Intermediate environmental and economic assessments of new green processes for obtaining new biobased products

IRODDI (Innovative Refining Process for Valorization of Vegetable Oil Deodorizer Distillates) is a project funded by the Bio-Based Industries Joint Undertaking (BBI JU) under the European Union's Horizon 2020 Research and Innovation programme (grant agreement N° 887407) aimed at developing new greener processes for obtaining new biobased products with specific properties derived from the Free Fatty Acids (FFAs) contained in the deodorizer distillates (DODs) residual streams of the deodorization process, the last step of the refining process of oils and fats.

To integrate and validate the IRODDI technologies and their technical performance to ensure their applicability at the industrial level, the 3 pillars of sustainability (environmental, techno-economic and social impacts) are being addressed. At present, TECNALIA has undertaken the preliminary life cycle environmental assessments (LCAs) for the neutralization of FFA with ionic liquids (IL) to obtain bio-surfactants and FFA enzymatic esterification to obtain bio-lubricants and polyols. Similarly, ZERO-E has focused on the economic and social life cycle assessments of the same processes. In doing so, the methodology established by the ISO 14040:2006 and ISO 14044:2006 standards has been used, following the established 4 different phases:

- The **goal and scope** definition phase, where the reasons for carrying out the study (goal) and the product system to be studied (scope) are defined;
- The **inventory analysis** phase or data collection for the Life cycle Inventory (LCI) development;
- The **impact assessment** phase, where an analysis of the data included in the LCI is accomplished, as well as, the transference of inputs and outputs into environmental impacts;
- The **interpretation** of the results and development of a set of conclusions.

For the preliminary LCA conducted, the system boundaries were established following a cradle-to-gate approach and focusing on the bio-compounds extraction/neutralization processes at laboratory scale. Recommendations from the EC´s Product Environmental Footprint (PEF) were followed and the 16 environmental impact categories were selected for the assessment. In order to characterise the life cycle environmental impacts, the LCA simulation was conducted using the SimaPro Software.

The results obtained highlighted the production processes and scenarios with the highest environmental impact, thus giving the opportunity to make initial recommendations to take forward towards theirs scaling up in the second stage of the project. In this regard, a most promising IL in terms of environmental performance was identified. As for the main environmental hotspots identification, results showed that the electricity consumption is a great contributor to all the environmental impact category indicators with over 50% of the impact. These initial results, however, should be taken as preliminary and are likely to significantly change when the processes are up-scaled, in which the influence of the energy consumptions is expected to be reduced due to the improved efficiency of the process and economies of scale.

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Following, the corresponding results for the neutralization with IL and enzymatic esterification and shown.

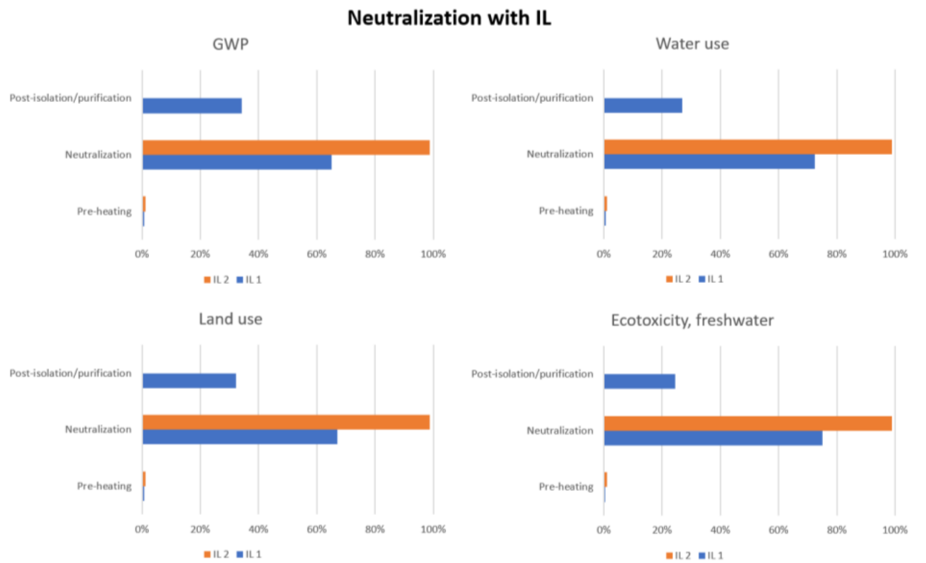

Figure 1: Impacts on the GWP, water use, land use and ecotoxicity in freshwater of the neutralization of FFA with IL

