm by 30 cm rectangular holes were excavated for the study.

Preparation of Plant Feed Substrates for Feeding Subterranean Termites

The feed substrates were purchased from within the study site, and they were dried for 72 hours at 30°C under the shade. Following drying, the substrates were measured with a ruler and handsawn into 20 cm by 5cm pieces.

Procedure for Gathering Data

After every five (5) days, the mounds selected were checked for termites' response to foraging on the feed substrates placed in the mound holes dug at 45cm x 30cm. After 30 days of checking, the mounds were opened/dug to remove the remaining feed substrates, which were then weighed. The subterranean termites, workers and soldiers were removed and collected in a transparent bucket of 1000ml. The collected termites were dried under room temperature for about 72 hours and finally oven-dried in the laboratory and ground into powder form, ready for proximate analysis. The leftover substrates were removed and dried under room temperature (30°C) and ground into powder form, ready for proximate analysis.

Determination of the Weight of Feed Substrates Consumed by Termites was Achieved using the Wood Consumption Formula:

$$(i) W_c = W_1 - W_2$$

Where:

W_c: represents the weight of wood eaten by termites

W₁: represents the original weight of wood before feeding.

W₂: represents the final weight of wood left over after the termites feeding.

Laboratory Analysis of Substrate Samples

The termite samples were examined at the University of Nairobi's Food Science, Nutrition and Technology department's Chemistry Laboratory for their moisture content, crude fat, crude protein, ash, fibre, carbohydrates, and energy (Kcal/100g).

Determination of Moisture Content

The oven drying method was used to determine the moisture content. After 30 minutes in the moisture oven at 105°C, the moisture pans were cooled in a desiccator. Using an analytical balance, the labelled pan was weighed (Wp) and then roughly 1g of the sample was weighed (Ws) and put on the pan. The samples were dried at 105°C for the entire night in the moisture air oven. After cooling the contents (the sample and crucible weight) to room temperature in the desiccator, the final weight (Wf) was determined.

The following formula was used to calculate the moisture content as a percentage:

$$(ii) \text{ Moisture content (\%)} = \frac{(W_s - W_f)}{(W_s - W_p)} \times 100$$

Where;

Wc: Is Pan Weight

Ws: Is the pan's and the sample's weight before drying

Wf: Is the pan and sample weight upon drying

Esther Extraction of Fat Content Determination

By dissolving the samples in petroleum ether (B.P 60-80°C) and then evaporating the ether in a Soxhlet device, the fat content of termites fed on the substrates was determined (Plate 4). The filter paper was folded around the sample into a cylindrical shape that fit into an extraction thimble, and a paper towel was used to cover the filter paper after each sample weighed two grams (W1). 250 ml of a round-bottomed, pre-dried flask (W2) was weighed, and 250–300 ml of petroleum ether (60–80°C) was added to the solvent flask. The distillation process was then initiated by connecting the solvent flask to

a distillation chamber. Following the solvent's distillation, the flask was taken out and heated to 105°C for roughly half an hour in an air oven. After that, the flask was taken out and allowed to cool in the dissector before being weighed (W3). The following formula was used to determine the fat content:

$$(iii) \text{ Crude fat (\%)} = \frac{(W_3 - W_2)}{W_1} \times 100$$

Where;

W1: Is the sample weight of subterranean termites in the ground.

W2: Is the solvent flask's weight.

W3: Is the combined weight of the extracted crude fat and the solvent flask.

Crude Protein Determination

Using the Kjeldahl method, crude protein was calculated by multiplying the feed's nitrogen content by 6.25 after it was measured. This component is based on the observation that 16% of protein is nitrogen. Digestion, distillation, and titration are steps in the process.

Digestion: A Kjeldahl flask containing about 2g of sample was weighed, and 25ml of concentrated sulfuric acid, 0.5g of copper sulphate, 5g of sodium sulphate, and a speck of selenium tablet were added.

After that, this was heated gradually in a fume cupboard to avoid excessive foaming, and it was left to digest for 45 minutes or more, or until the digesta turned a clear, pale green colour. After letting it cool fully, 100 millilitres of pure water were added quickly. Rinsing was added to the bulk after the digesting flask was rinsed two or three times.

Distillation: Distillation was done using Markham distillation equipment. After heating up the distillation apparatus with steam, 10 millilitres of the digest were poured through a funnel and let to boil. In order to prevent ammonia loss, ten millilitres of sodium hydroxide were subsequently

added from the measuring cylinder. This was reduced to 50 millilitres of 2% boric acid with methyl red indicator that had been tested.

Titration: 0.1N HCL was used to titrate the alkaline ammonia borate that was produced during distillation. The amount of acid utilised, or the titre value, was noted. Next, the acid volume used was entered into the following formula:

$$(iv)\%N = (14 \times VA \times 0.1) / 1000 \times 100 \times W \times 100,$$

Where;

VA: Stands for acid volume utilised, and

W: Stands for sample weight.

The crude protein was then calculated using the % N as follows: % crude protein = % N X 6.25

2.6.4 Crude Fibre Determination

A graduated 600 ml beaker containing a 1 g sample was filled with a modest amount of boiling distilled water and 25 ml of 2.04 N H₂SO₄ solution (Plate 6). Boiling distilled water was used to fill the 200ml capacity, and the mixture was left to boil on a hot skillet for around half an hour. A Buchner funnel that had been slightly packed with glass wool was used to filter the mixture, and boiling distilled water was used three times to wash away the leftover material. Following a quantitative transfer of the residue and glass wool back to the beaker, a tiny amount of boiling distilled water and 25 millilitres of 1.78 N KOH solution were added. More boiling distilled water was added to the amount to reach 200 ml, and the mixture was kept boiling on a hot skillet for 30 minutes. Once more, glass wool was used as a filter assist to filter the boiling samples, and they were then cleaned as before. After two hours of drying at 105°C in an air oven, the residue was chilled in a desiccator and weighed. After being moved into a crucible, the residue was ashed for four hours in a muffle furnace (400–6000C), cooled in a desiccator, and then weighed. Lastly, the sample's crude fibre content was determined using the formula:

$$(v) \text{ Crude fibre } (\%) = \frac{(P2 - P3)}{P1} \times 100$$

Where;

P1: represents the termite sample weight (g),

P2: the crucible and termite sample weight (g), and

P3: the crucible and termite sample weight (g) following cremation.

