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

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Abstract
The growing interest in alternative and sustainable protein sources has highlighted *Tenebrio molitor* for its high protein content (47%), balanced lipid profile, and versatility. Approved by the European Union under Regulation (EU) 2015/2283 as a novel food, it is recognized as a safe and sustainable nutritional source. It contains 37% fat, providing high energy density (574 kcal/100 g), with monounsaturated fatty acids (50%) - mainly oleic acid (48%) - associated with cardiovascular health. The amino acid profile shows high levels of glutamic and aspartic acids, and arginine, totaling 396 mg/g, of which 145 mg/g are essential amino acids, including leucine and valine, crucial for muscle synthesis and recovery. Therefore, *Tenebrio molitor* represents a complete protein source with significant nutritional benefits and strong potential for use in innovative food products and sustainable production chains.
Keywords: Edible insects, insect larvae, Novel food, amino acid profile, lipid composition, sustainable production chains, nutritional value.

1. Introduction

The growing demand for alternative and sustainable protein sources has driven interest in edible insects, which offer high feed conversion efficiency, lower environmental footprint, and potential for integration into circular food systems [1, 2]. Edible insects, including mealworms, require significantly less land and water than traditional livestock and produce fewer greenhouse gases, making them an attractive option to meet the protein needs of a growing global population while mitigating climate change impacts [2, 3]. Furthermore, insects can be reared on organic by-products, reducing food waste and contributing to a circular economy [1, 4, 5]. Among these species, *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 [1, 6]. The larvae provide high-quality protein with a complete amino acid profile, including essential branched-chain amino acids, and contain lipids rich in mono- and polyunsaturated fatty acids, which are beneficial for cardiovascular health [1, 7]. The composition of *Tenebrio molitor* larvae can also be modulated by their diet, allowing producers to optimize nutritional content for human or animal consumption [1, 7]. These characteristics make them suitable for incorporation into functional foods, protein supplements, and feed formulations [6, 7].

The consumption of *Tenebrio molitor* 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

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source [8]. This regulatory approval, based on rigorous safety assessments by the European Food Safety Authority (EFSA), has facilitated market expansion in the EU and provides a framework for future commercialization [8], including the recent 2025 authorization for the use of ultraviolet (UV)-treated larval powder [9]. The recognition of mealworms as novel food also emphasizes the growing acceptance of insects in European diets, supporting research, innovation, and investment in sustainable protein alternatives [1, 4, 6].

Taken together, *Tenebrio molitor* represents a high-quality, nutritionally complete, and environmentally sustainable protein source. Its potential applications span human nutrition, animal feed, and the development of innovative food products, aligning with global goals for food security, sustainability, and circular bioeconomy practices [1, 2, 6].

The present study aims to evaluate the protein and lipid composition of *Tenebrio molitor* larvae, analyzing their nutritional potential and relevance as a sustainable alternative to conventional protein sources.

2. Materials and method

2.1. Samples

Lyophilized and ground *Tenebrio molitor* larvae from a commercial supplier in Salvador, BA, Brazil, were analysed. *Tenebrio molitor* larvae were fed *ad libitum* with wheat bran, while vegetables such as cabbage and carrot were provided as a source of moisture. Samples were vacuum-sealed and stored under controlled conditions. All analyses were carried out in triplicate to ensure reproducibility.

2.2. Nutritional analysis

Total fat content was determined by Soxhlet extraction according to AOAC procedures [10]. Approximately 5 g of sample was mixed with anhydrous sodium sulfate and extracted with petroleum ether; the total fat was calculated based on mass differences after solvent removal.

Protein content was determined by the AOAC Kjeldahl method [10]. About 0.4 g of sample was digested, distilled, and titrated to determine total nitrogen (%), which was converted to protein content using a factor of 6.25.

Ash content was also determined according to AOAC [10] procedures by incineration at 500 °C until constant weight, and expressed as a percentage of total mineral content.

2.3. Fatty acid analysis

The fatty acid profile of *Tenebrio molitor* larvae was determined following ISO 12966-2:2017 [11].

