EDIBLE WINGED TERMITES: A NEGLECTED YET PROMISING SOLUTION FOR FUTURE FOOD SECURITY

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Review Article

The world's population rises by day which increases pressure on the already little land for productive agriculture. To guarantee food security of tomorrow's population, promising yet neglected and underutilised food sources have attracted global attention especially novel edible insects as a sustainable source of food and different industrial products. Edible termites are not only suitable candidates for this purpose but also have potential for vertical farming yet with little ecological damage. Due to their rich nutrient density, termites can ably be used in nutrition interventions if thorough and detailed research efforts are geared in this direction. Currently, the scientific literature available misses many critical aspects for the World Health Orga-nization (WHO) to declare termites as an ingredient in food and food industrial applications. Edible termites might confer special benefits to the human body due to their antitumor, antimicrobial and antioxidant properties in addition to their probiotic and prebiotic potential. As edible termites are reaching wider markets even in the European Union, it insights the urgent need for value chain regulation and quality control from termite harvesting to consumption. The fact that no allergy symptoms from termite consumption have so far been documented by scientists and health practitioners presents an opportunity for safe termite industrialisation, if rigorous hygiene, disinfection protocols and Hazard Analysis Critical Control Points (HACCP) have been followed from farmtofork.

INTRODUCTION

World food consumption patterns and preferences are expected to change due to population growth to a tune of ~ 10 billion and increased urbanization by 2050, and this will unavoidably increase animal protein demands by almost 60%.[1] The demand for protein food with low environmental impact is currently a great concern in the agro-food industry.[2] Eating and massproducing edible insects has potential for meeting the first three Sustainable Development Goals of the Unit-ed Nations (UN) by 2030. Following the Food and Agricultural Organization (FAO)'s publication titled 'Edible insects: future prospects for food and feed security',[3] termite consumption has become trendy in food science research, the commercial sector, and the media.[4] The global market for edible insects was forecasted to reach $710 million by 2024,[5] with edible insect flour alone valued at over $ 19.5 million revenue in 2017, yet future pro-tein demand is projected to increase to 3 million tons by 2030. Therefore, edible insect production provides hope for alleviating food and nutrition insecurity, particularly in underdeveloped countries grappling with poverty, malnutrition, and rapid population growth.[4] Research indicates that edible termites are a valuable, cost-effective, and sustainable food source, especially for malnutrition interventions.[6] They are promising candidates for fortifying therapeutic foods due to their high protein content, which is comparable to that of chicken, beef, and other animal protein sources, and conformity with WHO recommendations for dietary amino acids.[2] However, thorough research contrasting the protein digestibility of edible termites and that of animal proteins are scarce. Moreover, the bioavailability and bioaccessibility of nutrients from termites remain underexplored, with most researchers concentrating on termite nutrient characteriz-ation and proximate analysis.[7]

Different termite species may vary in nutrient bioa-vailability, necessitating informed decisions on which species to consume. In addition to protein, studies should concentrate on micro-nutrients, as these nutrient deficits continue to be a problem for public health in developing nations. Termites with high micronutrient content could be selected for mass rearing to address nutrit-ional deficiencies, especially during preg-na-ncy.[7]

Bread, crisps, meatloaves, and other foods can all be fortified with termites.[8] Termites meet the Codex alimentarius criteria and have a modest amount of omega3 fatty acids, making them appropriate for use in infant formula.[9]Despite the fact that termite consumption cuts across all continents, many consumers are unaware of antinutritional substances that some termite species may carry.[10] There is little research on these antinutritional components and how they interact with macro and micronutrients. This issue therefore needs be addressed because edible termites may contain high levels of mineral elements and heavy metals, requiring species-specific treatment before use in food appli-cations. Beyond food, edible termites offer indu-strial opportunities, including the production of antioxidants, antitumor and antimicrobial com-pounds, peptides, enzymes, and fatty acids.[4]

In addition to being naturally rich in mono and polyunsaturated fatty acids, termites produce oil that is anticipated to be cholesterolfree and of a quality comparable to virgin oils.[11] However, only a few studies have been directed towards the production and characterisation of termite oil, either for edible use or industrial applications.[12] Whether and how the different methods employed in termite oil extraction shall affect its quality and stability is another virgin research field which need be explored. Additionally, there is need to evaluate the potential of termite oil in development of functional foods.[12] Studies rega-rding both the fermentation of edible term-ites or their derivatives, and shelflife of fresh or proc-essed edible termites and their derivatives, are still scanty. Therefore, the goal of this review paper is to investigate the unmet research needs and untapped potential of edible termites in food industrial applications, a strategy that can sust-ainably offer food security with minimal environ-mental impact.