Ash Content Determination

Ash is the inorganic waste that results after four hours of 400–6000C burnt organic feedstock in a muffle furnace. A preheated crucible was filled with around 2.0g of the sample. After cooling in a desiccator for four hours at a temperature between 400 and 6000 degrees Celsius, the crucible was weighed. The ash content was computed as follows:

$$(vi) \% \text{ Ash} = \frac{(\text{wt of crucible} + \text{ash} - \text{wt of crucible})}{\text{wt of sample}}$$

Mineral Determination

Under mineral content determination, the samples are homogenised, weighed (1g), and dried at 105°C for one hour. The samples are heated in a muffle furnace at 550°C for approximately three hours until all organic matter is removed, and no carbonaceous particles remain. After cooling in a desiccator, the ash is dissolved in 1ml of nitric acid (HN03) within A 250 ml volumetric flask. The solution was diluted to 250 ml with distilled water and filtered through filter paper. The mineral concentration (Cu, Mn, Zn, Fe, and Mg) was measured using an Atomic Absorption Spectrophotometer (AAS) after a 10-minute warm-up period.

Data Interpretation

One-way ANOVA was used to analyse the data, and Minitab 17 Statistical Software and the R Project (R Version 2021) were used to perform the Least Significant Difference (LSD) test for post-Hoc results tests, and correlation coefficient of the termite's consumption rate with nutrient composition were carried out.

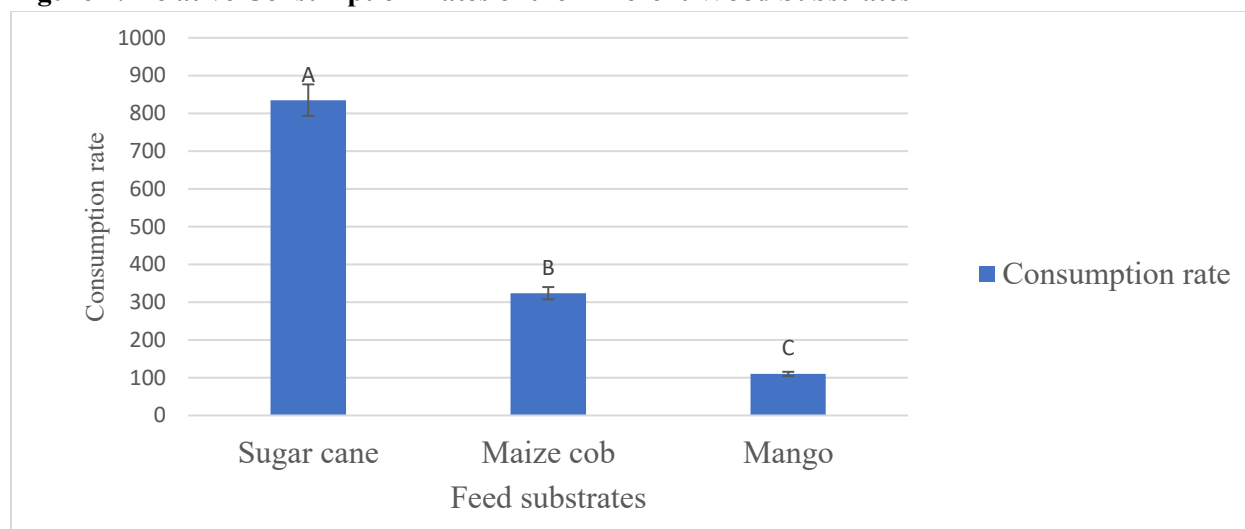
RESULTS OF THE STUDY

Feeding Preference of the Feed Substrates by Termites (*Macrotermes michaelseni*)

The Feeding preference on the feed substrates by termites (*Macrotermes michaelseni*). Based on the

results, Sugar cane (*Saccharum officinarum*) had the highest consumption rate ($835.00 \pm 21.64\text{g}$), followed by maize cob ($323.8 \pm 31.6\text{g}$) and mango wood ($110.2 \pm 50.5\text{g}$) respectively, as shown in Figure 1.

Figure 1: Relative Consumption Rates of the Different Wood Substrates



The Correlation Coefficient between Consumption Rates and Nutrient Composition

Pearson correlation analysis revealed that consumption rate was strongly and positively correlated with moisture ($r = 0.99$, $p < 0.001$), fat ($r = 0.98$, $p < 0.001$), and energy content ($r = 0.81$, $p < 0.01$), but negatively correlated with fibre ($r =$

-0.92 , $p < 0.001$), ash ($r = -0.97$, $p < 0.001$), and carbohydrate content ($r = -0.96$, $p < 0.001$). Protein content showed no significant association with consumption rate ($r = 0.50$, $p = 0.17$) as presented in the table below.

