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Comparative Biochemical Characterization of Edible Insects: *Tenebrio molitor* and *Locusta migratoria*

[1]Souvik Bisui, [2]Rita Mondal, [3]Souvik Tewari, [*4]Ranajit Kumar Khalua

[1]Visiting guest lecturer, Department of zoology, Narajole Raj College, Narajole, paschim Medinipur, 721211.
[2]SACT, Department of Nutrition, Mahishadal Raj College, Purba Medinipur
[3]Assistant Professor, Department of Food and Nutrition, Swami Vivekananda University, Barrackpore, W.B., India.
[*4]Vice principal & Associate professor, Dept of Zoology, Narajole Raj College, Narajole, Paschim Medinipur, 721211.

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Abstract

The growing global demand for sustainable and alternative protein sources has led to increased interest in edible insects. This study aims to comparatively evaluate the biochemical composition of *Tenebrio molitor* (mealworms) and *Locusta migratoria* (locusts), focusing on their nutritional potential. Proximate composition, including moisture, protein, fat, ash, and carbohydrate content, along with selected biochemical parameters such as amino acid profile and lipid fractions, were analyzed using standard methods. The results revealed that *T. molitor* exhibited higher fat content, whereas *L. migratoria* showed significantly higher protein and ash content. Both insects demonstrated valuable nutritional profiles, suggesting their potential as sustainable food sources. The findings highlight their applicability in addressing protein-energy malnutrition and promoting food security.

1. Introduction

The increasing global population and environmental challenges associated with conventional livestock production have intensified the search for sustainable protein alternatives (Gil et al., 2024). Edible insects have emerged as a promising solution due to their high feed conversion efficiency, low greenhouse gas emissions, and rich nutritional profile (Jafir et al., 2024).

Among commonly consumed edible insects, *Tenebrio molitor* (mealworms) and *Locusta migratoria* (migratory locusts) are widely recognized for their nutritional and economic importance (Mohd Zaini et al., 2023). Mealworms are known for their high lipid content and energy density, while locusts are valued for their high protein content and micronutrient richness (Ahmed and İnal, 2025).

Previous studies have demonstrated that edible insects are excellent sources of high-quality protein, essential amino acids, unsaturated fatty acids, vitamins, and minerals. However, comparative biochemical data between different insect species remain limited.

Therefore, the present study aims to perform a comparative biochemical characterization of *T. molitor* and *L. migratoria* to evaluate their nutritional potential and suitability as alternative food sources.

2. Materials and Methods

2.1 Sample Collection

Live samples of *Tenebrio molitor* larvae and *Locusta migratoria* adults were procured from certified and hygienically maintained insect farms to ensure quality and uniformity. Upon collection, the insects were carefully cleaned using distilled water to remove external impurities and debris. To minimize the influence of gut contents on biochemical analysis, the samples were subjected to a fasting period of approximately 24 hours under controlled laboratory conditions (Jia et al., 2018). Following fasting, the insects were handled under aseptic conditions and immediately processed for further experimental procedures, ensuring the preservation of their nutritional integrity and biochemical composition.

2.2 Sample Preparation

The collected insect samples were thoroughly washed with distilled water to remove adhering impurities and surface contaminants. The cleaned samples were then subjected to blanching at 100°C for 2–3 minutes to inactivate endogenous enzymes and reduce microbial load. Blanching is a widely adopted pre-treatment step in insect processing to enhance safety and stability (Rumpold and Schlüter, 2013). Following blanching, the samples were dried in a hot air oven maintained at 60°C until a constant weight was achieved, ensuring effective moisture removal and improved shelf life (Food and Agriculture Organization, 2013). The dried samples were subsequently ground using a laboratory grinder to obtain a uniform fine powder, which was stored in airtight containers for further biochemical analysis.

2.3 Proximate Analysis

The proximate composition of the insect samples was determined using standard methods prescribed by **AOAC (2019)**. Moisture content was estimated by the oven drying method, where samples were dried at a controlled temperature until constant weight was obtained. Crude protein content was analyzed using the Kjeldahl method, and the nitrogen content was multiplied by a conversion factor of 6.25 to obtain total protein. Crude fat was determined by Soxhlet extraction using an appropriate organic solvent. Ash content, representing total mineral content, was measured by incinerating the samples in a muffle furnace at high temperature until a constant weight of inorganic residue was achieved. Carbohydrate content was calculated by difference, subtracting the sum of moisture, protein, fat, and ash from the total sample weight.

