Study on the growth performance of rainbow trout *Oncorhynchus mykiss* fed with *Tenebrio molitor* larvae

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Abstract. This study explores substituting commercial feed for rainbow trout (*Oncorhynchus mykiss*) with *Tenebrio molitor* larvae. Edible insects, such as *Tenebrio molitor*, are an excellent and cost-effective protein source with a low environmental footprint. This species has the potential to replace conventional protein sources and be incorporated into various products. The study used rainbow trout fry, divided into two groups of 50 specimens each. The experimental group was fed exclusively with dried *T. molitor* larvae, while the control group received commercial granulated feed. Growth performance was monitored over 12 weeks, with weight measurements taken biweekly. Results indicated that after two weeks of transitioning from granulated feed to dried larvae, the experimental group exhibited increased body mass. However, the control group achieved higher overall growth rates, likely due to their familiarity with the granulated feed. Typically, rainbow trout recognized granulated feed more easily than *T. molitor* larvae. Incorporating larvae into a granulated form could improve feed recognition by the fish. Alternatively, a longer feeding period may allow for better adaptation to the larvae diet.
Key Words: alternative protein sources, granulated feed, insects, sustainable aquaculture.

Introduction. The global interest in cultivating the mealworm, *Tenebrio molitor*, has experienced a significant surge in recent years. This trend is primarily attributed to the growing demand for sustainable alternative protein sources (Hegedus et al 2023; Sava et al 2023; Muntean et al 2024) and to the decision of the European Food Safety Authority in 2021 to approve *Tenebrio molitor* as a novel food in the human diet, as authorized by Regulation (EU) 2015/2283 (Turck et al 2021). Exploring the nutritional aspects of salmonids is essential for promoting sustainable aquaculture (Ihuţ et al 2020; Cocan et al 2018), safeguarding wild stocks (Lațiu et al 2020; 2022), and enhancing our knowledge of ecological and food system resilience (Uiuiu et al 2020; 2024).

Tenebrio molitor is an omnivorous species that can feed on almost any plant or animal-based product, such as meat or feathers (Ramos-Elorduy et al 2002). This species undergoes complete metamorphosis (Figure 1), with a variable lifespan ranging from 280 to 630 days and consisting of four distinct stages (Ghaly & Alkoaik 2009). Eggs hatch at 10-12 days at a constant temperature of 18-20°C.

The larval stage of the mealworm is the longest phase of its life cycle, during which it undergoes 8 to 20 successive molts. This stage typically lasts 3 to 4 months at ambient temperatures, but can extend up to 18 months under unfavorable conditions. Mature mealworms are yellowish with brownish markings, measuring 20 to 32 mm in length and weighing between 130 and 160 mg. To increase larval size and delay metamorphosis, some producers incorporate juvenile hormones into the mealworms' diet. This method can produce larger specimens weighing up to 300 mg (Finke 2002). The pupal stage lasts 7 to 9 days at 25°C, but at lower temperatures, it can extend to as long as 20 days.

