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Strategies for reducing food waste: Life Cycle Assessment of a pilot plant for insect-based feed products

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1. Abstract

Food waste is an emerging problem that needs solutions for reducing it. A promising strategy is its utilisation as substrate for mass-rearing of edible insects to be used as a protein source for the livestock sector. This is a potentialyl valuable solution to two serious problems: the increasing amount of food waste and the global rising demand for feed. Plenty of studies have investigated the nutritive composition of insects and their utilisation as a source of protein for human consumption and animal feeding but less studied are the environmental consequences associated with their mass-rearing. LCA methodology can be applied to evaluate the potential environmental impacts of this processthis . In this context, this paper presents the results of an LCA of a pilot plant for rearing of "Hermetia illucens", located in South Italy.

2. Introduction

Food waste (FW) is an problem that urgently requires strategies for reducing it. Indeed, the EU [1] estimated that FW amounts in the EU27 to 89 million tonnes per annum and the projection for 2020 is 126 million tonnes (about 40% increase). Strategies to address the problem are oriented to improving the efficiency of food supply and consumption chains on the one hand and to find new solutions for FW treatment and valorisation on the other. In the context of waste valorisation, a promising strategy is the utilisation of FW as substrate for mass-rearing of edible insects to be used as a protein source for the livestock sector. They represent a potential valuable solution to two problems: the increasing amount of FW and the global rising demand for feed. In the international literature plenty of studies investigated the nutritive composition of insects and their utilisation as a source of protein both for human consumption and animal feeding, but less studied are the environmental consequences associated with their mass-rearing [2]. In order to properly evaluate the sustainability of insect-based products and their role as a valuable alternative of FW valorisation, the quantification of the environmental impacts associated to the whole life cycle of these processes should be carried out.

3. Methods

Life Cycle Assessment (LCA) is a methodology, standardized by ISO [3-4], which is applied to evaluate the environmental impact of the whole life cycle of a product, process or activity. LCA can be applied to evaluate the potential environmental impact of insect-based products, but there is still a lack of LCAs in this specific field of research and further applicative studies are necessary to broaden the environmental knowledge on the production of insect-based products. Following on, this paper presents the results of a

LCA, focused on the energy profiles (which are indicated as the main impacting in [2]), applied on a pilot plant for mass-rearing of *Hermetia illucens*, located in South Italy, producing 300 kg/day of dried larvae (used as fishmeal) and 3,346 kg/day of larvae manure (used as compost).

3.1 Scope of the study and Life Cycle Inventory Analysis

The scope of the analysis is to quantify the environmental impacts, with a specific focus on energy profiles, attributed to the production of insect-based feed products from mass-rearing of *Hermetia illucens* fed with FW from different sources. Primary data were collected from a pilot plant located in South Italy. To carry out the LCA study four different phases were analysed (Figure 1): eggs and larvae production (phase 1), substratum production (phase 2), compost and dried larvae production (phase 3), and distribution (phase 4). The input and output data are related to the functional unit of *one ton of food waste treated through larvae biodigestion*. Disposal of inorganic wastes (paper, plastic, etc.), obtained in the de-packing phase, is not included in system boundaries because out of the scope of this analysis. Are also excluded from the inventory GHG emissions at plant from the different processes, for the following motivations:

- the main focus of the study is on energy profiles (which are indicated as the main impacting in the only published LCA study on larvae meal [2])
- according IPPC, CH_4 emissions from organic waste occur only after several months, but in the investigated plant the whole process is completed in few days, so that these emissions are assumed as negligible and they were excluded from the inventory;
- no specific inventory data are present in the published international literature concerning other GHG emissions during the biodigestion activity of Hermetia illucens, so that it was not possible incluse them in the inventory;
- the only published LCA study on larvae meal [2] estimated the CH_4 production potential considering municipal organic waste and vegetable FW, but to our knowledge, to many uncertainties are associated with this choice because it is still unknown the difference between methane production potential of FW and larvae manure. So that the inclusion of this aspect would have imposed excessive uncertainty.

In addition to primary data, secondary data, only for pre-production processes (the ecoinvent database [5]), and literature data, for pruning waste combustion emissions [6], were utilized.