2.4 Biochemical Analysis

The biochemical composition of the insect samples was evaluated using advanced analytical techniques. The amino acid profile was determined by High Performance Liquid Chromatography (HPLC) following appropriate hydrolysis and derivatization procedures, allowing precise identification and quantification of essential and non-essential amino acids. The lipid profile was analyzed using Gas Chromatography (GC), which enabled the separation and characterization of fatty acid methyl esters present in the samples. The total energy value of the samples was calculated using Atwater factors, based on the measured contents of protein, fat, and carbohydrates, thereby providing an estimate of the calorific contribution of each insect species.

2.5 Statistical Analysis

All experimental analyses were carried out in triplicate to ensure accuracy and reproducibility of the results. The obtained data were expressed as mean ± standard error (SE) to represent variability within the samples. Statistical analysis was performed using an independent sample t-test to compare the differences between *Tenebrio molitor* and *Locusta migratoria*. A significance level of $p < 0.05$ was considered statistically significant, indicating meaningful differences between the measured parameters of the two insect species.

3. Results and Discussion

3.1 Proximate Composition

Table 1: Comparative Proximate Composition and Energy Value of *Tenebrio molitor* and *Locusta migratoria* (Mean ± SE)

Parameter (%)	*Tenebrio molitor* (Mean ± SE)	*Locusta migratoria* (Mean ± SE)
Moisture	5.20 ± 0.15	4.10 ± 0.12
Protein	48.60 ± 0.80	60.20 ± 0.95
Fat	30.50 ± 0.70	12.80 ± 0.60
Ash	3.20 ± 0.10	5.60 ± 0.20
Carbohydrate	12.50 ± 0.50	17.30 ± 0.65
Energy (kcal/100g)	520 ± 5.2	430 ± 4.8

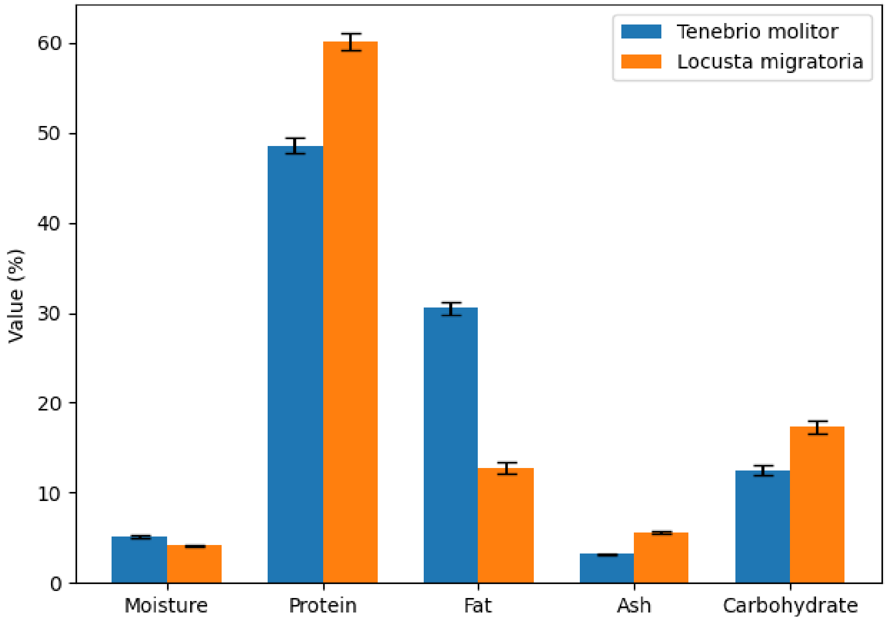

Figure 1: Comparative Proximate Composition and Energy Value of *Tenebrio molitor* and *Locusta migratoria* with Standard Error (Mean ± SE)