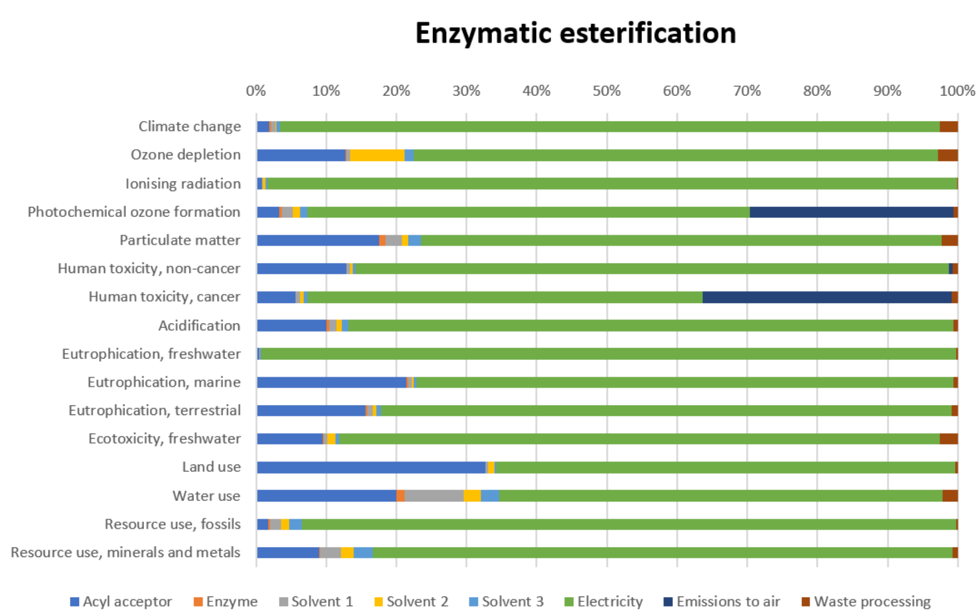

Figure 2: Enzymatic esterification environmental hotspots identification

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Regarding the preliminary economic assessment, the aim was to obtain a first estimation of the production costs of IRODDI's bio-based solutions and to identify the key hotspots causing the highest impact on the production costs for each process evaluated. The procedure for the costs estimation was based on the identification of the system boundaries, inlet and outlet flows of the product system defined together with their quantities and European market price.

First estimations using information of the processes at lab scale showed that the neutralization of DOD using of IL 1 is almost 3 times less costly than the same process performed using IL 2. In addition, the most contributing process step to the total production cost of the biosurfactant composition) was the neutralization step, followed by the drying and the DOD melting steps. In both scenarios, this contribution was mainly due to the high costs of the IL used at the evaluated scale. Furthermore, although the use of the IL 2 eliminates the need of a downstream processing unit, and consequently the energy consumption related costs for the water evaporation too, the low concentration of the IL 2 solution significantly increases the quantity of product use, hence, rising the production cost of the biosurfactant and accounting for 94% of the total bioproduct cost.

In the case of the enzymatic esterification process, preliminary results showed that a recovery of the solvent mix used for washing the enzyme will highly impact on the total production cost of 1kg neutralized DOD causing a reduction of around 57% in the final expenditures.

It is very likely that the results obtained for both processes assessed will significantly vary when considering costs of supplies at a large scale.