Termite consumption for protein energy malnutrition alleviation

According to UN, the world's population is pred-icted to be as high as 8.5, 9.7 and 11.2 billion by 2030, 2050, and 2100 respectively,[1] which shall inevitably have catastrophic effects on the size of the already limited agricultural land and directly increase food demand especially for high quality protein sources.[2] Satisfying food demands of such a population thus calls for both significant and sustainable food security endeavours.[11] We thus urge for a longterm strategy th-at will address world hunger, ensure presence of food in every house hold, and most importantly alle-viate malnutrition in underdeveloped countries. Edible winged termites (Figure 1) are examples of foods that require less land (can even be farmed vertically), water and natural resources to produce while generating fewer greenhouse gas emissions.[2] Moreover, dietary diversification is one of the recommendations in ensuring sust-ainable, ecologicallyfriendly, economicallyvia-ble and longterm food security; inclusion of various food types, especially the underexpl-oit-ed/utilized candidates in the diet remains a prom-ising food security endeavour.[2] Due to their food security and sustainability potential, edible insects have become a pertinent global topic in public media, research and commercial sectors.[4]

Figure 1: Edible winged termites from Uganda; ready for harvest (A), sun-dried (B)

About 3% of all edible insects on the globe are termites and are widely consumed in Africa, Central America, and some parts of Asia.[6] This dietary practice has the potential to improve global food security and sustainability.[9] There are about 43 species of termites that are consumed worldwide, and the Macrotermes genus, also known as 'big termites', are the most popular in Africa.[13] Edible winged termites are a seasonal component of the natural ecosystem, especially during the first rains after a long dry spell.[14] Despite having a high nutrient content, termites are underutilised as a sustainable food source.[15] Edible winged termites are typically consumed fresh, especially by those who harvest them. However, during times of abundant harvest, they are processed in various ways to extend their shelf life.[14] Preservation methods used include sun drying, fermentation, roasting, or frying in their own oil.[14] Edible termites can be consumed whole or ground up and added to other processed foods.[14] The usage of termites as food has increased as a result of a growing understanding of the nutritional value of insects in many rural communities and among food processors.[4] In sub-Saharan Africa, all termite castes, including workers, soldiers, queens, and alates, are consumed.[13] Protein energy malnutrition (PEM) is prevalent in many underdeveloped countries,[14] and at least one out of every five children suffers from PEM.[16] Animals are the main source of protein, but in underdeveloped countries, they are expensive and thus out of reach for majority of the povertystricken individuals.[4] Additi-onally, animal husbandry pollutes the environment and consumes a lot of agricultural area.[2] Promoting termite farming of edible species could offer a viable and reasonably priced alternative protein source for addressing PEM and dietary deficiencies, particularly in underdeveloped countries.[8] Protein is the main nutrient in most edible insects, constituting a dry mass ranging from 38% to 77%,[6] which is comparable to other animal protein sources.[2] Due to their quick reproductive cycles, insects are a possible replacement for conventional livestockbased protein sources because the former can be produced in big quantities in a short period. In addition, insect proteins are of excellent quality due to their large quantities of the amino acids lysine, tryptophan, and threonine, all of which are frequently lacking in the principal protein sources found in cereals.[4] To supplement their food intake, many populations, notably in Africa, eat winged termites, for example, Macrotermes subhyalinus.[13] Although the digestibility of insect protein (about 76-98%) is lesser than that of animalbased proteins like beef (98%) and egg white (95%), it boasts a greater digestibility compared to plantbased proteins (52%).[17] Surprisingly, it has been observed that the majority of insect species contain enough essential amino acids to satisfy WHO guidelines.[18] For example, the edible winged termite Macrotermes bellicosus from Nigeria contains all essential amino acids. Studies suggest that incorporating termites like Macrotermes bellicosus into cornbased diets can mitigate amino acid deficiencies, thus improving food quality. Additionally, fortifying local sorghum biscuits with termite protein enhances their protein and mineral content without compromising ta-ste.[19] In underdeveloped countries, insects are considered a promising solution to nutritionrelated deficiencies.[20] For example, Hodotermes mossambicus termites have been reported to help treat child malnutrition in Zambia.[21] Similarly, in Kenya, local communities around Lake Victoria be-lieve that edible winged termites have high nutritional value and encourage pregnant women plus children to include termites in their diets.[22] However, further studies and longterm experiments are necessary before definitive recommendations can be made regarding the significant impact of edible termites on human health and PEM alleviation. Lipids are the second most abundant nutrient in edible insects, particularly monounsaturated and polyunsaturated fatty acids, which must only be sourced from the diet and whose beneficial effects to the body are well-documented.[23] Edible termites have been reported to contain a high concentration of unsaturated fatty acids such as oleic acid. Since insects often contain less cholesterol than most animal-derived foods,[24] edible termites have potential to provide a healthier diet in this regard.