2.3.1. Lipid Extraction

The Lipid extraction was performed as described by Alves et al. [12]. The sample was weighed in triplicate into falcon tubes. To each tube, 75 µL of 0.1% BHT solution and 1 mL of absolute ethanol were added. The mixtures were homogenized for 30 min using a vortex mixer (Multi Reax, Heidolph Instruments, Schwabach, Germany). Next, 4 mL of n-hexane were added, and the samples were vortexed again for 30 min. Then, 2 mL of 1% NaCl solution was introduced, the mixture briefly vortexed, and centrifuged at 5000 rpm for 2 min (Megafuge 16, Heraeus, Hanau, Germany). The upper organic phase was collected, and the residue was re-extracted twice with 2 mL portions of n-hexane. The combined organic extracts were dried over anhydrous sodium sulfate to remove residual water. The extract was then evaporated under a nitrogen stream, reconstituted in 1 mL of n-hexane, transferred to Eppendorf tubes, and centrifuged at 13,000 rpm for 5 min (FRESCO 17, Heraeus, Hanau, Germany) prior to further analysis.

2.3.2. Fatty Acid Methylation

Lipids were first converted to fatty acid methyl esters (FAMEs) following the principles of ISO 12966-2:2011 [11]. In brief, after evaporating n-hexane from the lipid extract, the residue was dissolved in 1 mL of dichloromethane and 2 mL of 0.5 M methanolic potassium hydroxide. The mixture was vortexed and heated at 100 °C for 10 min in a thermostatic block (SBH130D/3, Stuart, Stafford, UK). After cooling on ice for 5 min, 2 mL of boron trifluoride in 14% methanol were added, and the mixture was heated again at 100 °C for 30 min to complete derivatization.

Following the reaction, 2 mL of deionized water and n-hexane were added. The samples were mixed and centrifuged at 3000 rpm for 5 min. The upper organic phase was collected, dried over anhydrous sodium sulfate, and centrifuged again. Finally, 1 mL of the clear supernatant was transferred into a 2 mL vial for GC-FID analysis.

2.3.3. GC Analysis

FAMEs were separated using a Shimadzu GC-FID system (Shimadzu, Tokyo, Japan) equipped with an AOC-20i autosampler, a split/splitless injector set at 250 °C, and a flame ionization detector at 270 °C.

Separation was achieved on a CP-Sil 88 capillary column (50 m × 0.25 mm i.d., 0.20 µm film thickness; Varian, Middelburg, The Netherlands). Helium was used as the carrier gas at a flow rate of 3.0 mL/min, and the oven temperature program was set as follows: 120 °C for 5 min, ramping at 2 °C/min to 160 °C (hold 2 min), then ramping at 2 °C/min to 220 °C (hold 10 min). The injection volume was 1 µL. Fatty acids were identified by comparing retention times with those of a 37-component FAME standard mixture (Supelco). Quantification was expressed as relative percentages of each fatty acid in the sample.

2.4. Amino acid analysis

Amino acid composition was determined following Machado et al. [13], using alkaline hydrolysis for tryptophan and acid hydrolysis for all other amino acids. Norvaline (2 mg/mL) was used as internal standard.

2.4.1. Alkaline hydrolysis (tryptophan)

Freeze-dried samples were mixed with 3 mL of 4 M KOH in nitrogen-flushed screw-cap tubes. To determine the optimal hydrolysis time and maximize tryptophan recovery, different incubation periods ranging from 2 to 24 h were tested - a hydrolysis time of 18 h was selected as optimal (Thermo block (SBH130D/3, Stuart, UK). After centrifugation (2500 rpm, 10 min), the supernatant (50 µL) was diluted with 0.1 M HCl (940 µL) and spiked with the internal standard (10 µL) prior to HPLC analysis. The mixture was centrifuged again at 13,000 rpm for 10 min before HPLC analysis.

2.4.2. Acid hydrolysis (remaining amino acids)

Samples were mixed with 3 mL of 6 M HCl, flushed with nitrogen for 3 min, sealed, and hydrolyzed at 110 °C for 24 h (Thermo block (SBH130D/3, Stuart, UK). After centrifugation (2500 rpm, 10 min), the hydrolysate (50 µL) was diluted in borate buffer, pH 10.2 (940 µL) and supplemented with the internal standard (10 µL). After a further centrifugation at 13,000 rpm for 10 min, the supernatant was ready for HPLC analysis.