Correlation of Consumption Rate with Nutrient Composition

Table 1: Shows Significant Levels of Correlation between Consumption Rates and Nutrient Composition

Variable	Pearson r	p-value	Significance
Moisture	0.986	0.000001	***
Fat	0.976	0.000007	***
Ash	-0.969	0.000018	***
CHO	-0.960	0.000042	***
Fibre	-0.915	0.000533	***
Kcal	0.811	0.007969	**
Protein	0.499	0.1716	ns

Significance levels:

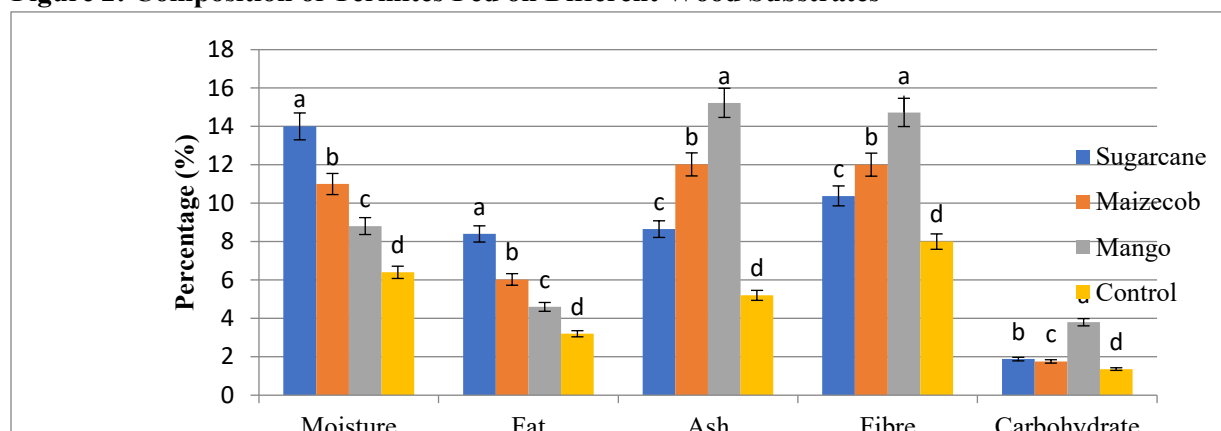
*** $p < 0.001$, ** $p < 0.01$, ns = not significant

Proximate Composition of Termites Fed on Different Plant Feed Substrates

The results in the graph below present an overview of the findings from the termites' proximal analysis. Termites (*Macrotermes michaelseni*) fed on different plant substrates had varying moisture contents. Termites fed on sugar cane (*Saccharum officinarum*) had the highest moisture content (14%), followed by termites fed on maize cob (*Zea*

mays) (11.1%), and termites fed on mango wood (*Mangifera indica*) (8.81%), with the lowest moisture content (6.4%) in the control. The ether extract/fat showed a similar trend, with sugar cane (*Saccharum officinarum*) exhibiting the highest fat content (8.4%), followed by maize cob (6.03%), mango wood (4.6%), and the control (3.2%), showing the lowest fat content.

Figure 2: Composition of Termites Fed on Different Wood Substrates

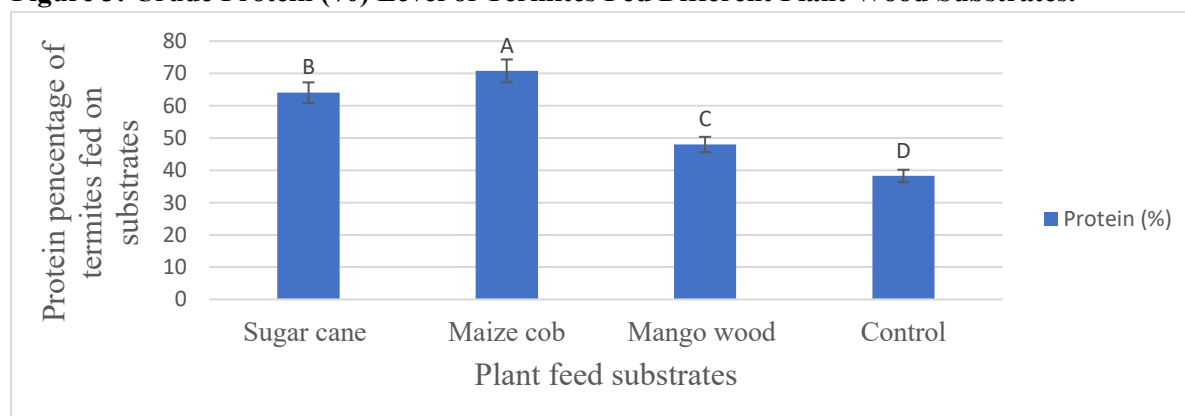


Crude Protein Level (%) of Termites Fed Different Plant Wood Substrates

Based on the data provided, there is an inverse relationship between the ash content of the food source and the resulting crude protein content in the termites (*Macrotermes michaelseni*): Mango wood had the highest ash percentage (15.23%), while the control had the lowest (5.2%). Meanwhile, termites

fed on maize cob achieved the highest protein levels (70.8%), whereas those fed on mango wood (the highest ash source) had significantly lower protein levels (47.9%). While mango wood contains the most mineral residue (ash), maize cob serves as the most effective substrate for maximising crude protein in this termite species.

Figure 3: Crude Protein (%) Level of Termites Fed Different Plant Wood Substrates.



Energy Content of Termites Fed Different Plant Wood Substrates

The energy content of the termites showed an almost similar trend: those given sugar cane had the

highest energy content (320.8%), followed by those fed maize cob (297.6%), mango wood (206.4%), and control (109.3%) termites, in that order (Figure 4).

