



RESEARCH ARTICLE

Harnessing the Nutritional Composition and Dietary-Health Potential of Edible Insects: A Case Study of Giant Longhorn Beetle Larvae (*Tithoes confinis*) in Morogoro Rural District, Eastern Tanzania

Patrick Cleophace Mpombeye¹, Arnold Onyango Watako¹, Dennis Ochuodho Otieno², and Andrea Malima Kigeso¹

¹Department of Plant, Animal and Food Sciences, School of Agricultural and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya; ²Department of Biological Sciences, Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya.

Edited by:

Dr S. Khursheed, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Kashmir, India.

Reviewed by:

Dr C. J. Iliya, Federal College of Horticulture Dadin -Kowa Gombe, Nigeria; Dr R.E. Mwaipopo, Mbeya University of Science and Technology, Tanzania.

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*Corresponding author e-mail address:
mpombeyecleophace@gmail.com
(Patrick Cleophace Mpombeye)

ABSTRACT

Insects are increasingly explored as alternative nutrient sources, offering sustainable solutions to enhance food security and dietary diversity in developing regions. The present study aimed to evaluate the proximate composition, mineral profile, and vitamin content of Giant Longhorn Beetle larvae (*Tithoes confinis*) from Morogoro Rural District, Eastern Tanzania. Results showed that the *T. confinis* larvae contained crude protein ($44.00 \pm 1.80\%$), crude fibre ($0.90 \pm 0.52\%$), crude fat ($22.90 \pm 0.95\%$), and nitrogen-free extract ($25.30 \pm 1.10\%$). Mineral analysis revealed high calcium (225 ± 0.59 mg/100 g; 65.5%) and magnesium (54.9 ± 0.15 mg/100 g; 16.0%), with notable levels of iron (21.4 ± 0.76 mg/100 g), zinc (17.3 ± 0.05 mg/100 g), potassium (10.7 ± 0.08 mg/100 g), sodium (8.72 ± 0.15 mg/100 g), and phosphorus (5.52 ± 0.12 mg/100 g). Vitamins included vitamin C (342 ± 39.65 mg/100 g; 75.6%), vitamin B6 (82.6 ± 4.74 mg/100 g; 18.2%), vitamin A (18.9 ± 1.08 mg/100 g; 4.18%), vitamin E (5.59 ± 0.14 mg/100 g; 1.24%), and vitamin B3 (3.34 ± 0.09 mg/100 g; 0.74%). These findings suggest that *T. confinis* larvae are nutrient-rich and could serve as valuable dietary supplements to enhance food and nutrition security.

Keywords: giant long-horned larvae, food security, mineral composition, nutritional benefits, proximate analysis composition, sustainable diets, vitamin composition.

INTRODUCTION

In developing countries, food insecurity remains a substantial challenge, disproportionately affecting women and children. In 2009, women accounted for 60% of the undernourished population worldwide (FAO, 2023). Sida (2015) highlighted that limited access to income, agricultural technology, education, and land contributes

significantly to malnutrition. Food security is achieved when individuals have continuous physical and economic access to adequate, safe, and nutritious food that meets their dietary needs and preferences, enabling an active and healthy life (FAO, 2023). Between 2015 and 2019, the global prevalence of undernourishment (PoU) remained around 7.7% (approximately 577 million people in 2015), but rose sharply to 9.1% in 2023, affecting about 733 million individuals (FAO, 2023). Regional disparities are stark: Asia accounted for over half of the world's undernourished (around 384–385 million in 2023), while Africa faced the highest relative burden, with 20.4% of its population, nearly 298 million people, undernourished (FAO, 2023). In 2024, global hunger declined slightly to 8.2% (673 million people), yet Africa showed minimal progress, with over 20% of its population still undernourished, translating to about 307 million individuals (FAO, 2023; UNICEF, 2025).

The growing world population intensifies food demand (Gałęcki, 2021), prompting exploration of alternative sources such as insects (Tao, 2018). Currently, more than 2.5 billion people consume insects as part of their diet (Melgar-Lalanne, Hernández-Álvarez, & Salinas-Castro, 2019). Insects are increasingly recognized for food and feed due to their lower land requirements compared to conventional farming (Tao & Olive Li, 2018). Although still unconventional, entomophagy is gaining traction in sub-Saharan Africa, with countries like Uganda and Kenya (INSFEED project) adopting insect consumption to support growing populations (Van Huis et al., 2015; Tao & Yao Olive Li, 2018). The giant longhorn beetle, one of the largest and most diverse beetle groups, holds ecological and economic importance. Its larvae are traditionally consumed in tropical countries such as Gabon, Senegal, Congo, and Tanzania (Ruby, 2015).