The role of edible termites as micronutrient fortificants and food supplements

Edible insects have the potential to meet the daily requirements for a number of vitamins and minerals, including riboflavin, pantothenic acid, biotin, and folic acid, as recommended by WHO and FAO.[6] Iron, Zinc, Calcium, Copper, Phosphorus, Magnesium, and Manganese are particularly abundant in termites.[2] Approximately [2] billion and [1] billion people suffer from Zn and Fe deficiency respectively. [25] Reports indicate 450,000 cases of Zn deficiency in Africa (58%), 40% in Asia, and 2% in Latin America, [26] with 17.3% of the world's population at risk.[27] Edible termites can be an important dietary source of these micronutrients due to their high Fe and Zn content, particularly in underdeveloped nations.[9] Many researchers emphasize that fortifying food products with termites can greatly improve the food's nutritional composition.[9] For instance, replacing traditional flours like wheat and sorghum meal with termite flour significantly increases the protein and mineral content of cookies.[28] Termitebased composite products, such as termite and sorghum blends, can be used in supplementary feeding and interventions against PEM due to their enriched nutrient content. Studies have demonstrated a significant increase in essential amino acids and certain minerals (Mn, Zn, Mg, Ca, P, Fe, Cu, Na, and K) as the proportion of termite meal in food products increases.[28] Interesting to note is that in some areas, flour made from soldier and alate termites has traditionally been added to soft porridge that is offered to children.[8] Other reports indicate that some mothers added termite powder to baby porridge to enrich it.[29] In another study,30 the Mn concentration in termites from the Odontotermes and Macrotermes genera, particularly Macrotermes subhyalinus, was found to be 50-100 times greater than those in other insects. The aforementioned authors thus concluded that even a small amount of termites could exceed the daily allowance of Mn for both adults and children. The nutrient density of edible winged termites is expected to drive the food industry towards innovative approaches for processing termites into various valueadded products, packaging them effectively, and marketing them in a way that is appealing to consumers.[14] This includes using termite protein in products like protein bars or fortifying bread, buns, biscuits, cookies, muffins, hamburgers, meatballs, and meatloaves, among other food items.[15] In East Africa, it is possible to industrially process termites and their by-products. For instance, in Kenya, Macrotermes subhyalinus was transformed into extruded ready to cook supplementary flour for improving the nutritional status of young children. Additionally, adding 8% termite flour (soldier caste) to honey produced an acceptable spread with numerous potential applications in the food industry, for example in pastries and sandwiches.[31] The versatility of termites in the production of sausages, muffins, meatloaf, crackers, bread, pasta, and extruded sn-acks was also demonstrated.[15] Furthermore, incorporating up to 25% Macrotermes subhyalinus powder into wheat flour did not compromise the sensory attributes of biscuits.[32] However, the constraints of wild termite harvesting prevent production of termite products from being scaled up, necessitating the mass rearing of edible winged termites for commercial use. Many studies on edible winged termites have highlighted their high nutrient density and potential to address food security, whether consumed fresh or processed.9 This is largely attributed to their elevated protein and fat content.9 Therefore, establishing consistent mineral concentrations through standardized nutritional assessments is crucial before assessing the marketability potential of edible winged termites.[33]