Figure 4: Energy Content of Termites Fed Different Plant Wood Substrates

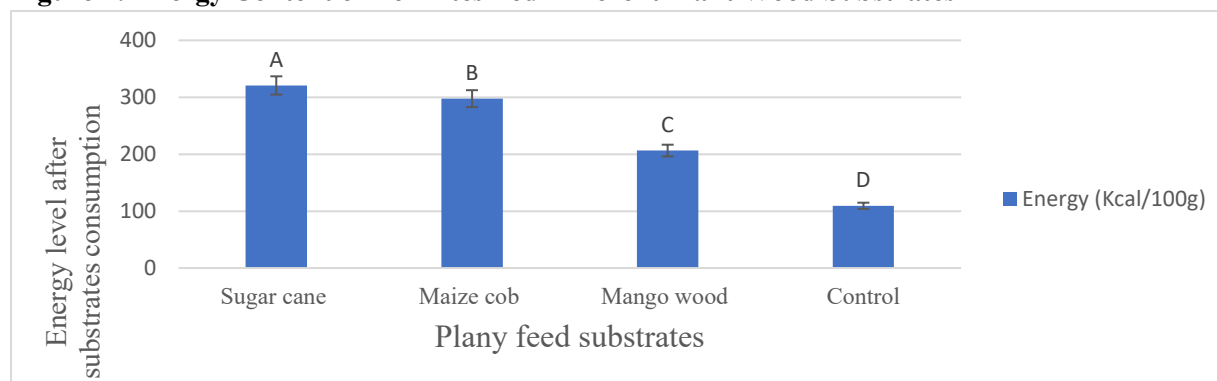


Table 2: Shows a Comparison of Selected Proximate Values in Termites Fed on Different Wood Substrates and Those on Other Feed Substrates

	Fat (%)	Protein (%)	Fibre (%)	CHO (%)
Termites fed on different Woods*				
Sugarcane	8.4 ± 0.12	64.03±0.5	10.4 ± 0.8	1.88 ± 0.72
Maize cob	6.03 ± 0.4	70.8 ± 0.3	12.4 ± 0.6	1.76 ± 1.0
Mango	4.6 ± 0.4	47.9 ± 0.3	14.7 ± 0.40	3.80 ± 0.2
Control	3.2± 0.2	38.3± 0.2	8.0 ± 0.8	1.36 ± 0.25
Sample proximate values for termites				
(Sogbesan & Ugwumba, 2008)	30.1	46.3	7.3	-
(Oyarzun et al., 1996)	15.04 ± 8.6	58.20 ± 3.67	-	-
(Ntukuyoh et al., 2012)	2.52 ± 0.10	56.44 ± 0.44	34.84 ± 0.10	34.84 ± 0.10

*Values determined by the author

Mineral Content of Plant Substrates for Feeding Termites (*Macrotermes michaelseni*)

The findings from the examination of the substrates' iron, copper, manganese, zinc and magnesium contents. Iron (809.75 ppm) and its relevance is crucial for transporting oxygen throughout the body via hemoglobin in red blood cells and myoglobin in muscle cells, and manganese (311.56 ppm) were highest in mango wood (*Mangifera indica*); copper

(3.89 ppm) relevantly essential for energy production, iron metabolism, and the formation of connection tissue and magnesium were highest in maize cob; and magnesium (2219.3 ppm) was highest in sugar. Magnesium acts as a cofactor in more than 300 enzymes, regulating diverse biochemical reactions cane, as displayed in the table below.

Table 3: Mean Data for Mineral Content of Different Feed Substrates Fed on by Termites

Substrates	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	Mg (ppm)
Mango	809.75 ± 0.686 ^a	0.00 ± 0.0000 ^b	311.56 ± 0.262 ^a	15.775 ± 0.134 ^c	1191.4 ± 5.75 ^b
Maize cob	260.19 ± 1.32 ^c	3.89 ± 0.0566 ^a	42.875 ± 0.445 ^c	18.020 ± 0.042 ^b	855.90 ± 0.304 ^c
Sugar cane	277.28 ± 1.36 ^b	0.00 ± 0.0000 ^b	49.950 ± 0.085 ^b	37.015 ± 0.035 ^a	2219.3 ± 2.45 ^a

DISCUSSION

Feeding Preference of Subterranean Termites

The feed preference by the subterranean termites throughout the feeding period under the selected feed substrates of mango wood, maize cob and sugar cane as listed in Figure 1 above. The results showed that the highest rate of wood consumption by the insect was observed throughout the period in sugar cane, with consumption of (835.00 ± 21.64g), followed by maize cob (324.8 ± 31.6g), and lastly mango wood (110.2 ± 50.5g) and was substantially different ($p \leq 0.001$). Wood consumption rates were employed to represent feeding preferences in this investigation and other studies of a similar nature (Ripa et al., 2007). As reviewed by Thorne et al. (2003), a number of authors identified factors that influence termite consumption rates, such as the size of the wood resource used in the study, the caste ratios of the colonies being tested, the ambient temperature in the laboratory or field, and termite mortality during the period. This can also be due to the variations in wood density that account for some of these preference patterns as Bustamante & Martius (1998) conducted research on five termite species that prefer low-density wood over higher-density wood. As sugar cane has been the highest preferred by termites in this study, according to Ali et al. (2021), who recorded that wood softness and palatability are key factors in wood feeding termites, with a remarkable preference for soft woods. Maize (*Zea mays* L.) cob is another material that contains abundant cellulose (Azubuike et al., 2012) for termites' feeding.

It has also been shown that wood density seems to be the main determinant of wood resistance against termites (Maynard et al., 2015). The contrasting results regarding wood density and hardness among

mango wood, sugar cane and maize cob highlight the complexity of termites' wood selection, suggesting that other factors, such as chemical composition or the presence of decay fungi, may play a more significant role in palatability. (Potter et al., 2008), Suitable woods are typically moist, or rotting in contact with the earth or kept moist in other locations. On maize cob preference, by the subterranean termites, a possible reason could be that maize cob contains more sugars and amino acid compounds known to increase bait attractiveness to termites (Lenz et al., 2011), and moreover, Hedlund & Henderson (1999) found that an increase in surface area of food increased the consumption by termites. Cobs are full of crannies, and the surface area is large relative to the dimension. On mango wood consumption, a variety of substances have been discovered to be present in *Mangifera indica* (Barreto et al., 2008).

