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Environmental impact assessment of black soldier fly production as a feed

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While insects are increasingly valued for their suitability as a feed in livestock and aquaculture production [1], their environmental superiority to conventional feed counterparts remains largely unconfirmed. To be a viable alternative to conventional feed, insect production systems need to showcase equivalent nutrient outputs at competitive environmental costs. For this, black soldier fly (*Hermetia illucens*) larvae (BSFL) are recognized as a suitable candidate, particularly due to their efficiency in converting a broad range of low-opportunity-cost organic material into valuable protein [1]. However, few studies exist to date which investigate the environmental performance of BSFL feed production systems using primary data [2-4]—therefore their eco-efficiency remains poorly understood. This study addresses this deficiency by assessing the environmental impacts associated with a Swiss facility producing BSFL meal for use in fish and poultry feed.

To this end, production scenarios were defined and assessed via attributional (aLCA) and consequential life cycle assessments (cLCA). The BSFL production system was observed in four distinct stages: adult population maintenance and egg production, nursery, larvae grow-out and, lastly, harvesting and processing into the final product at facility-gate. Upstream processes included external production and sourcing of diet components, electricity and water. Infrastructure was excluded. For the cLCA, the BSFL system was expanded to account for indirect impacts of diverting organic materials away from biogas or compost production and into the BSFL diet. The functional unit was 1 kg defatted, milled BSFL (DM: 96%, protein: 59%). Primary data on BSFL meal production was provided by a research-pilot scale facility in Switzerland [5]. Fish and poultry performance trials with the BSFL-feed confirmed its substitutability with fish and soybean meals, respectively. Regionalized secondary data from ecoinvent 3.6 described all upstream processes. Together, these datasets established the baseline.

Scenario analysis served the purpose of exploring the influence of BSFL production scale and location on environmental performance. Scenario development was guided by literature and experts and resulted in four scenarios: baseline at 0.7 t a^{-1} final product (b), production scaled to 20 t a^{-1} (b20) and the b20 scenario realized in both Mexico (b20M) and France (b20F). To assess potential impacts, IMPACT World+ was chosen due to its recently updated and spatially resolved methods and inclusion of additional substances [6]. All 18 midpoints were justified and used, and impact assessment calculations and sensitivity analyses were carried out using the open source LCA framework, Brightway2 [7].

Both aLCA and cLCA baseline results reveal higher impacts than literature values for fish and soybean meals. Electricity-use and direct emissions of larvae contribute the most to global warming potential (GWP). The increased production level in b20 made more efficient use of production equipment and thus absorbed a portion of impacts—yet not enough to deem BSFL-meal superior. When empirically measured direct emissions were replaced with assumed values found in present BSF LCA studies [2-4], results generally agreed. GWP impacts approached competitive levels in b20M and b20F which can be attributed to less use of climate control units in Mexico and the nuclear-based energy mix in France.

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