Food insecurity is particularly acute in Eastern Tanzania, especially in the Uluguru Mountains. Erratic rainfall, declining soil fertility, and limited access to modern farming techniques have reduced agricultural productivity, leading to seasonal shortages of staple crops like maize and cassava (Massawe et al., 2018). During the rainy season, household food and nutritional insecurity can rise to 80%, compared to 69% during harvest periods (Massawe et al., 2018). To cope, communities increasingly turn to entomophagy as a reliable protein source. The Morogoro Rural communities have a long tradition of preparing insect larvae through boiling, frying, and roasting, often enhanced with local spices and herbs (Van Huis, 2015). These dishes, ranging from stews and soups to stir-fried preparations, not only provide nutrition but also carry cultural and social significance (Mmari et al., 2017).

MATERIALS AND METHODS

This study was conducted in Morogoro Rural District, Eastern Zone of Tanzania, located between latitudes 6°30'–8°00' S and longitudes 37°30'–39°00' E. Three villages, Mazizi, Mgodini, and Maseyu, were purposively selected for insect larvae collection. The Eastern Zone was chosen due to its cultural significance in edible insect consumption, particularly beetle larvae (*T. confinis*), which are deeply embedded in the traditional diets of Eastern Tanzanian communities. The Luguru ethnic group, indigenous to the Morogoro Region, has a longstanding gastronomic tradition of consuming beetle larvae. This practice reflects the interconnection between cultural heritage, traditional ecological knowledge, and the sustainable use of local natural resources for food and household nutrition (NBS, 2022).

Fresh live larvae of *T. confinis* were collected from the wild by splitting dead wood with an axe (Figure 1). The larvae were transported to the laboratory in well-ventilated containers along with moist feed to maintain viability and were utilized within 24 hours of collection. Prior to processing, the larvae were cleaned and thoroughly washed with deionized water to remove soil particles, organic debris, and other contaminants. They were then oven-dried at a constant temperature of 65°C for 72 hours, following standard procedures to preserve nutritional integrity and minimize microbial degradation (AOAC International, 2019). The dried samples were finely ground using a Sheffield National MX 491N food grinder (UK) to pass through a 30-mesh (1 mm) sieve, ensuring homogeneity. The powdered samples were wrapped in dark polyethylene bags to prevent photo-degradation, sealed in clean airtight containers, and stored at 4°C for seven days prior to analysis. This procedure adhered to established methods for preserving sample quality before nutrient profiling (AOAC International, 2019). The moisture content, crude ash (mineral matter), crude fiber (carbohydrates), and crude fat (lipids) were determined following standard procedures outlined by the Association of Official Analytical Chemists (AOAC International, 2019). Ash content was measured by incineration at 525–550°C, the recommended combustion range for feedstuff analysis. Crude protein was calculated from nitrogen content using the conventional conversion factor of 6.25, based on the assumption

that proteins contain approximately 16% nitrogen. Carbohydrate content was estimated by difference, using the formula:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Protein} + \% \text{ Fat} + \% \text{ Fiber} + \% \text{ Ash} + \% \text{ Moisture}).$$



Figure 1. Collection and wild harvesting process of edible giant long horn beetle larvae.

Pharmacologically important metallic elements, including zinc and iron, were quantified using Atomic Absorption Spectrophotometry (AAS) with a Varian FS 240 Flame Spectrophotometer (AOAC International, 2023). Sample preparation involved wet digestion: two grams of dried, homogenized sample were incinerated in a muffle furnace at 550°C for three hours. The resulting ash was dissolved in 5 mL of 20% hydrochloric acid (HCl), diluted to 20 mL, homogenized, and centrifuged at 300 rpm for 10 minutes. The clear supernatant was analyzed for micronutrient content using AAS, ensuring accurate quantification of trace metals in complex biological matrices.

Vitamin A (retinol) and vitamin E (tocopherol) were quantified using colorimetric methods, with absorbance measurements taken at 325 nm and 410 nm, respectively, using a UV-Visible spectrophotometer. The analysis of ascorbic acid (vitamin C) was conducted via standard titration techniques, which are widely employed for the determination of water-soluble vitamins due to their accuracy and reliability. The B-complex vitamins, including thiamine (vitamin B1), riboflavin (vitamin B2), and cobalamin (vitamin B12), were assayed calorimetrically, with respective absorbance readings at 261 nm, 242 nm, and 361 nm. In contrast, niacin (vitamin B3) and pyridoxine (vitamin B6) were determined through titration methods. These approaches followed the established protocols commonly used in nutritional biochemistry to ensure precise measurement of both water- and fat-soluble vitamins in food and biological samples (AOAC International, 2023). Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 18.0 for Windows. All analyses were performed in duplicate to ensure reproducibility. Results were expressed as mean values $\pm$ standard error of the mean (SEM), providing estimates of variability and precision consistent with standard practices in quantitative nutritional research.