On the other hand, termites often prefer early wood, i.e., the wood that develops in spring with an abundance of rain and nutrients, which is generally softer and less dense, and is preferably consumed (Waller et al., 1990). (Owoyemi & Olaniran, 2014) Research also revealed that wood species with higher density classes are more resistant to *Macrotermes michaelseni*, and that density and weight loss following exposure had a stronger correlation coefficient of 0.9. Using the water immersion method, it has been demonstrated that mango wood in Kenya has a higher wood density than Eucalyptus saligna, with values of 0.66g/cm³ and 0.54g/cm³, respectively (Olale et al., 2019). Both have a higher density than sugar cane or maize cobs, as maize contains 22% cellulose, 10 to 14 protein, 9 to 24% starch, 5% phenolic acids (mainly ferulic and di-ferulic acid), 2% ash and 2-3% lipid (Carvajal-Millan et al., 2007). According to Huang

et al. (2012), 40% to 50% cellulose, 25% to 30% hemicellulose, 15% to 20% lignin, and other extractable components make up plant biomass and sugarcane bagasse (SCB). However, as has been shown in Malaysia, using the density factor alone is insufficient to assess the durability of lumber, even if a number of previous studies indicate that densities influence the termite's capacity to mechanically break the wood using its mandibles. It is important to take into account additional elements, such as the existence of harmful extractives (Roszaini et al., 2022). Other factors, such as terpenes found in timbers of tree species with higher resin content or as found in some dense growth rings are repelling (Zahid et al., 2012).

The moisture content (MC) of wood is another significant element. In this investigation, the moisture content of sugar cane was substantially greater than that of mango wood and maize cobs, with reported moisture levels of $8.81\% \pm 0.20\%$, $11.1 \pm 0.5\%$, and $14.3 \pm 0.65\%$, respectively. According to certain theories, wetness is most likely the most crucial environmental factor for subterranean termite survival (Strickland, 1950). Certain insects' cuticles act as a strong barrier to prevent water from evaporating (Wigglesworth, 1945). Relative humidity (RH) in areas where subterranean termites are present is generally acknowledged to be the main factor influencing survival because soft-cuticle subterranean termites are less able to retain water and are therefore more susceptible to desiccation (Hallmayer et al., 2011). Because subterranean termites dwell in galleries made of soil or wood, the air spaces inside these structures get saturated with moisture when wood and termite nesting materials have a moisture content (MC) of greater than 16% (Castillo et al., 2013). If desiccation is mostly caused by water loss through cuticular permeability, then this would ensure termites' survival.

In a study by McManamy et al. (2008), termites exposed to wood with low moisture content (MC) under perfect temperature and relative humidity

(RH) conditions were unable to survive, showing that wood moisture content (MC) was a significant determinant in determining termite survival. Pearson correlation analysis revealed that the consumption rate was strongly and positively correlated with moisture ($r = 0.99$, $p < 0.001$); according to Gautam & Henderson (2011), moisture increases the damping of a substrate nonlinearly, reduces the Venner disc's resonance frequency, and weakens structural vibrations. It is known that termites carry water in sacs (salivary reservoirs) to moisturise their food (the wood) by secreting this water to eat when the wood is dry.

If wood had a higher moisture absorption capability, it would be more likely to absorb water from various sources and thus would require a small amount of water to be transported to reach the ideal moisture content level. (Nakayama et al., 2005), which could be advantageous for termites from an energy point of view. It is likely that substrate moisture levels are controlled by the termites to enhance building activities and foraging efficiency (Evans et al., 2015). Termites also strongly favour moist and mouldy wood conditions, making it easier for termites to attack the wood. This fact is in line with Wang & Henderson (2012), who stated that several termites prefer decayed wood.

Effect of Wood Substrates on Proximate and Mineral Content of Termites

The protein content of the termite species (*Macrotermes michaelseni*) was the second highest (47.9 ± 0.3) to energy (206.4 ± 0.7) than the other values. Other studies have reported that termites have higher protein quality beneficial for human nutrition (Kinyuru et al., 2013), especially in an otherwise plant-dominated diet, typically in Western Kenya. According to Ordoñez-Araque & Egas-Montenegro (2021), they stated that the dominant insects' nutrient is protein and constitutes a total dry mass of 38-77%, whose upper range is close to other animal protein sources (Morales-Ramos & Rojas, 2001) and can be sourced from larger quantities within a fairly short period because

insects have a short reproduction interval compared to livestock-based sources. (Poissonnier et al., 2018) also recorded that carbohydrates were present in wood, thus providing the required nutrients to termites. The Ash content of the studied termites (*Macrotermes michaelseni*) was also higher. The higher Ash content (15.23 ± 0.5) in termites may be due to residual soil contamination during Harvesting and drying, although care was taken to avoid soil contamination after sampling (Shelomi, 2015).

In Pearson correlation analysis, Ash content ($r = -0.99$, $p < 0.001$) was negatively correlated with the consumption rates of the termites. Fibre has higher values (14.7 ± 0.40), although it has a negative correlation with termites' substrate consumption rates. This is because various authors have suggested that the fibre in insects represents chitin because it is similar structurally to cellulose (Eger et al., 2012). Therefore, high fibre content in insects may be due to chitin. Termites are among the insects with the largest fat content, according to (Solavan et al., 2006), and positively correlated with termites' consumption rates ($r = 0.98$, $p < 0.001$). (Behmer, 2009) examined the relationship between termites' dietary intake and performance and found that, in contrast to other insects, termites did not modify their food gathering and consumption practices to make up for nutrient imbalances.

