ISGC 2022

N°176 / OC
TOPIC(s) : Life cycle assessment, biodegradability, eco-toxicity / Biomass conversion

LCA methodology-based environmental impact assessment of levulinic acid obtainment from residual Cynara Cardunculus L. biomass and its valorization for the production of biomaterials for green electronics

AUTHORS

Roberto ROSA / UNIVERSITY OF MODENA AND REGGIO EMILIA, DEPARTMENT OF SCIENCES AND METHODS FOR ENGINEERING, VIA AMENDOLA 2, REGGIO EMILIA
Sheryl MOSTAFA AHMED / UNIVERSITY OF MODENA AND REGGIO EMILIA, VIA AMENDOLA 2, REGGIO EMILIA
Devid SASSI / UNIVERSITY OF MODENA AND REGGIO EMILIA, VIA AMENDOLA 2, REGGIO EMILIA
Paolo NERI / UNIVERSITY OF MODENA AND REGGIO EMILIA, VIA AMENDOLA 2, REGGIO EMILIA
Gianluca CAVALAGLIO / UIVERSITÀ TELEMATICA PEGASO, CENTRO DIREZIONALE ISOLA F2, NAPOLI
Valentina COCCIA / UNIVERSITY OF PERUGIA, VIA DURANTI 67, PERUGIA
Franco COTANA / UNIVERSITY OF PERUGIA, VIA DURANTI 67, PERUGIA
Anna Maria RASPOLLI GALLETTI / UNIVERSITY OF PISA, DEPARTMENT OF CHEMISTRY AND INDUSTRIAL CHEMISTRY, VIA MORUZZI 13, PISA
Micaela DEGLI ESPOSTI / UNIVERSITY OF BOLOGNA, DEPARTMENT OF CIVIL, CHEMICAL, ENVIRONMENTAL, AND MATERIALS ENGINEERING, VIA TERRACINI 28, BOLOGNA
Davide MORSELLI / UNIVERSITY OF BOLOGNA, DEPARTMENT OF CIVIL, CHEMICAL, ENVIRONMENTAL, AND MATERIALS ENGINEERING, VIA TERRACINI 28, BOLOGNA
Paola FABBRI / UNIVERSITY OF BOLOGNA, DEPARTMENT OF CIVIL, CHEMICAL, ENVIRONMENTAL, AND MATERIALS ENGINEERING, VIA TERRACINI 28, BOLOGNA
Anna Maria FERRARI / UNIVERSITY OF MODENA AND REGGIO EMILIA, DEPARTMENT OF SCIENCES AND METHODS FOR ENGINEERING, VIA AMENDOLA 2, REGGIO EMILIA

PURPOSE OF THE ABSTRACT

This work was performed in the framework of a wider research project financed by the Italian Ministry of Universities and Research under the program PRIN 2017, entitled "Development and promotion of levulinic acid and carboxylate platforms through the formulation of new and advanced PHA-based biomaterials and their exploitation for the application of 3D printed green-electronics", (Acronym: VISION; Grant Number: 2017FWC3WC) [1].

The VISION project aims at partially contributing to overcome the environmental issues related to the production, use and disposal of fossil-based polymers and additives by developing fully bio-based nanocomposites to be employed for the fabrication of piezoelectric as well as chemical sensors through additive manufacturing techniques, to be integrated with electronics leading to bio-based fully integrated systems.

Different types of lignocellulosic biomasses are studied in the VISION project (e.g. grape pomace and residual Cynara Cardunculus L. biomass) as renewable resources to obtain high-value molecules.

However, it is well-known that bioplastics are often surrounded by the myth ascribing them biodegradability and, above all, low or even none environmental impact. Therefore, to avoid to simply move the environmental burdens to a different phase in the biomaterial life cycle, all of the actions provided by the VISION project will be accurately quantified in terms of their environmental impacts by applying the Life Cycle Assessment (LCA) methodology.

Particularly, this work is focused on the obtainment of levulinic acid from residual Cynara Cardunculus L. biomass, through an acid catalyzed hydrolysis assisted by microwave heating, as recently optimized by some of the authors [2]. Particularly the environmental assessment comprised also the Cynara Cardunculus L. crop production. This allows to establish in a reliable and objective manner the advantages or disadvantages arising from the

exploitation of the residual biomass, with respect to the scenario characterized by biomass disposal on the agricultural soil. At this latter regard, a preliminary agricultural algorithm was developed in order to account, in the impact assessment phase, for the quality of the soil after the crop production, and its effect on the productivity.
The as-obtained levulinic acid can be then used to synthesize ketal-diester additives to be used as bioplasticizers, making possible to produce completely ecological bioplastics, counteracting the issue related to the non-biodegradability nature of conventional additives, such as phthalates [3]. Particularly, a three steps selective synthesis was recently optimized by some of the authors [4], in order to obtain five different molecules with different side chains that demonstrated remarkable plasticizing effectiveness when added to both Poly(Vinyl chloride) [3] and Poly(3-hydroxybutyrate) (PHB) [5].
The LCA results, in conjunction with those from the experimental activities, made it possible to find the optimal compromise (among the different modelled bioplasticizers) between environmental impacts and mechanical and thermal properties, highlighting the most impacting phases of each process, thus proposing alternative scenarios and possible meliorative interventions.

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS
LCA | bioplasticizers | biomass valorization | biopolymers

BIBLIOGRAPHY

[1] https://www.prin-vision.it/

[2] Raspolli Galletti A. M., Licursi D., Ciorba S., Di Fidio N., Coccia, V., Cotana F., Antonetti C. Sustainable exploitation of residual Cynara cardunculus L. to levulinic acid and n-butyl levulinate. Catalysts 11, 2021, 1082.

[3] Gao D. -W., Wen Z. -D. Phthalate Esters in the Environment: A Critical Review of Their Occurrence, Biodegradation, and Removal during Wastewater Treatment Processes. Sci. Total Environ. 541 (2016) 986–1001.

[4] Sinisi A., Degli Esposti M., Toselli M., Morselli D., Fabbri P. Biobased ketal-diester additives derived from levulinic acid: synthesis and effect on the thermal stability and thermo-mechanical properties of Poly(vinyl chloride). ACS Sustainable Chem. Eng. 7, 2019, 13920-13931.

[5] Sinisi A., Degli Esposti M., Braccini S., Chiellini F, Guzman-Puyol S., Heredia-Guerrero J. A., Morselli D., Fabbri P. Levulinic acid-based bioplasticizers: a facile approach to enhance the thermal and mechanical properties of polyhydroxyalkanoates. Mater. Advances 2021, Advanced Article, https://doi.org/10.1039/D1MA00833A.