



UNIVERSITY OF LIFE SCIENCES "KING MIHAI I" FROM TIMISOARA

"YOUNG PEOPLE AND MULTIDISCIPLINARY RESEARCH IN APPLIED LIFE SCIENCES"

13-14 November 2025



Tenebrio molitor Larvae: A Functional and Sustainable Protein Source for Human and Animal Nutrition

Susana Machado,^{1,2*} Daniel Lemos,¹ Anabela Costa,¹ Thiago F. Soares,¹ M. Beatriz P. P. Oliveira,¹ Carolina Oliveira de Souza,³ Miguel A. Prieto,² Rita C. Alves¹

¹REQUIMTE/LAQV, Department of Chemical Sciences, Faculty of Pharmacy, University of Porto, Portugal ²Instituto de Agroecología e Alimentación (IAA), Nutrition and Food Group (NuFoG), Department of Analytical Chemistry and Food Science, University of Vigo, Campus Auga, 32004 Ourense, Spain

³Graduate Program in Food Science / Department of Bromatological Analyses, Faculty of Pharmacy, Federal University of Bahia, Brazil

*smachado@ff.up.pt

Introduction

The growing demand for alternative and sustainable protein sources has driven interest in edible insects [1]. Among these, *Tenebrio molitor* stands out for its high protein content, balanced lipid profile, and versatility, showing potential for use in innovative food products and sustainable production chains [2]. Its consumption for human and animal use is approved by the European Union under Regulation (EU) 2015/2283 on novel foods, recognizing it as a safe and sustainable nutritional source [3].

Regulation 2015/2283

Rules for placing new foods on the market.
Whole insects and their parts (such as insect flour) and derived products may be marketed.