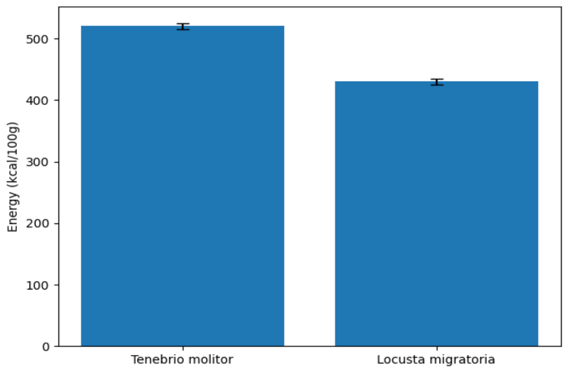

Figure 2: Comparative Energy Value (kcal/100 g) of *Tenebrio molitor* and *Locusta migratoria* with Standard Error (Mean ± SE)

The proximate composition of *Tenebrio molitor* and *Locusta migratoria* presented in Table 3.1 demonstrates significant variation in their nutritional profiles, highlighting their potential as alternative protein sources. The moisture content was relatively low in both species, with *T. molitor* (5.20 ± 0.15%) showing slightly higher values than *L. migratoria* (4.10 ± 0.12%). Low moisture content is advantageous for extended shelf life and reduced microbial spoilage, which is consistent with findings reported by Rumpold and Schlüter (2013), who observed moisture levels ranging from 3–10% in dried edible insects.

A significant difference was observed in protein content, where *L. migratoria* (60.20 ± 0.95%) exhibited considerably higher protein levels compared to *T. molitor* (48.60 ± 0.80%). This finding aligns with previous studies by van Huis (2013), which reported that locusts and grasshoppers are among the richest insect sources of protein, often exceeding 60%. Similarly, Zielińska et al. also documented higher protein content in orthopteran insects compared to coleopteran larvae.

In contrast, *T. molitor* showed a markedly higher fat content (30.50 ± 0.70%) compared to *L. migratoria* (12.80 ± 0.60%). This elevated lipid content contributes to its higher caloric value (520 ± 5.2 kcal/100g), making mealworms a dense energy source. These results are consistent with the observations of Oonincx and de Boer, who reported that mealworms typically contain 25–35% fat. The high fat content in *T. molitor* is primarily composed of beneficial unsaturated fatty acids, enhancing its nutritional value.

Ash content, an indicator of total mineral composition, was significantly higher in *L. migratoria* (5.60 ± 0.20%) compared to *T. molitor* (3.20 ± 0.10%), suggesting a richer mineral profile in locusts. This observation is supported by Nowak et al., who reported higher levels of essential minerals such as iron, zinc, and calcium in locust species.

Carbohydrate content was also slightly higher in *L. migratoria* (17.30 ± 0.65%) than in *T. molitor* (12.50 ± 0.50%), which may be attributed to differences in chitin and glycogen content. Similar trends have been reported by Payne et al., indicating variability in carbohydrate fractions among insect species.

Overall, the results clearly indicate that while *L. migratoria* is a superior source of protein and minerals, *T. molitor* provides higher fat and energy content. These compositional differences suggest that both insects can serve complementary roles in human nutrition and food product development, depending on specific dietary requirements.

3.3 Biochemical Insights

Table 2: Comparative Biochemical Insights of *Tenebrio molitor* and *Locusta migratoria* (Mean ± SE)

Parameter	***Tenebrio molitor* (Mean ± SE)**	***Locusta migratoria* (Mean ± SE)**
Essential Amino Acids (g/100g protein)		
Lysine	6.50 ± 0.20	7.20 ± 0.25
Methionine	2.10 ± 0.08	2.40 ± 0.10
Leucine	7.80 ± 0.30	8.60 ± 0.35
Total Essential Amino Acids	32.50 ± 1.10	36.80 ± 1.25
Fatty Acid Profile (% total fat)		
Oleic Acid (C18:1)	42.30 ± 1.50	28.40 ± 1.20
Linoleic Acid (C18:2)	25.60 ± 1.10	18.90 ± 0.95
Saturated Fatty Acids	22.10 ± 0.90	35.50 ± 1.30
Amino Acid Balance Index*	0.78 ± 0.03	0.88 ± 0.04