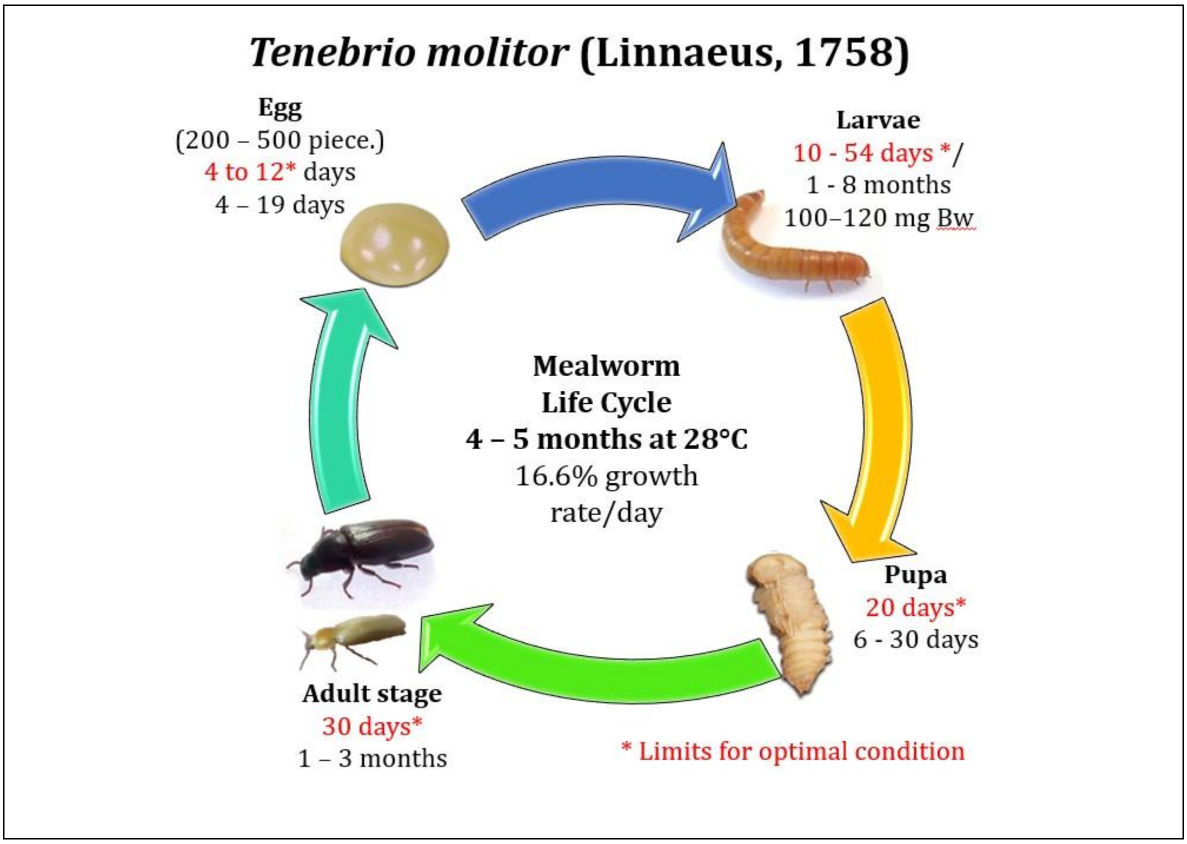

Figure 1. The complete metamorphosis of mealworm *Tenebrio molitor*. Bw - body weight; processed information from Canteri de Souza et al (2018) and Hong et al (2020).

The larvae of *T. molitor* are a nutrient-dense food source, containing an average of 24.13 g of protein, and 6.14 g of lipids per 100 g, along with a variety of vitamins and minerals (Orkusz 2021). They can be incorporated into animal feed in several forms, including fresh, dried, or powdered (Henry et al 2015). This study aimed to evaluate the potential of replacing commercial feed for rainbow trout *Oncorhynchus mykiss* with dried *T. molitor* larvae.

Material and Method. The research was conducted at a salmonid farm in Transylvania, utilizing rainbow trout *O. mykiss* fry as the biological material. Two groups were established: a control group (CG) and an experimental group (EG), each consisting of 50 specimens. At the start of the trial, the average body weight was 47.12±0.13 g for the CG and 47.20±0.16 g for the EG. The *T. molitor* larvae used in the study were raised on a substrate of wheat bran and carrots. Larvae were harvested weekly, prior to metamorphosis into pupae during the final molting stages. At this stage, they were easy to collect and appropriately sized for fish consumption. The harvested larvae were oven-dried at 120°C for 1 hour. Physicochemical analysis of the larvae included the determination of moisture content using oven-drying, fat content via the Soxhlet method, and protein content using the Kjeldahl method, as described by Iurcă & Răducu (2005). The dried *T. molitor* larvae were administered to the experimental group using an automatic feeder, allowing ad libitum consumption. The control group received Aqua Garant commercial feed with 3 mm granules tailored to the fish's age category. The substitution of trout feed with mealworms required an acclimation period of approximately two weeks, followed by biweekly body measurements over the next ten weeks. The experiment lasted 12 weeks. All collected data were statistically analyzed using ANOVA, with differences between the groups determined via a T-test.