RESULTS AND DISCUSSION

Proximate analysis

Edible insects are a promising alternative to traditional protein sources, with potential benefits for human health and the environment. However, there are a number of challenges associated with the production and supply of insects as food and feed, including seasonal availability, processing, preparation methods, scaling up production, and the development of a robust supply chain and market. The total number of entomophagous insect species worldwide is not certain. However, the most common insects consumed as food by humans globally are beetles (31%), which constitute about 40% of all known insect species. The results indicated that the moisture content of the sample was 6.54%, indicating the proportion of water present. Ash content, representing the total mineral matter, was recorded at 6.90%, reflecting the presence of essential inorganic nutrients remaining after combustion. Crude protein (CP) constituted 44.00% of the sample, highlighting its substantial contribution to growth, repair, and metabolic functions Meyer-Rochow et al., 2021). Fat or lipids (ether extract, EE) accounted for 22.90%, serving as a significant energy source and supporting various

physiological processes (Sosa & Fogliano, 2019; Yi et al., 2019), whereas crude fibre (CF) content was only 0.90%. Nitrogen-free extract (NFE), representing carbohydrate content, was 25.30%, functioning primarily as an energy source (Table 1).

Table 1. Proximate composition of giant long-horned beetle larvae

Nutrient Component/composition	Nutrient Concentration (%) DW	MSE
Moisture Content	6.54	0.12
Ash	6.90	0.15
Crude Protein (CP)	44.00	1.80
Fat/Lipids (EE)	22.90	0.95
Crude Fiber (CF)	0.90	0.52
Carbohydrates (NFE)	25.30	1.10

Note: MSE, mean standard error

Despite feeding on nutrient-poor, decaying wood, the larvae show high conversion efficiency, turning large amounts of this material into significant levels of protein and fat, making them a valuable nutritional source for humans and livestock. These larvae contain substantial amounts of protein, with studies showing values around 44.00 g per 100 g dry matter (DM), which, while slightly higher than beef (20.6 g/100g DM) and chicken (19.9 g/100g DM), this range observed in edible insects such as crickets (20.1 g/100g DM) and mealworms (19.4 g/100g DM) (FAO, 2023). The giant long horn beetle larvae (*T. confinis*) rich in fat, averaging about 22.90 g/100g DM, which is significantly higher than the fat content found in beef (9.3 g/100g DM) and chicken (7.2 g/100g DM), and also surpasses other insects like crickets (5.06 g/100g DM) and mealworms; 12.3 g/100g DM (Meyer-Rochow et al., 2021).

Mineral analysis

Results indicated that calcium (225 mg/100g DM) was the most abundant mineral, accounting for 65.5% of the total mineral content then magnesium (54.9 mg/100g DM, 16.0%), iron (21.4 mg/100g DM, 6.22%), zinc (17.3 mg/100g DM, 5.02%), potassium (10.7 mg/100g DM, 3.12%), sodium (8.72 mg/100g DM, 2.54%), and phosphorus (5.52 mg/100g DM, 1.61%). In terms of minerals (Table 2), beetle larvae (*T. confinis*) contributed important minerals: iron, zinc, and calcium, often in higher concentrations than in conventional meats. *T. confinis* larvae appeared to be rich in essential minerals, surpassing conventional meats and vegetables in their concentrations. The larvae contained 21.4 mg/100g DM of iron, significantly higher than the 2.6 mg/100g DM typically found in beef, 0.9 mg/100g DM in chicken, and 0.9 mg/100g in pork DM (USDA, 2019). Zinc was 17.3 mg/100g DM in the larvae, compared with 4.1 mg/100g DM in beef, 1.0 mg/100g DM in chicken, and 3.0 mg/100g DM in pork (USDA, 2019). The larvae provided 225 mg/100g DM of calcium, much higher than beef (10 mg/100g DM), chicken (11 mg/100g DM), pork (9 mg/100g DM), and most vegetables, such as spinach, which contains approximately 99 mg/100g DM (USDA, 2019). These comparisons demonstrate the larvae's superior mineral content, making them a highly nutrient-dense alternative to both animal meats and plant-based sources. This makes them particularly valuable in addressing micronutrient deficiencies in human diets (van Huis et al., 2015).

