Life cycle assessment of organic waste treatment by the larvae of *Hermetia illucens*

Navarro Ferronato[1,*], Riccardo Paoli[2], Francesco Romagnoli[2], Vincenzo Torretta[1]

[1] Department of Theoretical and Applied Sciences, University of Insubria, Varese, 21100, Italy
[2] Institute of Energy Systems and Environment, Riga Technical University, Riga, LV-1048, Latvia
*Presenting author email: nferronato@uninsubria.it

Keywords: Solid waste management, LCA, circular economy, sustainable development.

Introduction

Solid waste management (SWM) is central for a sustainable development at a global level. It becomes fundamental to find solutions that can also be applied in developing countries, where a large percentage of municipal solid waste is made of organic fractions (usually up to 50 to 80%). Standard techniques like composting and anaerobic digestion are not always easy to be applied due to economic, environmental, and technical issues. Therefore, it becomes of great interest to improve appropriate organic waste treatment options, that they can have a simple and immediate application on the waste, possibly using the infrastructure, technologies, and the market already present.

Recently, the use of insects' larvae are used to treat organic waste. The most valid would seem to be the *Hermetia illucens* or black soldier fly (BSF), due to its capacity to reduce the volume of waste (about 50%) (Beskin et al., 2018) and give an economic value to the final products like manure, protein, or animal feed (Joly and Nikiema, 2019). BSF larvae can be potential for treating organic fractions of municipal solid waste (MSW) due to the simplicity of the technique, low maintenance costs, reduction of waste volumes and related emissions.

The use of *Hemetia Illucens* in waste management is a new research field. The studies present in the literature are almost all still at the stage of pilot plants, without real implementations on an industrial scale. Furthermore, even fewer are the studies on the environmental impacts that a complete BSF process produces, even more if post treatments for the production of bioplastics and biodiesel are added. The aim of this research is to study the environmental impacts of BSF throw a life cycle assessment (LCA) and compare the results with other organic waste treatment options. The LCA has been implemented by secondary data collected by the scientific literature with the objective to provide a comprehensive result with the most favorable conditions in order to obtain better performances compared to composting and anaerobic digestion.

Methods

A Life Cycle Assessment (LCA) study was performed, using the SimaPro9.0 software. The results obtained were compared with other techniques for waste treatment such as composting, anaerobic digestion and final disposal in controlled landfills, while the last step was the evaluation of the pros and cons of the products obtained from the treatment with BSF in terms of environmental impacts and availability of local markets.

The LCA study is focused on a hypothetical food waste treatment plant. The functional unit is related to 1 ton of FW per day. This choice is consistent with other studies found in the scientific literature (Mertenat et al., 2019) and (Salomone et al., 2017). The IMPACT 2002+ was chosen as the characterization method. Among its "mid-point" impact categories, some indicators were chosen (Bava et al., 2019) and (Smetana et al., 2019): respiratory inorganics (kg $PM_{2.5}e$), ozone layer depletion (kg CFC-11e), terrestrial ecotoxicity (kg TEG), land occupation (m^2), aquatic eutrophication (kg PO_4), global warming (kg CO_2e), non-renewable energy (MJ). Waste collection and transport system are not considered within the LCA study since it does not depend on the type of treatment. The process therefore starts with the raw food waste that enters into the plant.

In this study, different parameters are analysed to understand how much it can influence the entire process in terms of environmental impacts. The starting case, defined S0, consists of a BSF treatment plant for treatment where any avoided impacts are considered, to show and understand how much the pure procedure can impact. Then a series of five parameters were analysed: equipment lifespan, variation of the production efficiency, use of renewable energy, variation of the treated volume, transport of the final product. Two avoided emissions were also considered: protein for fishmeal substitution; and production of bioplastics. Finally, different characterization methods were used in order to assess how much it can affect the results. For the inventory, secondary data are collected from the scientific literature. They were subsequently standardized, which consists in reporting all the data with the same unit of measure referring to the functional unit.

Results and discussion

In Figure 1 are reported the normalized results of the LCA, which represent the end-point impacts for each process in S0. It can be stated that the boiling procedure affects the most the use of non-renewable energy and ozone layer depletion, while storage is relevant for respiration inorganic and aquatic eutrophication. Rearing and breeding are relevant in terms of terrestrial ecotoxicity, composting is the most influenced for global warming and the rearing unit for land occupation.