Results and Discussion. Mealworms exhibit a high crude protein content, ranging from 47 to 60%, and a crude fat content between 31 and 43%, with approximately 60% water content. The ash content is relatively low, below 3%, but still higher than that found in conventional meat sources. The nutritional composition of *T. molitor* larvae is influenced by their diet (Klasing et al 2000). Chemical analysis comparing *T. molitor* larvae and commercial feed showed that both feed types have similar average values for crude protein and fat content (Figure 2).

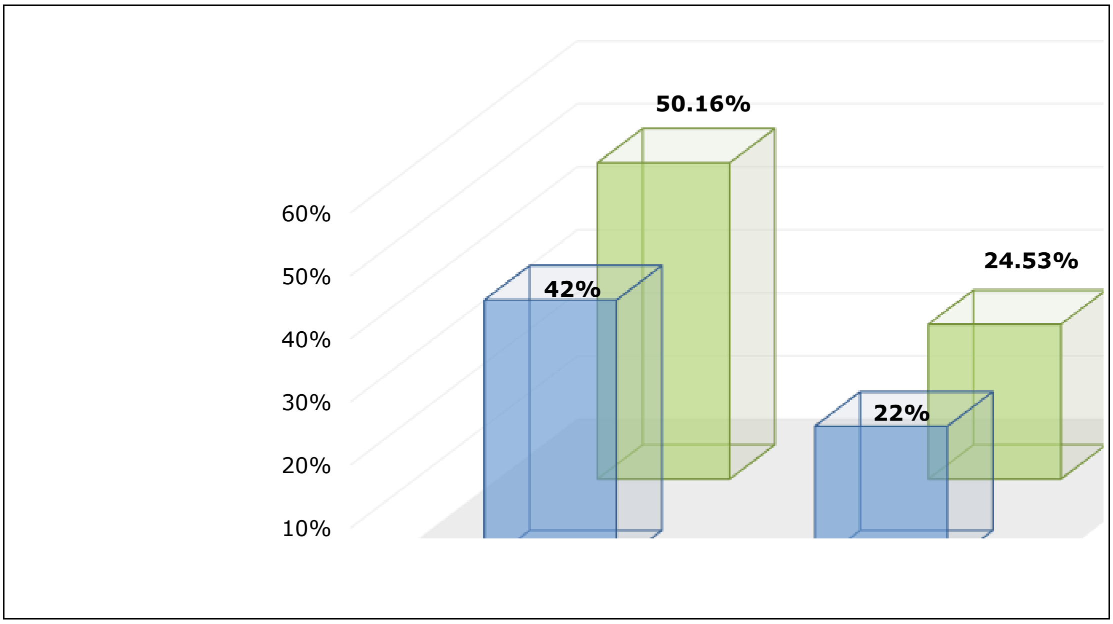

Figure 2. Chemical analysis of *Tenebrio molitor* larvae compared to commercial feed.

The physicochemical composition of *Tenebrio molitor* larvae, expressed on a dry matter basis, is presented in Figure 3. The average values obtained in this study are consistent with those reported by Orkusz (2021) and exceed the protein and fat content found in pork and beef.