Regulation 2021/882 (01/06/2021)
Dehydrated larvae

2021

Regulation 2022/169 (8/02/2022)
Frozen, dehydrated, and powdered larvae

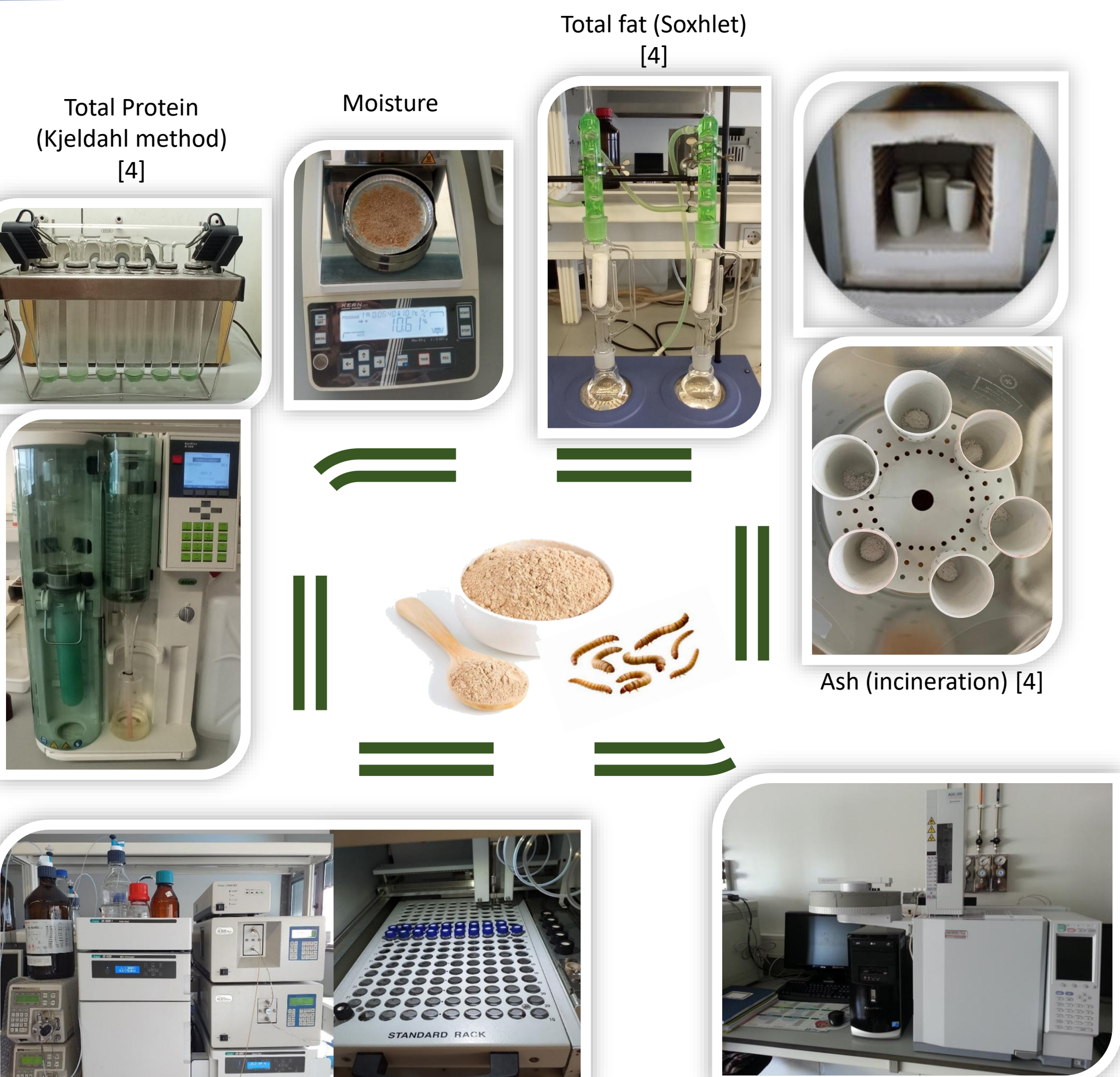
2022

Regulation 2025/89 (20/01/2025)
Whole larva powder treated with UV radiation

2025



Method



Total fat (Soxhlet) [4]

Moisture

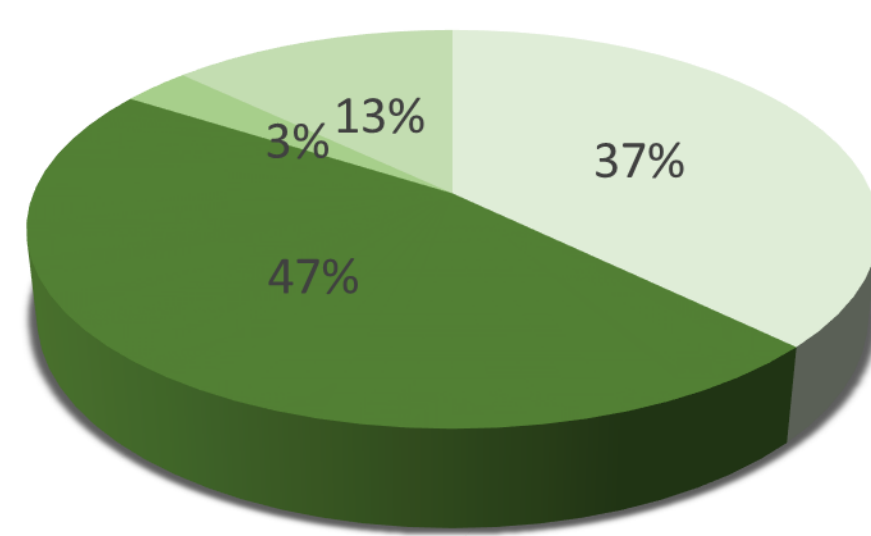
Total Protein (Kjeldahl method) [4]

Ash (incineration) [4]

The lipid extract was derivatized with KOH/methanol and BF₃/methanol, extracted with hexane, dried with anhydrous sodium sulfate. Fatty acids were characterized by gas chromatography (GC-FID) [5].

Total amino acids were released via acidic and alkaline hydrolysis and subjected to automatic online pre-column derivatization with OPA/3-MPA and FMOc, followed by RP-HPLC-FLD analysis [6].

Results and discussions



■ Fat ■ Protein ■ Ash ■ Total carbohydrates

Figure 1. – Macronutrient composition of *Tenebrio molitor* larvae (% dry weight): Protein, Fat, Ash, and Total Carbohydrates.

