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Evaluating the Environmental Impact of Tenebrio Molitor as a Sustainable Protein Alternative in Porcine Diets

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Abstract

The escalating environmental footprint of conventional livestock feed—primarily driven by soybean and fishmeal—necessitates a transition toward more sustainable protein sources. This study evaluates the environmental performance of insect meal (Tenebrio molitor) as a substitute for traditional protein sources in pig feed formulations. Central to this research is a comparative Life Cycle Assessment (LCA) conducted in adherence to ISO 14040/44 standards. Four distinct compound feed blends were analysed to assess their environmental profiles across various impact categories. To ensure a robust analysis, a dual-modelling approach was used, using both a mass-based and a protein-based Functional Unit (FU). The results indicate that conventional crop-based ingredients, specifically soybean meal, are the primary drivers of environmental burdens, largely due to intensive fertilizer application and land-use change effects. The integration of insect meal successfully mitigated these impacts, demonstrating superior land-use efficiency and the capacity for waste valorization. Furthermore, while the LCA quantified standard metrics, the study also addressed qualitative sustainability crises inherent to fishmeal production, such as overfishing and marine ecosystem destabilization, which often escape traditional LCA modelling. Overall, the substitution of soy with Tenebrio Molitor meal emerged as the most effective strategy for reducing the environmental load of porcine feed formulation. Given the nutritional focus of the study, the protein-based FU proved to be the more relevant metric for determining sustainability. These results underscore the potential of insect-based proteins as a scalable solution, positioning them as a fundamental component in the development of sustainable, resilient livestock production systems.

Keywords: life cycle assessment (LCA), sustainable protein, pig feed formulations, soybean meal, fishmeal, insect meal