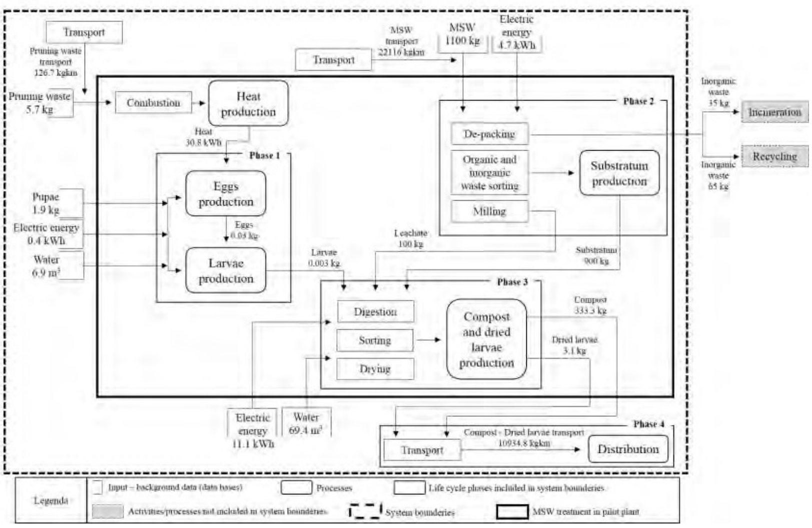

Figure 1: Phases and main inventory data for 1 t of food waste treated

3.2 Life Cycle Impact Assessment (LCIA)

SimaPro 8 software [7] was used to assess the environmental impact of the considered system. LCIA was conducted using CML 2 baseline 2000 method [8] (considering the ten different impact categories detailed in Figure 2), except for Global Warming Potential (GWP) for which the IPCC 2007 GWP 100a v. 1.02 method [9] was used.

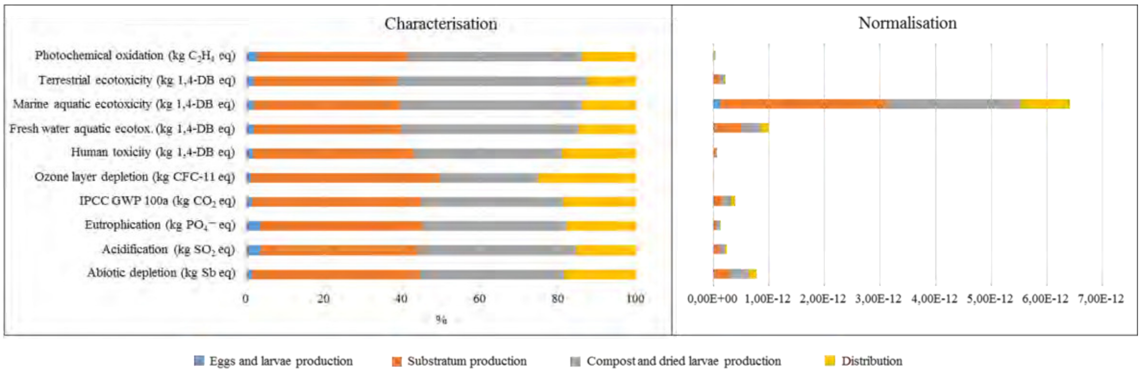

Figure 2: LCIA characterisation and normalisation results

Characterisation results (Figure 2) highlight that higher environmental impacts for each category are caused by phases 2 and 3; the lowest impacts are associated to phase 1. For example, considering the total impact related to GWP (17.6 kg CO_2 eq), the contribution of phases 2 and 3 is respectively 7.6 kg CO_2 eq and 6.5 kg CO_2 eq; while phase 1 contributes for 0.3 kg CO_2 eq. An examination in depth underscores that, in the substratum production (phase 2), the transport of municipal solid waste contributes about 60% to the total impact of each category; on the other hand, in the compost and dried larvae production (phase 3), electric energy consumed in the drying sub-process contributes about 90%. The comparison of impact categories through normalisation step (Figure 2) highlights that the most influenced compartment is the marine aquatic ecotoxicity (6.4E-12 Pt). A detailed analysis shows that the main processes which contribute to this impact category result are: the transport of municipal solid waste to the treatment plant (18.1 %), in phase 2, and the consumption of electric energy in milling (phase 2) and drying (phase 3) sub-processes (67.3 %).

4 Conclusion

The LCA analysis on the production of insect-based products shows that the phases with the highest environmental impacts are substratum production and compost and dried larvae production; furthermore, the compartment mainly affected is the marine acquatic ecotoxicity, greatly caused by the transport of municipal solid waste to the treatment plant and the consumption of electric energy in milling and drying sub-processes.

Many uncertainties and data lacks still remain and need to be further investigated in future improvement of the research. In particular, a key aspect on which the authors are still working concidering that no specific inventory data of Hermetia illucens is present in the published international literature, is to find a solution for collecting primary data for air emissions (no emissions in water and soil are caused by the process), carrying out experimental studies on the GHG emissions from the whole process.

Consequently a sensitivity analysis will be carried out in order to evaluate the consequences associated to uncertainty of this and other parameters.

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