2.4.3. HPLC analysis

Amino acids were analyzed using a Jasco HPLC system (Jasco, Tokyo, Japan) comprising PU-980 pumps, an AS-4150 autosampler and an FP-2020 Plus fluorescence detector. Automated on-line pre-column derivatization with OPA/3-MPA (primary amino acids) and FMOC (secondary amino acids) was performed according to Henderson et al. [14] Separation was achieved on a ZORBAX Eclipse Plus C18 column (4.6 × 250 mm, 5 µm; Agilent Technologies, USA) maintained at 50 °C (CO-4061 oven). Mobile phase A consisted of phosphate/borate buffer (pH 8.2), and mobile phase B of MeOH:ACN:H_2O (45:45:10). The gradient followed Machado et al. [13] 0.85′ min, 2% B; 33.4′, 57% B; 33.5 min 85% B; 39.3′, 85% B; 39.4′, 2% B; 40.0′, 2% B (flow rate: 1.5 ml/min). Detection was performed at $\lambda_{ex}/\lambda_{em}$ = 340/450 nm for OPA derivatives and 266/305 nm for FMOC derivatives.

3. Results and Discussion

3.1. Nutritional composition

Tenebrio molitor larvae exhibit a high protein content (46.8 ± 0.36%), confirming their potential as an excellent source of high-quality protein for both human and animal nutrition. This is consistent with recent studies reporting protein levels between 44% and 52% [15, 16, 17].

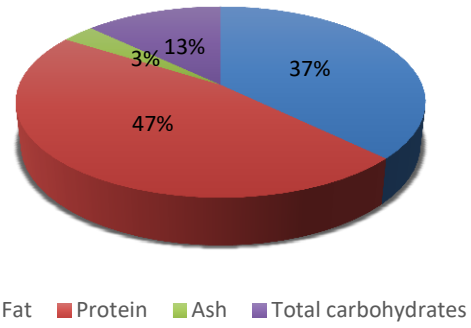

Figure 1. – Macronutrient composition of *Tenebrio molitor* larvae (% dry weight): Protein, Fat, Ash, and Total Carbohydrates.

Total fat content was 37.3 ± 0.11%, within the typical range reported in the literature (28-40%) [13,16]. Ash content in *Tenebrio molitor* larvae was 3.07 ± 0.02%, which is consistent with literature values ranging from 2% to 4% [6,18]. This fraction represents the mineral content of the larvae, including essential elements such as iron, zinc, and magnesium. Total carbohydrates, estimated by difference, accounted for 12.9 ± 0.38% (Figure 1).
The combination of high protein and fat contents contributes to a high energy density (574.1 ± 0.41 kcal/100 g), comparable to other edible insects. [19].

3.2. Fatty acid analysis

The fatty acid profile of *Tenebrio molitor* larvae revealed a predominance of monounsaturated fatty

acids (MUFA), accounting for 50.02% of the total, followed by polyunsaturated fatty acids (PUFA) at 24.07%, and saturated fatty acids (SFA) at 25.88% (Figure 2). 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). This lipid distribution is nutritionally favorable, since higher proportions of MUFA and PUFA are linked with improved cardiovascular markers and greater dietary value [20].

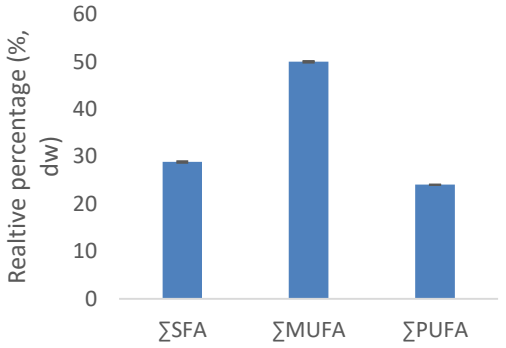

Figure 2. – Proportions of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA) in *Tenebrio molitor* larvae (% of total fatty acids).

These results are consistent with recent studies that have identified similar lipid profiles in *Tenebrio molitor*. For example, [16] reported that oleic acid was the predominant MUFA, accounting for 38.41% of the total fatty acids, while linoleic acid was the main PUFA. Furthermore, [1] stated that the lipid composition of these larvae is influenced by diet, with variations in MUFA and PUFA contents depending on the feeding substrates used [21].