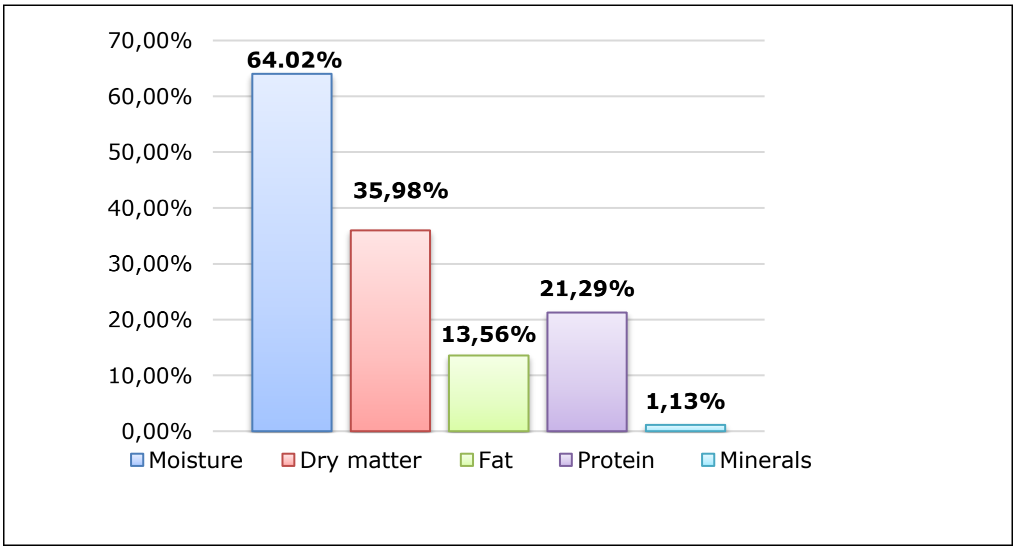

Figure 3. The physicochemical analysis of *Tenebrio molitor* larvae reported to the dry matter content.

During the study, a lower growth was observed for the experimental group compared to the control group (Figure 4). In the control group, fish easily detected the commercial feed due to its oily and aromatic components. Despite the high nutritional profile of mealworms for fish, their dry form and placement on the water surface did not emit sensory stimuli to attract fish, resulting in reduced consumption. Consequently, both groups maintained the same average body weight of 47 g at the end of the initial two weeks. However, from week 4 onward, the control group showed a significantly higher average body weight of 72.06±0.23 g, compared to the experimental group, which had an average of 60.64±0.30 g.

