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Circular Solutions Through Insect Bioconversion: Advancing Sustainable Waste Management

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Abstract

Sustainable food production with zero waste is a major challenge for modern societies. The rapid increase in organic waste driven by population growth has intensified environmental pressures, including soil and water contamination, greenhouse-gas emissions, and depletion of natural resources. Insect-based organic-waste management has emerged as a rapidly developing sector, with several species evaluated for their ability to convert waste streams into valuable products. Insects are highly efficient bioconverters due to their fast growth rates, simple nutritional requirements, and ability to thrive on low-value organic substrates, making them ideal candidates for circular-economy applications. Among them, the black soldier fly (BSF), *Hermetia illucens*, and the yellow mealworm (YM), *Tenebrio molitor*, are the most extensively studied. Two European PRIMA projects, OLIWA and CIPROMED, have served as a cornerstone for advancing this field, bringing together collaborations across multiple Mediterranean countries. The OLIWA project utilizes BSF to valorize olive-processing residues, while CIPROMED employs YM as a bioconverter of agro-industrial byproducts such as cotton, cannabis, whey, raisin, and dairy side-streams. Both projects adopt a circular-economy approach to repurposing agro-industrial waste, yielding highly promising environmental and economic benefits, including reduced waste volumes, lower disposal costs, and the generation of high-value insect-derived products. These insect species demonstrate strong potential to support sustainable waste-management strategies through effective bioconversion, producing outputs such as insect biomass, chitin, chitosan, frass, and insect-derived oils. As research and industrial interest continue to grow, insect-based bioconversion systems hold significant promise for scalable, cost-effective, and environmentally resilient waste-management solutions.

Keywords: Bioconversion, black soldier fly larva, yellow mealworm, circular economy, waste reduction