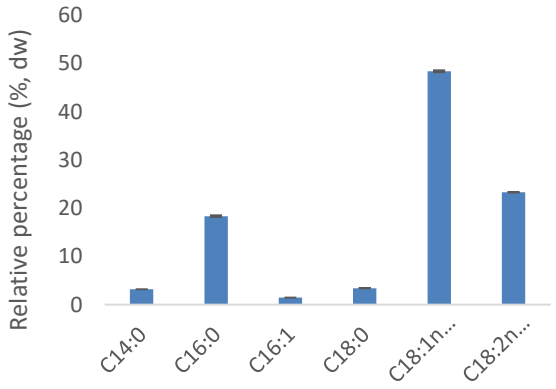

Figure 3. – Fatty acid profile of *Tenebrio molitor* larvae.

3.3. Amino acid analysis

The amino acid composition of *Tenebrio molitor* larvae revealed a total amino acid (∑AA) content of 395.84 mg/g dry matter (Figure 4). Essential amino acids (∑EAA) accounted for 145.77 mg/g, representing 36.8% of the total amino acids, while non-essential amino acids (∑NEAA) contributed 250.07 mg/g (63.2%). Branched-chain amino acids (∑BCAA = 74.94 mg/g) represented approximately 18.9% of total amino acids and 51.4% of the essential amino acids. This high proportion of BCAA - comprising leucine, isoleucine, and valine - indicates the nutritional potential of *Tenebrio molitor* as a high-quality protein source, particularly relevant for applications in muscle protein synthesis and sports nutrition.

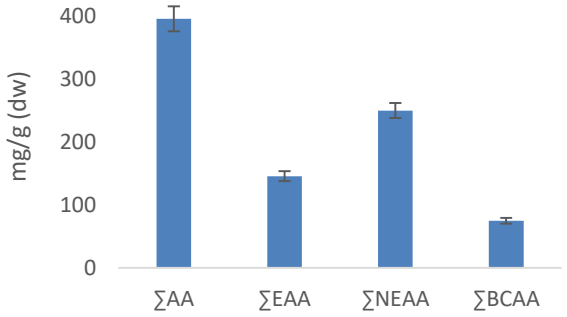

Figure 4. – Total amino acid (AA), branched-chain amino acid (BCAA), essential amino acid (EAA), and non-essential amino acid (NEAA) contents in *Tenebrio molitor* larvae (mg/g dry matter).

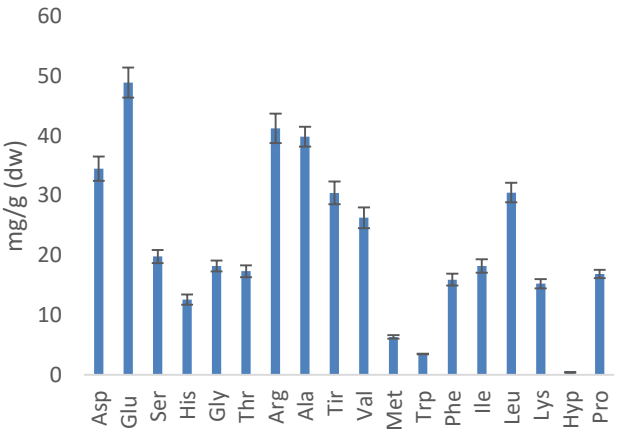

Figure 5. – Amino acid profile of *Tenebrio molitor* larvae.