Termites have been able to utilise wood, which is often an unpromising substrate in terms of nutrition, thanks to their extra ability to depend on gut symbiont groups. According to reports, termites carefully regulate how much micronutrient they eat (Judd et al., 2017). This offers an intriguing contrast to macronutrients and is in line with the observations that termites obtain micronutrients from the soil rather than wood, and that the micronutrient content of various soils varies. Sugar cane and maize cob attract a high number of termites (Meyer-Rochow et al., 2021). Therefore, sugar cane and maize cob, which would otherwise go to waste, offer sustainable, safe and promising

substrates for mass rearing of subterranean termites, meant for human and livestock consumption.

CONCLUSION

In conclusion, the results' weight loss values indicated the degree of termite preference amongst the wood species of sugar cane (*Saccharum officinarum*), maize cob (*Zea mays*), and mango wood (*Mangifera indica*). Termites (*Macrotermes michaelseni*) love these wood types, which are referred to as highly favoured woods and have demonstrated a higher proportion of weight loss. The greater the weight loss percentage, the more the wood was preferred by the termites. The results have indicated that termites have preferred sugar cane over other species of wood. Based on the results, it can be concluded that the order of the preferred wood species for the subterranean termites among substrates tested was sugar cane, followed by maize cob and mango wood.

Based on weight loss, maize cobs have the potential to be an alternative to sugar cane as a wood bait due to their susceptibility to termites' feeding habits. According to the research described in this thesis, sugar cane had significantly higher moisture content ($p \leq 0.001$) than maize cob and mango wood. Another important factor that might have affected desire is the wood's moisture content (MC), which is positively correlated with termite consumption. The proximate analysis and mineral determination show that termites contain a significant proportion of protein, fats and minerals. Termites have unique nutritional qualities that can be exploited to provide high-quality diets for developing countries.

REFERENCE

- Ali, (2021). Feeding Preferences of Subterranean Termites, *Odontotermes obesus* (Rambur) (Blattoidea: Termitidae) in Field and Their Control and Developing Bait Strategies. *Egyptian Academic Journal of Biological Sciences. A, Entomology*, 14(1), 83–92. <https://doi.org/10.21608/eajbsa.2021.151774>

- Alves (2014). Students' attitudes toward and knowledge about snakes in the semiarid region of Northeastern Brazil. *Journal of Ethnobiology and Ethnomedicine*, 10(1), 30. <https://doi.org/10.1186/1746-4269-10-30>
- Ayieko (2007). Improving non-formal education for street children at rescue centre Eldoret. *Second Regional Research Seminar of UNESCO Forum for Regional Science for Committee Africa, Accra, Ghana, 22nd-24th March*.
- Azubuikwe (2012). Physicochemical properties of maize cob cellulose powders reconstituted from ionic liquid solution. *Cellulose*, 19(2), 425–433.
- Baker, P. B., & Marchosky, R. (2005). *Arizona termites of economic importance*.
- Barreto (2008). Characterization and Quantitation of Polyphenolic Compounds in Bark, Kernel, Leaves, and Peel of Mango (*Mangifera indica* L.). *Journal of Agricultural and Food Chemistry*, 56(14), 5599–5610. <https://doi.org/10.1021/jf800738r>
- Behmer, S. T. (2009). Insect herbivore nutrient regulation. *Annual Review of Entomology*, 54(1), 165–187.
- Bignell, D. E., & Eggleton, P. (2000). Termites in Ecosystems. In T. Abe, D. E. Bignell, & M. Higashi (Eds.), *Termites: Evolution, Sociality, Symbioses, Ecology* (pp. 363–387). Springer Netherlands. https://doi.org/10.1007/978-94-017-3223-9_17
- Bignell (2011). *Biology of Termites: A Modern Synthesis*. Springer Netherlands. <https://doi.org/10.1007/978-90-481-3977-4>
- Boulogne, (2017). Ecology of termites from the genus *Nasutitermes* (Termitidae: Nasutitermitinae) and potential for science-based development of sustainable pest management programs. *Journal of Pest Science*, 90(1), 19–37.
- Bustamante, (1998). Nutritional preferences of wood-feeding termites inhabiting floodplain forests of the Amazon River, Brazil. *Acta Amazonica*, 28, 301–301.
- Carvajal-Millan, (2007). Maize bran gum: Extraction, characterization and functional properties. *Carbohydrate Polymers*, 69(2), 280–285.
- Castillo, (2013). Feeding Response of Subterranean Termites *Coptotermes curvignathus* and *Coptotermes gestroi* (Blattodea: Rhinotermitidae) to Baits Supplemented With Sugars, Amino Acids, and Cassava. *Journal of Economic Entomology*, 106(4), 1794–1801. <https://doi.org/10.1603/EC12301>
- Donovan (2001). Gut content analysis and a new feeding group classification of termites. *Ecological Entomology*, 26(4), 356–366.
- Dorta (2012). Reutilization of Mango Byproducts: Study of the Effect of Extraction Solvent and Temperature on Their Antioxidant Properties. *Journal of Food Science*, 77(1), C80–C88. <https://doi.org/10.1111/j.1750-3841.2011.02477.x>
- Eger (2012). Elimination of Subterranean Termite (Isoptera: Rhinotermitidae) Colonies Using a Refined Cellulose Bait Matrix Containing Noviflumuron When Monitored and Replenished Quarterly. *Journal of Economic Entomology*, 105(2), 533–539. <https://doi.org/10.1603/EC11027>
- Evans (2015). 'Entomophagy': An evolving terminology in need of review. *Journal of Insects as Food and Feed*, 1(4), 293–305.
- Freymann (2008). The importance of termites (Isoptera) for the recycling of herbivore dung in tropical ecosystems: A review. *European Journal of Entomology*, 105(2), 165–173. <https://doi.org/10.14411/eje.2008.025>