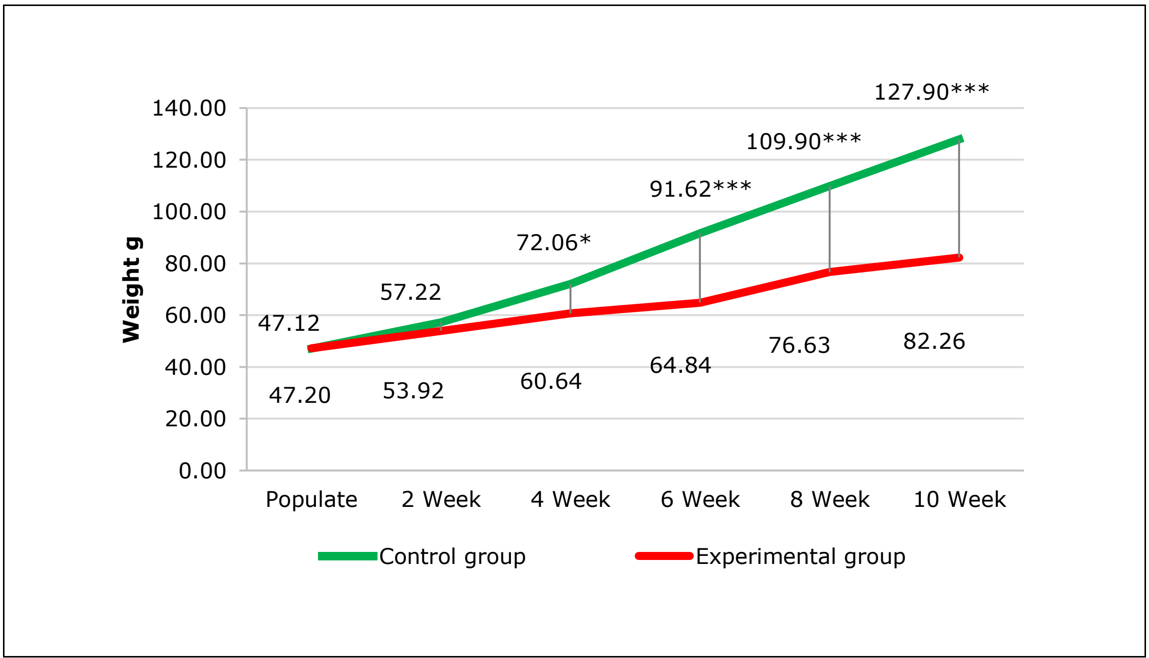

Figure 4. The growth dynamics of the rainbow trout feed with *Tenebrio molitor* larvae; * - $p<0.05$; *** - $p<0.001$.

Conclusions. In summary, after an initial adaptation period, the rainbow trout started consuming *T. molitor* larvae. However, the feeding rate decreased significantly. Despite these challenges, *T. molitor* larvae have demonstrated their potential as an alternative feed for rainbow trout, as they are easy to farm on plant-based substrates, grow rapidly, and are rich in both fat and protein. These larvae could potentially replace conventional commercial fish feed either partially or entirely. To maximize their use in aquaculture, it is essential to offer *T. molitor* larvae in granulated form, supplemented with fish oil and other necessary nutrients. This will not only improve the nutritional profile of the feed, but also enhance its olfactory appeal to the fish, ensuring better consumption rates. Overall, while *T. molitor* larvae offer a promising protein source, their successful integration into aquaculture systems depends on the proper formulation and optimal environmental conditions to ensure their effectiveness.

Conflict of Interest. The authors declare that there is no conflict of interest.

References

Canteri de Souza P., Custódio Caloni C., Wilson D., Almeida R. S., 2018 An invertebrate host to study fungal infections, mycotoxins and antifungal drugs: *Tenebrio molitor*. Journal of Fungi 4(4):125.

Cocan D., Popescu F., Laţiu C., Uiuiu P., Coroian A., Răducu C., Coroian C. O., Mireşan V., Kokkinakis A., Constantinescu R., 2018 Effects of thermal stress on