The antioxidant and prebiotic potential of edible winged termites

Termites possess a distinctive chitinous exoskeleton, which is considered a form of dietary fiber.[6] Chitin content in insects normally ranges from 11.6 to 137.2 mg/kg of dry matter.[2] Chitin serves a dual role, exhibiting antioxidant properties,[4] as well as antitumor and antimicrobial activities.[34] However, it can also provoke allergic reactions.[35] According to earlier reports,[14] chitin might exhibit prebiotic properties, potentially promoting the proliferation of probiotic microbiota in the stomach. This, in turn, could significantly reduce the growth of diseasecausing microbes, potentially mitigating intestinal and environmental enteric dysfunction. According to prior studies, chitin's prebiotic potential can improve gut health by promoting the development of native gut microorganisms, which will facilitate digestion.[36] Chitin and its derivatives have been shown to inhibit the growth of undesirable intestinal microbes like Vibrio cholera, enteropathogenic Escherichia coli, and Salmonella typhimurium in the human stomach while encouraging the growth of beneficial intestinal microbes like Lactobacillus and Bifidobacteria.[37] For instance, previous reports indicate that cricket chitin caused a 5.7-fold increase in the growth of Bifidobacterium animalis,[38] and inhibited E. coli proliferation.[36]

Edibility of termite oil and its industrial prospects

Edible winged termites are naturally rich in oil, and this is why they are typically fried in their own oil during the preparation for consumption. Apart from the [2] theses identified in existing literature, [12],[39] there is hardly any studies concerning the extraction and characterization of termite oil. Nevertheless, there is hope for termite oil being a healthier option than animal oil for human consumption due to the former's richness in unsaturated fatty acids and minimal cholesterol content. Development of functional foods e.g., termite oil, particularly that from the Macrotermes subhylanus species is a possibility worth investigatin.[12] To extract edible insect lipids, a number of extraction techniques have been used, including soxhlet, supercritical CO2, and folch.[40] Although the lipid extraction process chosen has minimal effect on the composition of fatty acid extracted, it greatly affects the types of lipids extracted. For instance, organic solvents can extract phospholipids, glycerides, and triacylglycerols but aqueous extraction exclusively produces triacylglycerols.[40] Insect lipids or oils derived through aqueous extraction are of the best quality, similar to virgin oils.[40] Preservation of thermally sensitive components during the extraction, solvent characteristics such as chemical inertness must therefore be taken into consideration when choosing an appropriate oil extraction technique. Insect oils, which are normally liquids at room temperature, are used in the food industry for a number of purposes, including use as frying oils and foodgrade lubricants. Previous reports have indicated that termites and caterpillars possess the highest lipid concentrations among all insects.[41] Never-the-less, there is still scarcity of literature on the extraction of insect lipids and their utilization in the food industry.

Bioaccessibility, bioavailability of nutrients and protein digestibility of edible termites

While most scientific literature focuses on quantifying protein content, indispensable amino acids, fatty acid composition and other nutrients present in edible termites, these nutrients' bioaccessibility and bioavailability in the human body have sadly not been addressed.[30] Moreover, bioavailability of minerals in edible winged termites is likely to be high compared to those in foods of plant origin,[42] hence termite minerals can be used in addressing inadequate nutrient intake which manifests in many developing countries especially those which practice entomophagy.[43] The bioavailability and accessibility of nutrients from edible termites hold more significant nutritional relevance for consumers than their proximate composition, as proximate analysis does not reveal how much of these nutrients actually enters the bloodstream for absorption. Therefore, rather than just focusing on the proximate composition of edible termites, nutritional studies need to assess nutrient bioavailability and accessibility in the human body after termite consumption.[2] Surprisingly, the Fe content of most edible insects is almost similar to that of meat, however the bioavailability of this nutrient in insects has received minimal scientific attention.[44] Even though present literature indicates presence of carotene, vitamins B_1, B_2, B_6, C, D, E, and K in edible insects,[45] investigations regarding bioavailability of these vitamins are still insufficient.[2] In a similar vein, although Macrotermes subhyalinus has been reported to have a high Mn concentration,[30] further studies are required to investigate this mineral's bioavailability and interactions with other dietary minerals during human digestion. Important to note, the cooking procedure might also affect the bioavailability of termite nutrients because some nutrients can leach during boiling.[46] Addressing global deficiencies such as those in Fe and Zn could potentially be achieved through termite consumption, given the hypothesis that minerals from edible insects might have higher bioavailability compared to plantbased sources.[47] However, contamination from soil or termite mounds, which are the natural habitat of edible termites,[9] might be a source of high Fe concentration in edible termites, possibly rendering this Fe less bioavailable in the human body. Relatedly, there was no considerable difference observed in Fe status of children fed on insectbased complementary foods and those fed on plantbased complementary foods in Cambodia.[48] These findings justify the need for more research on the bioavailability of nutrients from edible termites to reconcile existing contradictions and provide more informed recommendations. Termites also have a greater Protein Efficiency Ratio (PER) than several other protein sources, including eggs. For instance, the edible winged termite Macrotermes bellicosus has a PER of 1.18, surpassing that of casein, which is 0.86,[49] or similar to casein, as reported in earlier studies. Similarly, the biological value of the termite Macrotermes nigeriensis has been reported to range from 85.49% to 93.02%, which is higher than the biological value for casein (73.45%).[49] It is worth noting that digestibility of edible insects' protein is affected by the preparation and cooking regime used. For example, a significant reduction in protein digestibility was observed in toasted and dried grasshoppers yet this result did not occur in termites. According to a research conducted in Uganda, protein digestibility in white ants ranged from 46% to 63% depending on the cooking method used, including boiling, dry pan frying, and boiling followed by sun drying.[39] The mechanism for improvement of edible termites' protein digestibility is both less documented and not well understood hence necessitating researchers to explore this grey area of termite research.