- Gautam, B. K., & Henderson, G. (2011). Wood Consumption by Formosan Subterranean Termites (Isoptera: Rhinotermitidae) as Affected by Wood Moisture Content and Temperature. *Annals of the Entomological Society of America*, 104(3), 459–464. <https://doi.org/10.1603/AN10190>
- Gope, B., & Prasad, B. (1983). Preliminary observation on the nutritional value of some edible insects of Manipur. *Journal of Advanced Zoology*, 4(1), 55–61.
- Govorushko, S. (2019). Economic and ecological importance of termites: A global review. *Entomological Science*, 22(1), 21–35. <https://doi.org/10.1111/ens.12328>
- Hallmayer (2011). Genetic heritability and shared environmental factors among twin pairs with autism. *Archives of General Psychiatry*, 68(11), 1095–1102.
- Harris, W. V. (1970). Termites of the Palearctic region. *Biology of Termites*, 295–313.
- Hatti-Kaul (2007). Industrial biotechnology for the production of bio-based chemicals – a cradle-to-grave perspective. *Trends in Biotechnology*, 25(3), 119–124. <https://doi.org/10.1016/j.tibtech.2007.01.001>
- Hedlund (1999). Effect of Available Food Size on Search Tunnel Formation by the Formosan Subterranean Termite (Isoptera: Rhinotermitidae). *Journal of Economic Entomology*, 92(3), 610–616. <https://doi.org/10.1093/jee/92.3.610>
- Huang (2012). Graphene based catalysts. *Energy & Environmental Science*, 5(10), 8848–8868.
- Ibrahim, B. U., & Adebote, D. A. (2012). Appraisal of the economic activities of termites: A review. *Bayero Journal of Pure and Applied Sciences*, 5(1), 84–89.
- Jouquet, (2016). Termites: The neglected soil engineers of tropical soils. *Soil Science*, 181(3/4), 157–165.
- Judd (2017). A geometric analysis of the regulation of inorganic nutrient intake by the subterranean termite *Reticulitermes flavipes* Kollar. *Insects*, 8(3), 97.
- Katayama (2008). Entomophagy: A key to space agriculture. *Advances in Space Research*, 41(5), 701–705.
- Kenis, M., Koné, N., Chrysostome, C. A. A. M., Devic, E., Koko, G. K. D., Clottey, V. A., Nacambo, S., & Mensah, G. A. (2014). Insects used for animal feed in West Africa. *Entomologia*. <https://doi.org/10.4081/entomologia.2014.218>
- Khan, M. A., & Ahmad, W. (2018). *Termites and Sustainable Management: Volume 1-Biology, Social Behaviour and Economic Importance*. Springer.
- Kinyuru (2013). Nutrient composition of four species of winged termites consumed in western Kenya. *Journal of Food Composition and Analysis*, 30(2), 120–124. <https://doi.org/10.1016/j.jfca.2013.02.008>
- Lenz (2011). The Potential and Limits of Termites (Isoptera) as Decomposers of Waste Paper Products. *Journal of Economic Entomology*, 104(1), 232–242. <https://doi.org/10.1603/EC10155>
- Maynard (2015). Temperate forest termites: Ecology, biogeography, and ecosystem impacts. *Ecological Entomology*, 40(3), 199–210. <https://doi.org/10.1111/een.12185>
- McMahan, E. A. (1966). *Studies of termite wood-feeding preferences*.
- McManamy (2008). *Wood Moisture Content Affects the Survival of Eastern Subterranean Termites*

- (Isoptera: Rhinotermitidae), Under Saturated Relative Humidity Conditions. 52(1), 13.
- Meyer-Rochow (2021). Chemical composition, nutrient quality and acceptability of edible insects are affected by species, developmental stage, gender, diet, and processing method. *Foods*, 10(5), 1036.
- Morales-Ramos (2001). Nutritional Ecology of the Formosan Subterranean Termite (Isoptera: Rhinotermitidae) - Feeding Response to Commercial Wood Species. *Journal of Economic Entomology*, 94(2), 516–523. <https://doi.org/10.1603/0022-0493-94.2.516>
- Nagnan, P., & Clement, J. L. (1990). Terpenes from the maritime pine *Pinus pinaster*: Toxins for subterranean termites of the genus *Reticulitermes* (Isoptera: Rhinotermitidae)? *Biochemical Systematics and Ecology*, 18(1), 13–16. [https://doi.org/10.1016/0305-1978\(90\)90025-B](https://doi.org/10.1016/0305-1978(90)90025-B)
- Nakayama (2005). Feeding activities of *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe) as affected by moisture content of wood. *Journal of Wood Science*, 51(1), 60–65. <https://doi.org/10.1007/s10086-003-0612-0>
- Neoh (2012). Do Termites Avoid Carcasses? Behavioral Responses Depend on the Nature of the Carcasses. *PLoS ONE*, 7(4), e36375. <https://doi.org/10.1371/journal.pone.0036375>
- Ntukuyoh (2012). Evaluation of nutritional value of termites (*Macrotermes bellicosus*): Soldiers, workers, and queen in the Niger Delta region of Nigeria. *International Journal of Food Nutrition and Safety*, 1(2), 60–65.
- Olale (2019). A simple field based method for rapid wood density estimation for selected tree species in Western Kenya. *Scientific African*, 5, e00149.
- Ordoñez-Araque, R., & Egas-Montenegro, E. (2021). Edible insects: A food alternative for the sustainable development of the planet. *International Journal of Gastronomy and Food Science*, 23, 100304.
- Owoyemi (2014). Natural resistance of ten selected Nigerian wood species to subterranean termites attack. *International Journal of Biological Sciences and Applications*, 1(2), 35–39.
- Oyarzun, S. E., Crawshaw, G. J., & Valdes, E. V. (1996). The Edentate Conservation Fund–Swift Grants for Field Research. *International Zoo Yearbook*, 16, 38–46.
- Paul, B. B., & Rueben, J. M. (2005). Arizona termites of economic importance. *Cooperative Extension Work. University of Arizona*, 1–19.
- Pearce, M. J. (1997). *Termites: Biology and pest management*. Cab International.
- Poissonnier (2018). Nutrition in extreme food specialists: An illustration using termites. *Functional Ecology*, 32(11), 2531–2541. <https://doi.org/10.1111/1365-2435.13200>
- Potter, M. F., Romero, A., & Haynes, K. F. (2008). Battling bed bugs in the USA. *Proceedings of the Sixth International Conference on Urban Pests*, 401–406.
- Ripa (2007). Field evaluation of potential control strategies against the invasive eastern subterranean termite (Isoptera: Rhinotermitidae) in Chile. *Journal of Economic Entomology*, 100(4), 1391–1399.
- Rosenberg (2023). The global biomass and number of terrestrial arthropods. *Science Advances*, 9(5), eabq4049. <https://doi.org/10.1126/sciadv.abq4049>
- Roszaini, K., Mailina, J., Shaharuddin, H., Zaihan, J., & Nor-Azah, M. A. (2022). BIOTOXICITY OF TROPICAL PLANT ESSENTIAL OILS AGAINST SUBTERRANEAN TERMITES *COPTOTERMES CURVIGNATHUS*. *Journal of Tropical Forest Science*, 34(2), 210–220.

