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Insect meal from rice by-product as low-impact feed in aquaculture: life cycle assessment of different insect diets

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1. INTRODUCTION

As the production and use of feed is recognised as a major environmental impact factor in aquaculture, research is increasingly focused on the discovery of new, more sustainable formulations and feeds. Insect bioconversion can allow the re-utilization and valorization of these by-products to produce alternative protein sources for fish farming, thus reducing the environmental impact (Siddiqui et al., 2022). Within this scenario, the newRIFF project aims to explore the possibility of replacing traditional protein sources in Rainbow trout feeds with protein meal from two insect species (*Hermetia illucens* and *Tenebrio molitor*) bred on locally available waste matrices, including by-products of rice processing. Therefore, the aim of this study is to evaluate the environmental performance of different isoproteic insect substrates. Once the two best substrates in term of insect growth performance have been defined, those will be used for massive insect rearing to produce insect larvae meal. The latter will then be incorporated into the formulation of aquafeed for trout farming and the Life Cycle Assessment (LCA) of the entire supply chain, from food waste to the produced fish, will be carried out.

2. METHODS

The Life Cycle Assessment (LCA) approach was applied to analyse the environmental impact of formulated isoproteic diets (Table 1). The functional unit chosen was 1 kg of diet and the "from cradle to farm gate" perspective was applied to define the system boundaries. Both primary data and secondary data were used for the analysis. In particular, primary data were used for the analysis of the impact of the rice by-products. Then, an economic allocation was performed between rice and rice by-products. Secondary data were used to model the impact of the other wastes included in the analysis, their processing (e.g., drying and grinding if necessary) and the transport for their supply (set at 30 km).

3. RESULTS AND DISCUSSION

CONTROL SUBSTRATE showed better environmental results than the other ones in all impact categories except for Ozone depletion, Land use and Resource use, fossil (Table 2). Climate change of the tested diets ranged from 0.1 (CONTROL DIET) to 0.4 kg CO_2 eq/kg diet (DIET 4). However, if the avoided impact for the avoided processing of reused wastes was added to the analysis, the climate change impact decreased from 6% for DIET 4 to 43% for DIET 1. However, when compared to other diets in the literature, these substrates had a lower impact: Thevenot et al. (2018), reported an impact of 1.14 kg CO_2 eq/kg of diet, while Oonincx et al. (2012) reported an impact of 0.68 kg CO_2 eq/kg of diet. However, it is important to note that the composition of the cited substrates was composed of ingredient primary and the authors also considered the impacts of their production in the analysis and that it was not possible to compare nutritional aspects due to lack of data.

4. CONCLUSIONS

In this study, the environmental impacts of the analysed diets increase as the inclusion of rice by-products increases. It is important to note that insect breeding substrates can influence the growth performance and nutritional composition of insect meal, therefore it will be necessary to assess the environmental performance of the entire supply chain, including the production of insect meal and trout farming for a definitive and clear overview of this new proposal

5. ACKNOWLEDGEMENTS

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Table 1: Percentages (%) of inclusion of different ingredients and wastes in different formulated diets.

INGREDIENTS	CONTROL DIET	DIET 1	DIET 2	DIET 3	DIET 4
Breading waste	46.9	9.3		1.9	
Feed waste	39.6	75.2	64	78.6	43.5
Dry distillery stillage	5.4	2.5	9.5	2.5	12.2
Coffee silver film	6.6	1.9			2.1
Hazelnut film	1.5	0.6			
Broken rice		1.5	3.5		
Broken parboiled rice				3.5	8
Green grain			3		2
Rice husk		2.5	2		
Parboiled rice husk				2	
Rice bran		5	15.5		
Parboiled rice bran				9	5
Other rice by-products		1.5	2.5		
Other parboiled rice by-products				2.5	27.2

Table 2. Environmental impact of the different formulated diets. Impact values were calculated using the Environmental Footprint (EF3.0) V1.03

IMPACT CATEGORY	Unit	CONTROL DIET	DIET 1	DIET 2	DIET 3	DIET 4
Climate change	kg CO_2 eq	0.098	0.108	0.232	0.122	0.408
Ozone depletion	mg CFC11 eq	0.014	0.011	0.025	0.013	0.040
Photochemical ozone formation	g NMVOC eq	0.169	0.207	0.390	0.258	0.802
Particulate matter	disease inc./1M	0.003	0.006	0.011	0.008	0.027
Human toxicity, non-cancer	CTUh/10M	0.002	0.005	0.006	0.005	0.012
Human toxicity, cancer	CTUh/10M	0.0002	0.0002	0.0004	0.0003	0.0010
Acidification	mol H+ eq/100	0.049	0.097	0.168	0.128	0.412
Eutrophication, freshwater	g P eq	0.016	0.017	0.029	0.019	0.046
Eutrophication, marine	g N eq	0.07	0.33	0.67	0.51	2.02
Eutrophication, terrestrial	mol N eq/100	0.14	0.36	0.63	0.49	1.67
Ecotoxicity, freshwater	CTUe	0.85	1.77	3.58	1.49	5.08
Land use	Pt	3.97	3.87	10.98	2.78	12.59
Water use	m3 depriv.	0.70	1.01	2.53	2.70	11.26
Resource use, fossils	MJ	1.49	1.18	2.56	1.36	4.14
Resource use, minerals and metals	mg Sb eq	0.09	0.18	0.40	0.18	0.68