Fermentation of edible termites

As fermentation changes the food texture, flavour, and other properties, it has attracted increasing

As fermentation changes the food texture, flavour, and other properties, it has attracted increasing interest in the processing of numerous insect products.[50] For instance, a study revealed that fermented sauces prepared from grasshoppers (Locusta migratoria) had better sensory qualities than store-bought fish sauce.[51] When edible ins-ects are fermented either naturally or using star-ter cultures, useful substances are produced, including vital fatty acids, alcohols, vitamins, amino acids, and digestible proteins.[52] Thus, fermentation as a processing technique might promote both the functionality and acceptance of termites and termites' derivatives/products in the food industry. Due to the high protein content found in insects, particularly as a source of nitrogen, selecting an appropriate microbial starter culture is crucial for efficient fermentation of edible termites. This selection is necessary to effectively break down both organic and inorganic nitrogen sources, such that optimal acidification outcomes are achieved.[53] Additionally, the rigid exoskeleton of insects can hinder microbial access to the substrate, thereby impacting the fermentation proces.[54] Consequently, it is advisable to preprocess edible insects before fermentation, for example blanching, milling, and boiling.[51] Although limited research has delved into the utilization of fermentation techniques for the processing of edible termites, existing literature provides compelling evidence that this approach offers several advantages when compared to traditional processing methods.[55] These advantages include: i) enhancing sensory profiles, ii) improving the bioavailability of various nutrients, including minerals, iii) eliminating antinutritional factors, iv) increasing the production of valuable substances like organic acids, amino acids, and polymers,v) favouring the growth of beneficial gut microorganisms, and vi) inhibiting the proliferation of detrimental microbes, thus leading to an enhancement in gut health.[54]

Antinutrients in edible termites

Antinutrients, or antinutritional factors, are naturally occurring compounds found in foods that hinder the intake, digestion, absorption, and utilization of nutrients.[56] They include substances such as phytates, tannins, saponins, oxalates, among others. These antinutrients interfere with enzymes responsible for metabolism, affecting the digestibility of protein and the absorption of minerals, consequently reducing their bioavailability.[4] The saponins, flavonoids, alkaloids, tannins, and oxalates contents in the edible termite Macrotermes facilger collected from Zimbabwe have been reported. Similarly, the termite Macrotermes nigeriensis from northern Nigeria was found to contain cyanogenic glycoside, oxalate, phytates, saponins, and tannins.[57] In the same vein, winged termites obtained from southwestern Nigeria had phytate (0.011 - 0.217 mg/100 g), tannin (0.024 - 0.051 mg/100 g) and oxalate (0.181 - 0.46 mg/100 g) whose values were lower than the GRAS values of 22.10 mg/100 g, 150–200 mg/100 g and 105 mg/100 g respectively, hence presumed to be safe.[58] However, in another study, contradictory results were reported regarding oxalate content (0.5-2.3 mg/100 g) in termite meal,[59] indicating the need for further research to reconcile these discrepancies. The composition of antinutrients in insects, including termites, varies depending on their geographical location. For instance, Macrotermes facilger from Zimbabwe exhibited higher levels of oxalate (931 mg/100 g), tannin (170 mg/100 g), alkaloids (52,300 mg/100 g), and saponin (53,300 mg/100 g) compared to most Nigerian termites. It's important to note that many studies on the antinutritional components of edible termites have not thoroughly examined interactions among these components and their overall interplay with other termite nutrients. Therefore, further research is needed to provide comprehensive information and a more holistic assessment of the nutritional quality of edible termites.[4] Additionally, some antinutrients act as mineral chelators, leading to micronutrient deficiencies in the body.[60] For example, oxalate induces Ca deficiency,[61] phytate hinders the uptake of Mg, Fe, and Ca,[58] while saponin inhibits the absorption of minerals and vitamins in the stomach.[62] Unfortunately, M. nigeriensis from southwestern Nigeria was found to have high levels of saponin (1470 mg/100 g) and phytate (15.21 mg/100 g).[63] Various factors, including the lifecycle stage and geographical location, influence the presence of antinutritional factors in edible insects, partiularly termites.[4] Presence of antinutritional factors in all the four castes of Macrotermes subhylanus, with varying concentrations of oxalate, phytate, and tannin was observed in an earlier study.[64] Among these, the worker termite caste exhibited the highest values, possibly due to their close interaction with the environment while collecting food for other termite castes. It's important to consider that termites acquire their food from the surrounding environment, and the concentration of antinutritional factors in termites is influenced by the available food choices in their environment.[58]