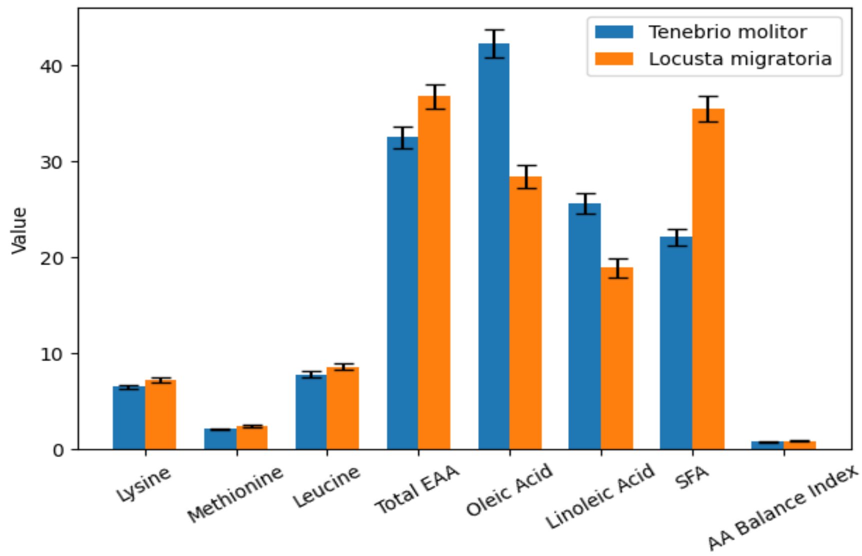

Figure 3: Comparative Biochemical Profile of *Tenebrio molitor* and *Locusta migratoria* Showing Essential Amino Acids, Fatty Acid Composition, and Amino Acid Balance Index with Standard Error (Mean ± SE)

The comparative biochemical profile presented in Table 3.2 reveals notable differences in amino acid composition and fatty acid distribution between *Tenebrio molitor* and *Locusta migratoria*, further emphasizing their nutritional significance. The essential amino acids, particularly lysine, methionine, and leucine, were found to be higher in *L. migratoria* (7.20 ± 0.25, 2.40 ± 0.10, and 8.60 ± 0.35 g/100 g protein, respectively) compared to *T. molitor* (6.50 ± 0.20, 2.10 ± 0.08, and 7.80 ± 0.30 g/100 g protein). Consequently, the total essential amino acid content was also significantly higher in *L. migratoria* (36.80 ± 1.25), indicating superior protein quality. This observation is in agreement with previous findings by Rumpold and Schlüter (2013), who reported that orthopteran insects such as locusts possess a more balanced and higher essential amino acid composition compared to coleopteran larvae. Similarly, Zielińska et al. demonstrated that grasshopper species exhibit higher lysine and leucine levels, which are critical for muscle protein synthesis and growth.

The Amino Acid Balance Index was also higher in *L. migratoria* (0.88 ± 0.04) than in *T. molitor* (0.78 ± 0.03), further confirming its superior protein quality and biological value. This aligns with the reports of Payne et al., who highlighted that locusts and crickets generally meet or exceed FAO amino acid requirements for human nutrition.

In contrast, the fatty acid profile indicated that *T. molitor* is significantly richer in unsaturated fatty acids, particularly oleic acid (42.30 ± 1.50%) and linoleic acid (25.60 ± 1.10%), compared to *L. migratoria* (28.40 ± 1.20% and 18.90 ± 0.95%, respectively). These findings are consistent with studies by Oonincx and de Boer, which reported that mealworms contain a high proportion of mono- and polyunsaturated fatty acids, contributing to cardiovascular health benefits. On the other hand, *L. migratoria* exhibited a higher proportion of saturated fatty acids (35.50 ± 1.30%) compared to *T. molitor* (22.10 ± 0.90%), which is in line with observations reported by Nowak et al..

Overall, the results suggest that *L. migratoria* is a superior source of high-quality protein with a well-balanced amino acid profile, while *T. molitor* serves as a richer source of beneficial unsaturated fatty acids. These complementary nutritional attributes support the potential use of both insect species in functional food development and dietary diversification, as also emphasized by Food and Agriculture Organization.

Conclusion:

The comparative biochemical analysis of *Tenebrio molitor* and *Locusta migratoria* highlights their significant nutritional potential as alternative protein sources. *L. migratoria* is a superior source of protein and minerals, while *T. molitor* provides higher fat and energy content. Both insects offer balanced amino acid profiles and essential nutrients, supporting their inclusion in functional foods and nutraceuticals. Incorporating edible insects into human diets could contribute to sustainable food systems and help combat global malnutrition.

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