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Insect-Based Valorisation of Residual Plastics: Optimizing *Galleria mellonella* Larval Rearing for Circular Economy Applications

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ABSTRACT

Plastics represent one of the most pressing environmental challenges, with nearly 400 million tonnes generated as waste annually, much of which remains unrecyclable through existing mechanical or chemical methods. Addressing residual fractions such as polyurethane foams, synthetic fibres, and mixed multilayer plastics requires novel valorisation strategies that extend beyond conventional recycling. Our team explored the potential of the wax moth Galleria mellonella, whose larvae can metabolize diverse polymers due to biochemical similarities between beeswax and synthetic plastics. This approach enables the conversion of unsorted, nonrecyclable plastic waste into high-value outputs, including proteins, lipids, and biofertilizer, thereby creating an industrial symbiosis model aligned with circular economy principles. To establish technological foundations for scale-up, we investigated larval density as a critical parameter in the plastic transformation process. Experimental results demonstrated survival rates above 90% across tested ranges, with surface densities between 0.03 and 0.82 larvae/cm² and volume densities between 0.025 and 0.67 larvae/cm³. Optimal performance occurred below 0.3 larvae/cm², informing future rearing system design for efficiency and throughput. These findings provide essential insights for integrating insect-based plastic valorisation into sustainable waste management strategies, complementing existing recycling technologies while addressing systemic barriers to circular plastics.

Keywords: bioconversion; circular economy; *Galleria mellonella*; plastic waste; sustainable protein