Table 2. Laboratory analysis of vitamin composition of giant long-horned beetle larvae

Mineral Component	Concentration (mg/100g)	Concentration (%)	MSE
Calcium (Ca)	225	65.5	0.59
Magnesium (Mg)	54.9	16.0	0.15
Iron (Fe)	21.4	6.22	0.76
Zinc (Zn)	17.3	5.02	0.05
Potassium (K)	10.7	3.12	0.08
Sodium (Na)	8.72	2.54	0.14
Phosphorus (P)	5.52	1.61	0.12

Note: MSE, mean standard error

Vitamin analysis

In addition to their high protein and lipid content, *T. confinis* larvae are a significant source of essential vitamins, particularly B-complex and antioxidant vitamins, which are crucial for metabolic, neurological, and immunological functions. In Table 3, nutritional analysis revealed that vitamin C (ascorbic acid) was the most abundant, present at 342 mg/100g DM and accounting for 75.6% of the total vitamin content. This is noteworthy given its key roles in immune support, collagen synthesis, and antioxidant protection (Murray et al., 2020). Vitamin B6 (pyridoxine), important for amino acid metabolism and neurotransmitter synthesis, was recorded at 82.6 mg DM/100g (18.2%), a concentration considerably higher than that found in many plant-based foods. The larvae also contained vitamin A (retinol) at 18.9 mg/100g DM (4.18%), which supports vision and epithelial cell integrity (van Huis et al., 2015), and vitamin E (alpha-tocopherol) at 5.59 mg/100g DM (1.24%), known for its antioxidant role and function in cellular membrane stability (Ghosh et al., 2017). Niacin (vitamin B3), which facilitates energy production and DNA repair, is present at 3.34 mg/100g DM (0.738%), a concentration comparable to or exceeding that found in some meats and cereals (Sosa & Fogliano, 2019). These findings are consistent with prior studies on other edible insects, such as palm weevil larvae and mealworms, which have also been shown to contain appreciable levels of riboflavin (B2), niacin (B3), pantothenic acid (B5), and vitamin B12 (Sosa & Fogliano, 2019). Vitamin B been reported in significant amounts in various insect species, positioning edible larvae as a crucial alternative source for populations at risk of B12 deficiency due to limited access to animal-sourced foods (Van Huis et al., 2015). While vitamin concentrations can vary depending on species, developmental stage, and diet, *T. confinis* larvae demonstrated a diverse and nutrient-dense vitamin profile that underscores their potential value as a sustainable and functional food source (Table 3).

Table 3. Laboratory analysis of vitamin composition of giant long-horned beetle larvae

Vitamin Component	Concentration (mg/100g)	Concentration (%)	MSE
Vitamin A (Retinol)	18.9	4.18	1.08
Vitamin B1/B2/B12	–	–	–
Vitamin B3 (Niacin)	3.34	0.738	0.09
Vitamin B6 (Pyrodoxine)	82.6	18.2	4.74
Vitamin C (Ascorbic Acid)	342	75.6	39.65
Vitamin E (Tocopherol)	5.59	1.24	0.14

Note: MSE, mean standard error

The Dietary-Health Potential of Edible Giant Longhorn Beetle Larvae

The nutritional composition of *T. confinis* larvae suggests substantial potential in mitigating malnutrition-related diseases, particularly chronic kidney disease (CKD), which is often characterized by protein-energy wasting and micronutrient deficiencies due to factors such as metabolic disturbances and reduced nutrient intake (Chan et al., 2021). From Table 1, with a protein content of 44.00% and fat content of 22.90%, *T. confinis* larvae offer high-quality macronutrients that are critical for maintaining muscle mass and meeting the elevated protein demands of CKD patients (Chan et al., 2021). Their exceptionally high vitamin C content (342 mg/100g DM), far exceeding that of conventional animal-based foods, supports antioxidant defenses and immune function, which are often compromised in individuals with CKD (Daenen et al., 2019). Moreover (Table 2), essential minerals such as calcium (225 mg/100g DM), magnesium (54.9 mg/100g DM), and iron (21.4 mg/100g DM) found in *T. confinis* can address common deficiencies observed in CKD, helping to maintain electrolyte balance and red blood cell production (van Swelm et al., 2020).