Among individual amino acids, glutamic acid (48.88 mg/g) and aspartic acid (34.46 mg/g) were the most abundant, followed by arginine (41.23 mg/g),

alanine (39.82 mg/g), and leucine (30.48 mg/g). Methionine (6.32 mg/g), tryptophan (3.48 mg/g) and hydroxy-proline (0.40 mg/g) were present in the lowest concentrations (Figure 5). Similar amino acid profiles were reported [18,22,23], who found that glutamic acid, aspartic acid, and leucine are typically dominant in mealworm larvae, with total amino acid contents ranging between 298 and 400 mg/g dry matter, depending on diet and rearing conditions. The proportion of essential amino acids in this study (36.8%) falls within the range reported in recent literature, although slightly lower than some values (38-42%) expressed on a protein basis. The observed abundance of BCAAs is comparable to values reported [22, 23, 24] who found 54–91 mg/g BCAA in mealworm larvae, suggesting stable proportions regardless of rearing substrate. The high levels of essential and branched-chain amino acids observed in this study are consistent with the general nutritional characterization of *Tenebrio molitor* larvae as a high-quality protein source, as reviewed by Hong et al 2020 [24].

4. Safety and Consumer Considerations

Although the nutritional composition of *Tenebrio molitor* is favourable, its use as food requires careful consideration of safety aspects, particularly allergenicity. Mealworm proteins may cause cross-reactivity in individuals allergic to crustaceans due to shared allergens such as tropomyosin, as highlighted in both experimental studies and EFSA assessments [25, 26, 27]. Thermal processing may reduce, but not completely eliminate, allergenic potential, emphasizing the need for appropriate labeling and consumer awareness [28].

In addition to allergenic concerns, consumer acceptance remains a significant barrier in Western markets. Cultural perceptions, food neophobia, and the "yuck factor" influence the willingness of individuals to incorporate edible insects into their diets, even when nutritional benefits are well recognized [29, 30]. Strategies such as using insect flour in processed products, clear labeling, and educational campaigns have been shown to increase acceptance [31].

5. Conclusion

The *Tenebrio molitor* larvae evaluated in this study confirms that they are a nutrient-dense source of high-quality protein and lipids, with a favorable balance of fatty acids and essential amino acids. Their composition supports their potential as an alternative protein source for human and animal nutrition. The larvae's lipid and amino acid profiles suggest benefits for health, particularly regarding essential fatty acids and branched-chain amino acids. Moreover, the species capacity for sustainable rearing on organic substrates aligns with circular economy principles, reinforcing its role as a promising ingredient for functional foods, supplements, and feed formulations. The values obtained fall within the ranges reported for larvae reared on wheat bran alone or with supplemented substrates, indicating that the standard diet used here produced a typical nutrient composition.

Overall, *Tenebrio molitor* represents a safe, nutritionally valuable, and environmentally sustainable protein source.

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Conflicts of interest / Competing interests: No conflict of interest

Ethics approval: No ethic situation.

Availability of data and material: All relevant data have been included within the manuscript.

References

1. Morales ML, Segura-Borrego MP, Aguilera-Velázquez JR, Callejón RM, Gutiérrez-Praena D, Ubeda C. Insight into the chemical and nutritional fat profile of Tenebrio molitor larvae reared on different Agri-food by-products. *Food Res Int*. **2025**;209:116223. https://doi.org/10.1016/j.foodres.2025.116223
2. Huis AV, Itterbeeck JV, Klunder H, Mertens E, Halloran A, Muir G, et al. *Edible insects: future prospects for food and feed security*. **2013.**
3. Gautam A, Gyawali I, Poudel S, Devkota S, Acharya R, Kandel M, et al. Insects as Food and Feed Source: A Comprehensive Review on Nutritional Value, Food Safety Concern, Environmental Benefits, Economic Potential, Technological Innovations, Challenges, and *Future Prospects. Food Front*. **2025.** https://doi.org/10.1002/fft2.70092
4. Lisboa HM, Nascimento A, Arruda A, Sarinho A, Lima J, Batista L, et al. Unlocking the Potential of Insect-Based Proteins: Sustainable Solutions for Global Food Security and Nutrition. *Foods.*