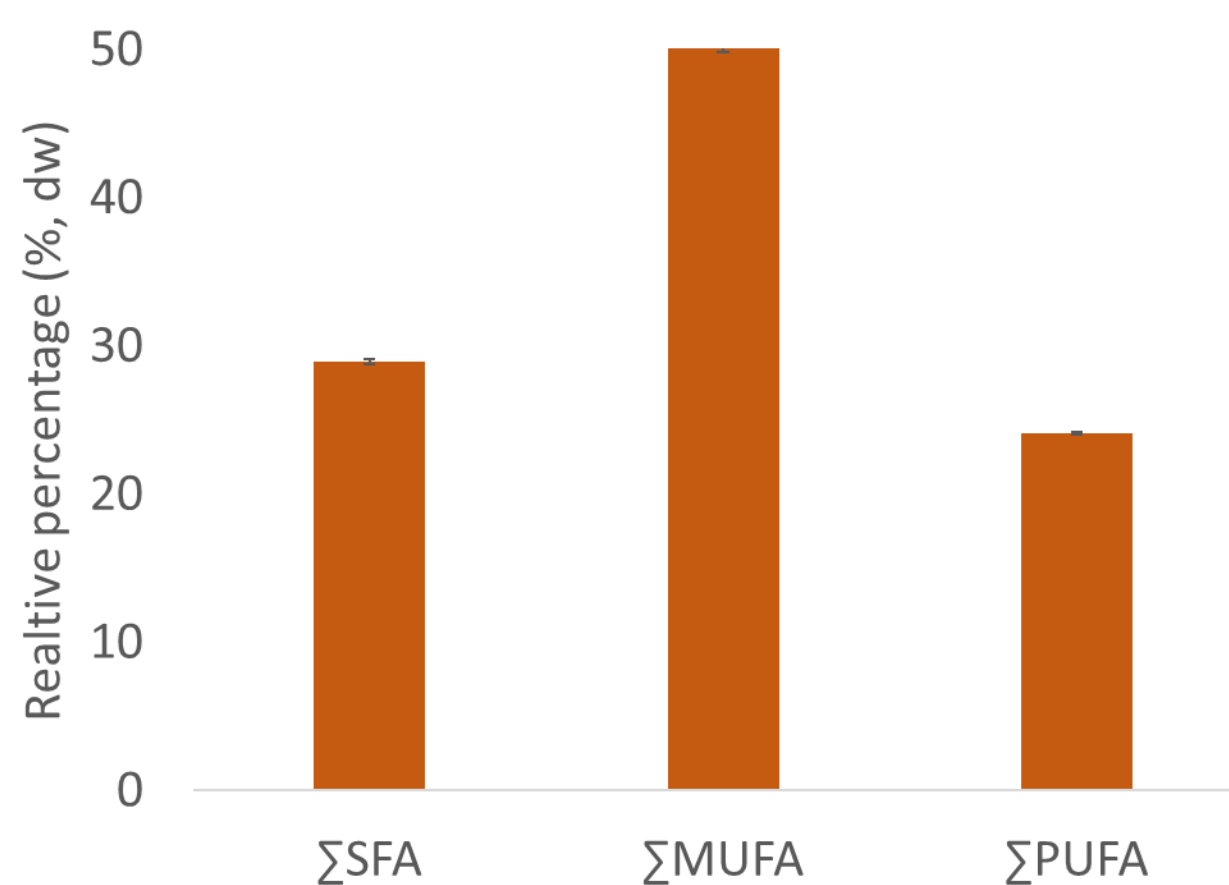


Figure 2. – Proportions of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA) in *Tenebrio molitor* larvae (% of total fatty acids).

Tenebrio molitor exhibits a high protein content (47%) indicating that it is an excellent source of high-quality protein, for human and animal diets. Total fat content of 37% contributes significantly to the energy value, resulting in a high energy density (574 kcal/100 g) (figure 1).