Safety and quality concerns in edible termite processing

Insects, due to their high protein content, are often susceptible to fungal growth when not handled or stored under optimal conditions.[20] Using lateral flow immunochromatography, edible winged termites of the species Macrotermes falciger from Zambia were tested for the presence of aflatoxin.[65] The results revealed an average aflatoxin concentration of 24 μg/kg, which exceeded the accepted limit of 10 μg/kg in Zambia. This highlights the potential for edible termites to contribute to aflatoxicosis, particularly when sold as ready-to-eat street food. Therefore, it is crucial to implement proper hygiene practices throughout the entire food chain, from harvesting to consumption, to ensure food safety. Currently, edible winged termites are wildly harvested which makes this food susceptible to biological contamination from the soil.[66] Animals present in the environment deposit their faecal material on the ground/soil which in turn becomes a breeding place for pathogenic microbes like E. coli, hence finding their way into the termite body. Termites' ingestion of polluted feed can also raise the microbial load in their digestive tracts. HACCP must thus be implemented along the entire food chain, from termite collection to consumption, in order to mitigate this problem.[67] Microbiological contamination along the entire food chain is a serious concern when it comes to processing and eating edible termites. For instance, in Kenya, five people tragically died after consuming termites that had been stored in plastic bags for four days.[68] Adopting hygienic processing practices, following a HACCP plan, and using appropriate packaging could prevent such tragedies.[69] It is important to carryout microbial load analysis of the gut for fresh, processed, and stored edible termites because it reveals presence of several types of bacteria (aerobic and anaerobic) and spores that may be present. In another study,[70] processed termites from illegal markets in Congo had a high microbial load. This suggests that a processing regime is vital prior to consumption of edible termites so that the microbial load is reduced to an acceptable level.[71] Furthermore, there is a possibility of heavy metal accumulation e.g. Cadmium and Lead in insects acquired from the soil and thus, heavy metal presence in such insects like termites need to be evaluated.[69]

Conclusion

In final remark, edible termites and products derived from them find many applications in the food industry and thus, promotion of edible termite consumption plus farming is a promising sustainable approach for not only global food security but also environmentally friendly. The fact that no allergy symptoms from termite consumption have so far been documented by scientists and health practitioners presents an opportunity for safe termite industrialisation, if rigorous hygiene, disinfection protocols and HACCP have been followed from farmtofork.

Research gaps and Future prospects

Species of edible termites are many and their nutrient density depends on many variables such as diet/feed of the termite, developmental stage/alate form, processing condition or posth-arvest treatment, among others. Sadly, most of the studies did not report such vital data which makes it difficult to make solid nutritional conclusions. In majority of the literature, researchers characterized a few species and little micronutrient data is present. Moreover, wide variations exist in the nutritional results obtained from different regions/countries about the same termite species, and therefore; **(i)** detailed studies are needed to compare different findings and identify sources of contradiction **(ii)** extensive nutritional trials and surveys are required to identify the best edible termite species for human consumption and mass rearing in a given region. Very few publications aimed to assess the bioavailability of nutrients from edible termites yet this forms the gist of any nutritional study. Animal feeding models and clinical trials are thus necessary before solid recommendations in PEM interventions can be made. Protein digestibility of edible termites has been examined in very few studies. From our knowledge, there is a dearth of information on the bioavailability of nutrients from fermented edible termites and the impact of antinutritional compounds on the bioavailability of nutrients. The gut microbiota of edible termites may enhance the nutrient value of termites. Future research activities are encouraged to investigate the prebiotic, and antioxidant potential of edible termites based on in vivo models.

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