2024;13(12):1846. https://doi.org/10.3390/foods13121846
5. Gebreyes BG, Teka TA. The Environmental and Ecological Benefits of Edible Insects: A Review. *Food Sci Nutr.* **2025**; 13(6):e70459. https://doi.org/10.1002/fsn3.70459
6. Costa S, Pedro S, Lourenço H, Batista I, Teixeira B, Bandarra N, et al. Evaluation of Tenebrio molitor larvae as an alternative food source. *NFS J.* **2020**;21:57–64. https://doi.org/10.1016/j.nfs.2020.10.001
7. Huang GX, Zhang YR, Yu TH, Yuan BQ, Huang DW, Xiao JH. Productive performance of yellow mealworm larvae in different protein and carbohydrate levels in the same energy substrate. *Anim.* **2025**;19(7):101555. https://doi.org/10.1016/j.animal.2025.101555
8. EFSA Panel on Nutrition NF, Allergens F, Turck D, Bohn T, Castenmiller J, De Henauw S, et al. Safety of frozen and dried formulations from whole yellow mealworm (Tenebrio molitor larva) as a novel food pursuant to Regulation (EU) 2015/2283. *EFSA J.* **2021**;19(8):e06778. https://doi.org/10.2903/j.efsa.2021.6778
9. EFSA Panel on Nutrition NF, Allergens F, Turck D, Bohn T, Castenmiller J, De Henauw S, et al. Safety of UV-treated powder of whole yellow mealworm (Tenebrio molitor larva) as a novel food pursuant to Regulation (EU) 2015/2283. EFSA J. **2023**;21(6):e08009.10. https://doi.org/10.2903/j.efsa.2023.8009
10. AOAC. Official Methods of Analysis. 21st Edition. Washington DC, EUA; **2019.**
11. ISO. ISO 12966-2: 2017. Animal and vegetable fats and oils — Gas chromatography of fatty acid methyl esters — Part 2: Preparation of methyl esters of fatty acids. Geneva: International Organization for Standardization; **2017.**
12. Alves RC, Casal S, Oliveira MBPP. Determination of vitamin E in coffee beans by HPLC using a micro-extraction method. *Food Sci Technol Int.* **2009**;15(1):57-63. https://doi.org/10.1177/1082013208102695
13. Machado S, Costa AS, Pimentel F, Oliveira MBP, Alves RC. A study on the protein fraction of coffee silverskin: Protein/non-protein nitrogen and free and total amino acid profiles. *Food Chem.* **2020;**326:126940. https://doi.org/10.1016/j.foodchem.2020.126940
14. Henderson JW, Ricker RD, Bidlingmeyer BA, Woodward C. Rapid, accurate, sensitive, and reproducible HPLC analysis of amino acids. Amino acid analysis using Zorbax Eclipse-AAA columns and the Agilent. **2000**;1100(1100):1-10.
15. Papastavropoulou K, Koupa A, Kritikou E, Kostakis M, Dervisoglou S, Roussos A, Perdikis D, Thomaidis NS, Oz E, Oz F, Proestos C, Wu H. Study of the effect of feeding Tenebrio molitor larvae during their rearing on their growth, nutritional profile, value and safety of the produced flour. *Food Chem X*. **2024**;24:101838. https://doi.org/10.1016/j.fochx.2024.101838
16. Mattioli S, Dal Bosco A, Cartoni Mancinelli A, Cotozzolo E, Castellini C, Ranucci D. Chemical composition, fatty acid profile, antioxidant content and microbiological loads of lesser mealworm, mealworm and superworm larvae. *Ital J Food Sci.* **2024**;36(1):1–12. https://doi.org/10.1080/1828051X.2023.2293856
17. Ferri I, Dell'Anno M, Spano M, Canala B, Petrali B, Dametti M, Magnaghi S, Rossi L. Characterisation of *Tenebrio molitor* reared on substrates supplemented with chestnut shell. *Insects.* **2024**;15(7):512. https://doi.org/10.3390/insects15070512
18. Kopecká A, Kouřimská L, Škvorová P, Kurečka M, Kulma M. Effect of Temperature on the Nutritional Quality and Growth Parameters of Yellow Mealworm (*Tenebrio molitor L.*): A Preliminary Study. *Appl Sci.* **2024**;14(6):2610. https://doi.org/10.3390/app14062610
19. Orkusz A, Dymińska L, Banaś K, Harasym J. Chemical and nutritional fat profile of Acheta domesticus, Gryllus bimaculatus, Tenebrio molitor and Rhynchophorus ferrugineus. *Foods.* **2024**;13(1):32. https://doi.org/10.3390/foods13010032
20. Kolobe SD, Manyelo TG, Malematja E, Sebola NA, Mabelebele M. Fats and major fatty acids present in edible insects utilised as food and livestock feed. *Vet Anim Sci.* **2023** Sep 7;22:100312. https://doi.org/10.1016/j.vas.2023.100312
21. Lawal KG, Kavle RR, Akanbi TO, Mirosa M, Agyei D. Enrichment in specific fatty acids profile of Tenebrio molitor and Hermetia illucens larvae through feeding. *Future Foods.* **2021**;3:100016. https://doi.org/10.1016/j.fufo.2021.100016
22. Jankauskienė A, Aleknavičius D, Andrulevičiūtė V, Mockus E, Bartkienė E, Juknienė I, et al. Nutritional Composition and Safety Parameters of Mealworms (Tenebrio molitor) Reared on Substrates Derived from By-Products. *Appl Sci.* **2024**;14(7):2744. https://doi.org/10.3390/app14072744
23. Wu RA, Ding Q, Yin L, Chi X, Sun N, He R, et al. Comparison of the Nutritional Value of Mysore Thorn Borer (Anoplophora chinensis) and Mealworm Larva (Tenebrio molitor): Amino Acid, Fatty Acid, and Element Profiles. *Food Chem*. **2020**;323:126818. https://doi.org/10.1016/j.foodchem.2020.126818
24. Hong J, Han T, Kim YY. Mealworm (Tenebrio molitor Larvae) as an Alternative Protein Source for Monogastric Animal: A Review. *Animals.* **2020**;10(11):2068. https://doi.org/10.3390/ani10112068
25. Verhoeckx KCM, van Broekhoven S, den Hartog-Jager CF, Gaspari M, de Jong GAH, Wichers HJ, et al. House dust mite (Der p 10) and crustacean allergic patients may react to food containing Yellow