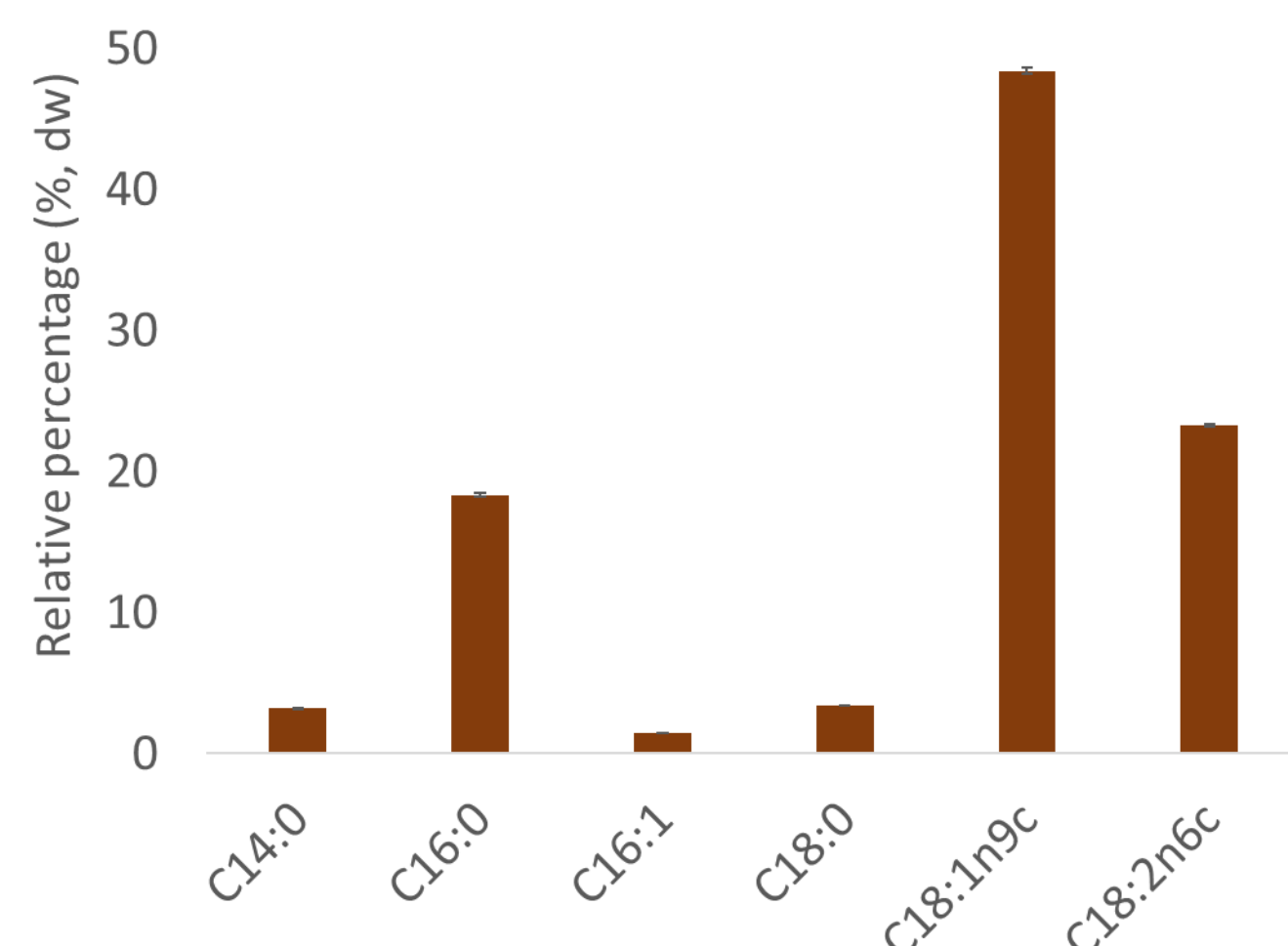


Figure 3. – Fatty acid profile of *Tenebrio molitor* larvae.

Among the MUFA, oleic acid (C18:1n9c) was identified as the main component, representing 48.41%, while linoleic acid (C18:2n6c) was the most abundant PUFA, accounting for 23.28%. The most prevalent SFA were palmitic acid (C16:0) at 18.34% and stearic acid (C18:0) at 3.42% (Figure 3).

The lipid profile is dominated by oleic acid (48%), linoleic acid (23%), and palmitic acid (18%). Notably, monounsaturated fatty acids (50%) predominated over saturated (26%) and polyunsaturated (24%) fatty acids, reflecting a nutritionally favourable pattern associated with cardiovascular health and lipid balance (figure 2).

The amino acid profile revealed high concentrations of glutamic acid (49 mg/g), aspartic acid (34 mg/g), and arginine (41 mg/g), important for metabolic, protein synthesis, and growth (figure 4).

Total amino acids were 396 mg/g, reflecting a high protein content and quality. Of this total, 145 mg/g were essential amino acids, with leucine (30 mg/g) and valine (26 mg/g) standing out. These branched-chain amino acids (BCAAs) are fundamental for muscle synthesis, recovery, and energy metabolism (figure 5).

