

Shaping Sustainable Bioplastics: Tools and Methods for Assessing Environmental Impacts in Early-Stage Development

Floriana Coppola¹, Serena Righi^{1,2}

1. Introduction

Over the last decades, extensive efforts have been made to valorise food waste and find alternatives to petroleum-based plastics [1-2]. One promising approach involves developing biopolymers and added-value bioplastic products from low-grade food waste. However, scaling up bioplastic technologies remains high-risk, with the central issue being uncertain demand, largely due to high production costs [1]. In this context, the BioLaMer project aims to explore an innovative fly larvae biorefinery concept to produce two biopolymers – polyhydroxyalkanoates (PHA) and chitosan. These biopolymers will be developed into coatings suitable for packaging and medical applications, the whole system being guided by a life cycle thinking (LCT) approach [3].

Bio-based plastics are not inherently more sustainable than fossil-derived plastics [1]. A comprehensive life cycle assessment (LCA) will help identify key hotspots and thoroughly assess environmental impacts for optimization of the BioLaMer biorefinery system. Screening tools and indicators based on the LCT approach will support the early-stage development of its output products with preliminary evaluation of environmental impacts. The limited data available during early-stage development often render LCA inadequate for assessing environmental impacts. Paradoxically, it is precisely at this stage that information on environmental impacts of potential raw material candidates and process alternatives is most valuable for guiding design decisions toward the most sustainable choices.

This review paper explores methods for evaluating the environmental impacts of low technological readiness levels (TRL) innovations. Screening methods [4], green chemistry metrics [5-6] and LCT tools adapted for emerging technologies [7] will be critically evaluated for their potential application in the development of bioplastic coatings, as envisaged in the BioLaMer system.

2. Methods

The literature review will follow the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) methodology [8]. A set of search terms, strategically combined with Boolean operators, will be used to search on Scopus relevant peer-reviewed articles, published in the last decade. To evaluate their relevance, the articles will undergo two-level screening: first title and abstract, then full text.

3. Results and discussion

Although the need for such screening tools and simplified LCA was recognized in the 1990s [9], limited consensus remains on their application across industry, academia and institutions. For instance, while the American Chemical Society Green Chemistry Institute Pharmaceutical Roundtable endorsed the process mass intensity metric [10], recent literature calls for a more

¹ University of Bologna, Interdepartmental Research Centre for Environmental Sciences, Via S. Alberto, n. 163, 48123, Ravenna, Italy

² University of Bologna, Department of Physics and Astronomy, Viale Berti Pichat 6/2, 40127 Bologna, Italy

E-mail: floriana.coppola2@unibo.it

comprehensive assessment framework that combines quantity-based process metrics with life cycle impact-based metrics [11]. While life cycle screening approaches have been proposed [4], the Joint Research Center suggests that for technologies at low maturity levels, prospective LCA is preferable due challenges in data representativeness [12].

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4. Conclusion

By exploring the wide range of available tools and methods, our goal is not to find a flawless approach – acknowledging that such a method likely does not exist – but to evaluate the most suitable option for our needs, while being transparent and aware about its limitations. Striking a balance among understandability, simplicity, computability, resource efficiency, and the ability to provide relevant insights is critical for selecting the appropriate method for environmental assessments of early-stage technologies.

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5. References

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