mealworm proteins. *Food and Chemical Toxicology*. **2014**;65:364-73. https://doi.org/10.1016/j.fct.2013.12.049

26. EFSA Panel on Nutrition NF, Allergens F, Turck D, Castenmiller J, De Henauw S, Hirsch-Ernst KI, Kearney J, Maciuk A, Mangelsdorf I, McArdle HJ, Naska A, Pelaez C, Pentieva K, Siani A, Thies F, Tsabouri S, Vinceti M, Cubadda F, Frenzel T, Heinonen M, Marchelli R, Neuhäuser-Berthold M, Poulsen M, Prieto Maradona M, Schlatter JR, van Loveren H, Ververis E, Knutsen HK. Scientific Opinion on the safety of dried yellow mealworm (*Tenebrio molitor* larva) as a novel food pursuant to Regulation (EU) 2015/2283. *EFSA J.* **2021**;19(1):6343. https://doi.org/10.2903/j.efsa.2021.6343
27. German Federal Institute for Risk Assessment NRLfApiF, NRL-AP, Garino C, Zagon J, Braeuning A. Insects in food and feed–allergenicity risk assessment and analytical detection. *EFSA journal*. **2019**;17:e170907. https://doi.org/10.2903/j.efsa.2019.e170907
28. Pali-Schöll I, Meinlschmidt P, Larenas-Linnemann D, Purschke B, Hofstetter G, Rodríguez-Monroy FA, et al. Edible insects: Cross-recognition of IgE from crustacean-and house dust mite allergic patients, and reduction of allergenicity by food processing. *World Allergy Organization Journal.* **2019**;12(1):100006. https://doi.org/10.1016/j.waojou.2018.10.001
29. Simeone M, Scarpato D. Consumer Perception and Attitude toward Insects for a Sustainable Diet. *Insects*. **2022**;13(1):39. https://doi.org/10.3390/insects13010039
30. Ros-Baró M, Sánchez-Socarrás V, Santos-Pagès M, Bach-Faig A, Aguilar-Martínez A. Consumers' Acceptability and Perception of Edible Insects as an Emerging Protein Source. International Journal of Environmental *Research and Public Health.* **2022**;19(23):15756. https://doi.org/10.3390/ijerph192315756
31. Ardoin R, Prinyawiwatkul W. Consumer perceptions of insect consumption: a review of western research since 2015. *International Journal of Food Science and Technology.* **2021**;56(10):4942-58. https://doi.org/10.1111/ijfs.15167