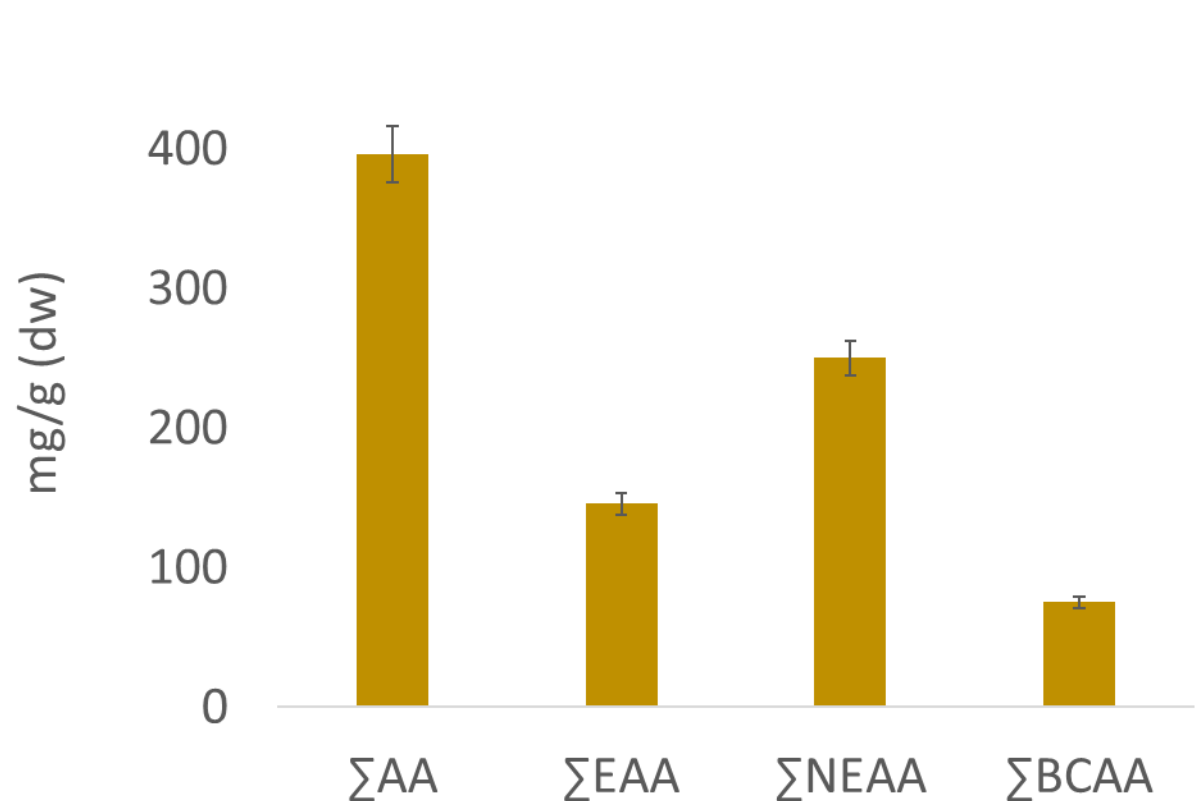


Figure 4. – Total amino acid (AA), branched-chain amino acid (BCAA), essential amino acid (EAA), and non-essential amino acid (NEAA) contents in *Tenebrio molitor* larvae (mg/g dry matter).