- Sankara (2018). Indigenous knowledge and potential of termites as poultry feed in Burkina Faso. *Journal of Insects as Food and Feed*, 4(4), 211–218.
- Saunio (2019). The global methane budget 2000–2017. *Earth System Science Data Discussions*, 2019, 1–136.
- Shelomi, M. (2015). Why we still don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework. *Trends in Food Science & Technology*, 45(2), 311–318.
- Siddiqui (2023). An overview of fermentation in the food industry—Looking back from a new perspective. *Bioresources and Bioprocessing*, 10(1), 85. <https://doi.org/10.1186/s40643-023-00702-y>
- Sogbesan, A. O., & Ugwumba, A. A. A. (2008). Nutritional evaluation of termite (*Macrotermes subhyalinus*) meal as animal protein supplements in the diets of *Heterobranchius longifilis* (Valenciennes, 1840) fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences*, 8(1), 149–158.
- Solavan (2006). Effect of the subterranean termite used in the South Indian folk medicine. *Indian J Tradit Knowl*, 5, 376–379.
- Staunton (2008). *Urban pest management in Australia*. UNSW Press. https://books.google.com/books?hl=en&lr=&id=zzptBgAAQBAJ&oi=fnd&pg=PP5&dq=Hadlington+S,+Staunton+I.+2008&ots=nLqDCQAXmU&sig=o0HYER_45-eMf14RqvSBYqReACo
- Strickland, M. (1950). Differences in toleration of drying between species of termites (*Reticulitermes*). *Ecology*, 31(3), 373–385.
- Su, N.-Y., & Scheffrahn, R. H. (2000). Termites as Pests of Buildings. In T. Abe, D. E. Bignell, & M. Higashi (Eds.), *Termites: Evolution, Sociality, Symbioses, Ecology* (pp. 437–453). Springer Netherlands. https://doi.org/10.1007/978-94-017-3223-9_20
- Suiter (2009). The 3-ounce (90-cc) water swallow challenge: A screening test for children with suspected oropharyngeal dysphagia. *Otolaryngology–Head and Neck Surgery*, 140(2), 187–190. <https://doi.org/10.1016/j.otohns.2008.11.016>
- Thorne (2003). Evolution of eusociality and the soldier caste in termites: Influence of intraspecific competition and accelerated inheritance. *Proceedings of the National Academy of Sciences*, 100(22), 12808–12813. <https://doi.org/10.1073/pnas.2133530100>
- Tokuda (1997). Cellulose Digestion in the Wood-Eating Higher Termite, *Nasutitermes takasagoensis* (Shiraki): Distribution of Cellulases and Properties of Endo- β -1,4-galactanase. *Zoological Science*, 14(1), 83–93. <https://doi.org/10.2108/zsj.14.83>
- Verspoor (2020). Macronutrient intake and frailty: The Rotterdam Study. *European Journal of Nutrition*, 59(7), 2919–2928. <https://doi.org/10.1007/s00394-019-02131-0>
- Waller (1990). Measuring wood preference in termites. *Entomologia Experimentalis et Applicata*, 56(2), 117–123. <https://doi.org/10.1111/j.1570-7458.1990.tb01388.x>
- Wang, C., & Henderson, G. (2012). Evaluation of Three Bait Materials and Their Food Transfer Efficiency in Formosan Subterranean Termites (Isoptera: Rhinotermitidae). *Journal of Economic Entomology*, 105(5), 1758–1765. <https://doi.org/10.1603/EC12201>
- Wigglesworth, V. B. (1945). Transpiration through the cuticle of insects. *Journal of Experimental Biology*, 21(3 & 4), 97–114.
- Zahid (2012). Assessment of technologies and dogs for detecting insect pests in timber and forest products. *Scandinavian Journal of Forest*

Research, 27(5), 492–502.

<https://doi.org/10.1080/02827581.2012.657801>

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