hematological and metabolic profiles in Brown bullhead, *Ameiurus nebulosus* (Lesueur, 1819). AgroLife Scientific Journal 7(1):33-41.
Finke M., 2002 Complete nutrient composition of commercially raised invertebrates used as food for insectivores. Zoo Biology 21(3):269-285.
Ghaly A. E., Alkoaik F. N., 2009 The yellow mealworm as a novel source of protein. American Journal of Agricultural and Biological Sciences 4(4):319-331.
Hegedus C., Andronie L., Uiuiu P., Jurco E., Lazar E. A., Popescu S., 2023 Pets, genuine tools of environmental pollutant detection. Animals 13:2923.
Henry M., Gasco L., Piccolo G., Fountoulaki E., 2015 Review on the use of insects in the diet of farmed fish: past and future. Animal Feed Science and Technology 203:1-22.
Hong J., Taehee H., Yoo Y. K., 2020 Mealworm (*Tenebrio molitor* larvae) as an alternative protein source for monogastric animal: A review. Animals 10(11):2068.
Ihuţ A., Răducu C., Cocan D., Munteanu C., Luca I. T., Uiuiu P., Lațiu C., Rus V., Mireşan V., 2020 Seasonal variation of blood biomarkers in huchen, *Hucho hucho* (Actinopterygii: Salmoniformes: Salmonidae) reared in captivity. Acta Ichthyologica et Piscatoria 50(4):381–390.
Iurcă I., Răducu C., 2005 [The technology of animal products industrialization]. AcademicPres, Cluj-Napoca. [In Romanian].
Klasing K., Thacker P., Lopez M. A., Calvert C. C., 2000 Increasing the calcium content of mealworms (*Tenebrio molitor*) to improve their nutritional value for bone mineralization of growing chicks. Journal of Zoo and Wildlife Medicine 31(4):512-517.
Lațiu C., Cocan D., Uiuiu P., Matei M. C., Ihuț A., Nicula S. A., Lațiu I., Constantinescu R., Mireșan V., 2020 The influence of damming on the distribution of brown trout *Salmo trutta* Linnaeus, 1758 and European grayling *Thymallus thymallus* Linnaeus, 1758 (Pisces: Salmonidae) from Someșul Cald river. Scientific Papers. Series D. Animal Science 63(2):528-538.
Laţiu C., Papuc T., Muntean G., Uiuiu P., Constantinescu R., Matei-Laţiu M. -C., Nicula A. -S., Craioveanu C., Mireșan V., Cocan D., 2022 Fish species diversity from Someșul Cald river: 50 years after cascade dam constructions. Fronters in Environmental Science 10:918745.
Muntean, G.-C.; Simedru, D.; Uiuiu, P.; Tanaselia, C.; Cadar, O.; Becze, A.; Coroian, A. Evaluation of Alternative Sources of Proteins and Other Nutrients with Potential Applications in Fish Nutrition. Molecules 2024, 29, 2332. https://doi.org/10.3390/molecules29102332
Orkusz A., 2021 Edible insects versus meat—nutritional comparison: Knowledge of their composition is the key to good health. Nutrients 13:1207.
Ramos-Elorduy J., Avila G. E., Rocha-Hernandez A., Pino J. M., 2002 Use of *Tenebrio molitor* (Coleoptera: Tenebrionidae) to recycle organic wastes and as feed for broiler chickens. Journal of Economic Entomology 95(1):214-220.
Sava A., Uiuiu P., Lațiu C., Cocan D., Muntean G. -C., Papuc T., Ihuț A., Răducu C., Becze A., Craioveanu C., Munteanu C., Constantinescu R., Mireșan V., 2023 PAHs, physicochemical and microbiological analyses of trout processed by traditional smoking, in different types of packaging. Fishes 8:424.
Turck D., Bohn T., Castenmiller J., De Henauw S., Hirsch-Ernst K. I., Knutsen H. K., Maciuk A., Mangelsdorf I., McArdle H. J., Naska A., Pelaez C., Pentieva K., Siani A., Thies F., Tsabouri S., Vinceti M., 2021 Safety of frozen and dried formulations from whole yellow mealworm (*Tenebrio molitor* larva) as a novel food pursuant to Regulation (EU) 2015/2283. EFSA Journal 19(8):e06778.
Uiuiu P., Cocan D., Constantinescu R., Latiu C., Sava A., Hegedűs C., Coroian A., Ihut A., Raducu C., Miresan V., 2020 Water quality parameters which influence rainbow trout (*Oncorhynchus mykiss*) welfare in classic systems. Scientific Papers. Series D. Animal Science 63(1):509-515.
Uiuiu P., Constantinescu R., Papuc T., Muntean G. -C., Matei-Lațiu M. C., Becze A., Cocan D., Lațiu C., Martonoș C. O., 2024 Influence of longitudinal fragmentation on length–weight relationships of fishes in the Someșul Cald River, Romania. Fishes 9(10):420.

Received: 15 September 2024. Accepted: 19 November 2024. Published online: 24 December 2024.
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How to cite this article:
Răducu C., Cocan D., Constantinescu R., Mireșan V., Huluba C., Munteanu C., Ihuț A., 2024 Study on the growth performance of rainbow trout *Oncorhynchus mykiss* fed with *Tenebrio molitor* larvae. ABAH Bioflux 16(1):32-37.