Beyond renal health, the nutrient-dense profile of *T. confinis* larvae positions them as a valuable tool in combating general malnutrition, particularly in regions with limited access to diverse diets. Deficiencies in micronutrients such as vitamin A (18.9 mg/100g DM), vitamin E (5.59 mg/100g DM), and zinc (17.3 mg/100g DM) can impair immune function, vision, and developmental health, especially in children and pregnant women (Stevens et al., 2022). Additionally, the presence of vitamin B-complex components from (Table 3), including B6 (82.6 mg/100g DM) and B3 (3.34 mg/100g DM), supports neurological function and energy metabolism, both of which are crucial in recovery from undernutrition and chronic disease (Kennedy, 2016). Integrating edible insect larvae like *T. confinis* into community nutrition strategies could thus provide a sustainable, locally sourced solution to various forms of nutritional deficiency and chronic illness. *T. confinis* larvae contain a

notably high calcium concentration of 225 mg/100g DM, potentially contributing to improved bone mineral density in older adults when included as part of a balanced diet. Furthermore, the larvae's substantial levels of vitamin B6 (82.6 mg/100g DM) are crucial for supporting neurological health and mitigating the risk of age-related cognitive decline (Kennedy, 2016). Deficiencies in these vitamins are linked to neurodegenerative conditions and impaired memory in ageing populations (Smith & Refsum, 2016).

During pregnancy, nutrient demands increase significantly to support fetal growth and maternal health. Iron is essential to prevent pregnancy-related anemia, which has been associated with low birth weight and increased maternal morbidity (Means, 2020). *T. confinis* larvae provide 21.4 mg/100g DM of iron, substantially higher than many conventional meats and complemented by 342 mg/100g of vitamin C, which enhances non-heme iron absorption (Hurrell & Reddy, 2019; Stoffel et al., 2020). Calcium and magnesium contents (54.9 mg/100g DM) contribute to fetal skeletal development and muscle function, reducing risks of complications such as preterm labor (Audhya, 2021). For infants, nutrients such as vitamin A, zinc (17.3 mg/100g DM), and B-complex vitamins are essential for immune competence, vision, and neurodevelopment (Stevens et al., 2022). However, direct consumption of *T. confinis* larvae may not be suitable for infants; their nutrient profiles offer valuable dietary contributions through maternal nutrition and breastfeeding.

CONCLUSIONS

The present study underscores the significant nutritional composition and dietary potential of *T. confinis* larvae, positioning them as a valuable alternative protein and micronutrient source in the context of food security and dietary supplementation. The larvae exhibit a rich nutritional profile, including high levels of protein, essential fats, vitamins (particularly Vitamin C (ascorbic acid), Vitamin B6 (pyridoxine, pyridoxal, pyridoxamine), and Vitamin A (retinol, retinal, retinoic acid, and retinyl esters) and minerals such as calcium, iron, and zinc, nutrients that are critically important for vulnerable populations such as the elderly, pregnant women, and young children. These nutritional attributes make *T. confinis* a functional food resource capable of addressing micronutrient deficiencies and contributing to the prevention of diet-related non-communicable diseases such as anemia, osteoporosis, and cognitive decline. Despite these benefits, the full integration of *T. confinis* into mainstream food systems still challenged by its limited availability in the wild, labor-intensive harvesting methods, and lengthy life cycle, which restrict large-scale cultivation. This study recommends that further multidisciplinary research evaluate their nutritional quality, safety, environmental influences, and long-term health benefits; the potential presence of anti-nutritional factors and allergens calls for further toxicological and biochemical evaluations. In addition, efforts should focus on exploring sustainable harvesting and domestication potentials and sensory acceptance, and processing innovations to enhance safety and consumer appeal, promoting community awareness, and integrating edible insects into local and national food and nutrition policies. Such initiatives could support sustainable nutrition strategies, improve livelihoods, and contribute to addressing malnutrition and food insecurity among vulnerable populations in Tanzania.

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AUTHORS' CONTRIBUTIONS

Patrick Cleophas Mpombeye: conceptualization, methodology, data collection, analysis and curation and writing original draft. Arnold Onyango Watako and Dennis Ochuodho Otieno: conceptualization, review of manuscript and general academic supervision. Andrea Malima Kigeso: thoroughly reviewed the manuscript, confirmed the accuracy and authenticity of the data and its interpretation before submission.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

The study conducted after obtaining the necessary administrative permission for data collection from Morogoro Rural District authorities. Ethical approval obtained from Ethics Review Committee, Jaramogi Oginga Odinga University of Science and Technology (JOUST) under Letter Ref No A451/P/0139/21.

CONSENT FOR PUBLICATION

Consensus for the publication of this study and its findings was granted by the academic supervisors, who provided academic supervision and oversight throughout the research.

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AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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