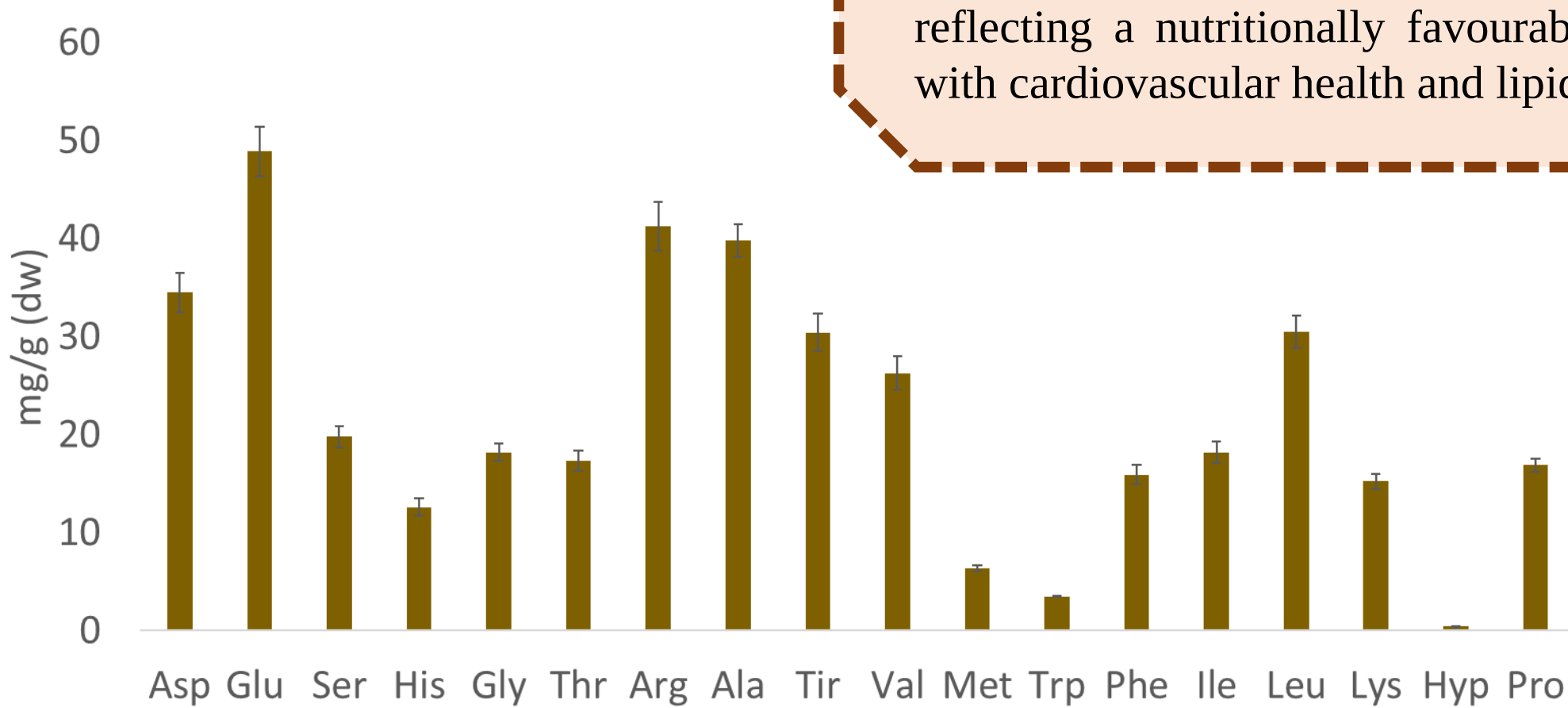


Figure 5. – Amino acid profile of *Tenebrio molitor* larvae.

Conclusion

- *Tenebrio molitor* proved to be a highly nutritious protein source, combining high-quality proteins, essential amino acids, a balanced lipid profile, and high energy density;
- Its predominant monounsaturated fatty acids and the presence of BCAAs provide important nutritional benefits for human and animal health;
- These characteristics make it suitable for innovative food products and protein supplementation, aligning with sustainable and safe food practices.

References

- [1] Huis, A. V., Itterbeeck, J. V., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). FAO Forestry Paper 171. Rome: FAO.
- [2] Morales, M. L., Segura-Borrego, M. P., Aguilera-Velázquez, J. R., Callejón, R. M., Gutiérrez-Praena, D., & Ubeda, C. (2025). *Food Research International*, 209, 11622.
- [3] EFSA (2021). *EFSA Journal*, 19(8), 6778. doi:10.2903/j.efsa.2021.6778
- [4] AOAC. 21st Edition, Washington DC, EUA; 2019
- [5] ISO. (2017). ISO 12966-2: 2017. Developed by ISO/TC 34/SC 11: Animal and vegetable fats and oils. In: International Organization for Standardization Geneva.
- [6] Machado S., Costa A.S., Pimentel F., Oliveira M. B. P., Alves R.C. (2020). *Food Chemistry*, 326, 126940.

Acknowledgement: PT national funds (FCT/MCTES, FCT and Ministério da Ciência, Tecnologia e Ensino Superior) through the project UID/50006 -Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. AlProSos (Sustainable regional protein-rich foods), funded by CYTED (ref. 125RT0165).