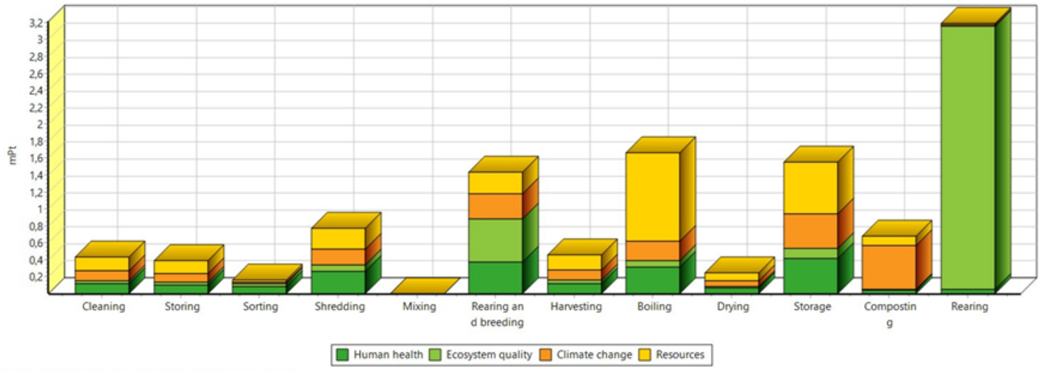

Figure 1. Life cycle environmental impacts of the treatment system (normalized values).

An interval analysis has been carried out after the sensitivity analysis. The best and the worst conditions were assessed and the ranges of values for each environmental impact indicators were obtained. he comparison with the scientific literature is reported in Table1. Data were obtained from (Mondello et al., 2017).

Table 1. Comparison of environmental impacts with the scientific literature.

	Unit	Sanitary landfill	Composting	Anaerobic digestion	BSF
Global warming	Kg CO_2e	1182	60	30	(-34.3/+38.6)
Ozone layer depletion	Kg CFC-11e	304E-05	7.75E-06	5.03E-06	(-9.8E-06/+5E-06)
Terrestrial ecotoxicity	kg1,4-DB	0,95	0.21	0.14	0.329
Aquatic eutrophication	kg PO_4e	0,85	0.11	0.06	0.0532
Non-renewable energy	MJ	1543	6874	982	(-1021/574)

Conclusions

The outcomes of the research suggest that the most impacting step in the treatment of organic waste by BSF larvae is the rearing unit. The use of renewable energies allows decreasing the global warming potential of about 26%, considerably impacting the results. Finally, fishmeal production has better environmental benefits compared to bioplastics production. However, data in the literature are still scarce and specific ones with primary data would be needed to understand the effective synthesis efficiency of the conversion of proteins from BSF in bioplastics. Finally, good results are obtained compared to other treatment options, suggesting the use of BSF as a promising option compared to conventional organic waste treatment.

References

Bava L, Jucker C, Gislon G, et al. (2019) Rearing of *Hermetia Illucens* on Different Organic By-Products: Influence on Growth,Waste Reduction, and Environmental Impact. Animals 9: 289.

Beskin KV, Holcomb CD, Cammack JA, et al. (2018) Larval digestion of different manure types by the black soldier fly (Diptera: Stratiomyidae) impacts associated volatile emissions. Waste Management 74: 213-220.

Joly G and Nikiema J (2019) Global experiences on waste processing with black soldier fly (*Hermetia Illucens*): from technology to business. Resource Recovery and Reuse Series 16.

Mertenat A, Diener S, Zurbrügg C (2019) Black Soldier Fly biowaste treatment – Assessment of global warming potential. Waste Management 84: 173-181.

Mondello, G., Salomone, R., Ioppolo, G., Saija, G., Sparacia, S., & Lucchetti, M. C. (2017). Comparative LCA of alternative scenarios for waste treatment: The case of food waste production by the mass-retail sector. Sustainability, 9(5), 827.

Salomone R, Saija G, Mondello G, et al. (2017) Environmental impact of food waste bioconversion by insects: Application of Life Cycle Assessment to process using *Hermetia illucens*. Journal of Cleaner Production 140: 890-905.

Smetana S, Schmitt E and Mathys A (2019) Sustainable use of *Hermetia illucens* insect biomass for feed and food: Attributional and consequential life cycle assessment. Resources, Conservation & Recycling 144: 285-29.