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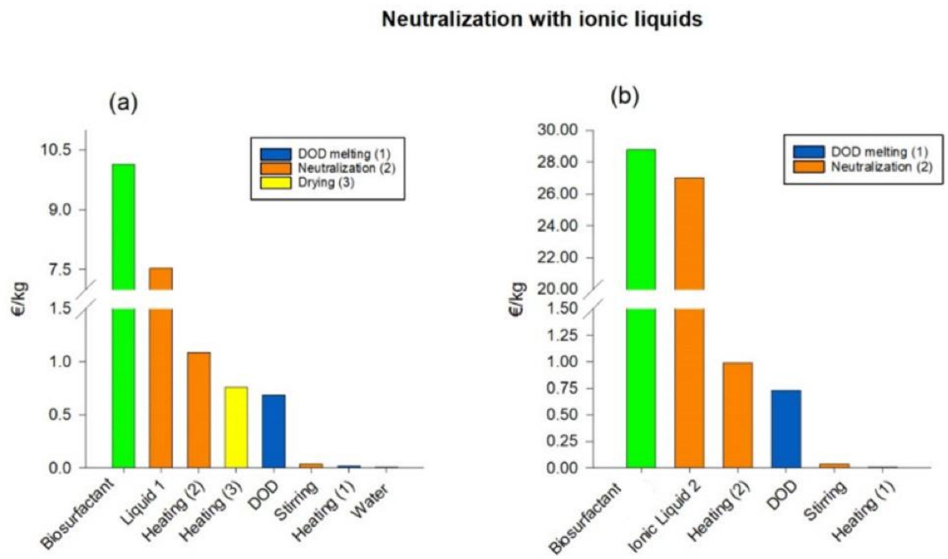

Figure 3: Production cost estimation of 1 kg biosurfactant by neutralization with (a) Ionic Liquid 1 and (b) Ionic Liquid 2

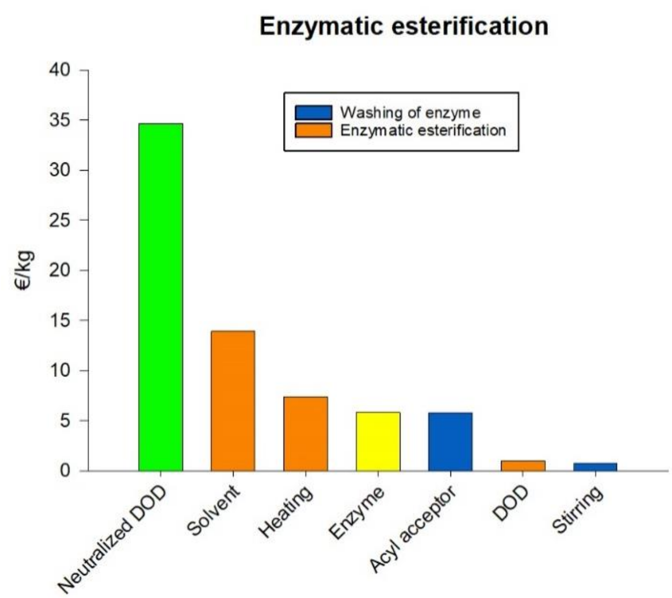

Figure 4: Production cost estimation of 1kg neutralized DOD by Enzymatic Esterification

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On the other hand, the S-LCA follows the main stages of the life cycle thinking defined by the ISO 14040:2006 standard: definition of the goal and scope, life cycle inventory, life cycle impact assessment and interpretation. Nevertheless, the S-LCA methodology is not standardized and there is not a common agreement on the indicator selection. The methodology selected to analyse the social impacts of the IRODDI project suggests a systematic and quantitative approach to apply S-LCA for production process design assessments; it is based on UNEP guidelines. This methodology is applicable for process and technologies that are at initial stage of development. The methodology includes the following 5 main steps: i) goal and scope definition; ii) data collection; iii) stakeholder's evaluation; iv) indicator selection; v) S-LCA interpretation.

The first identification of the most relevant stakeholders linked to IRODDI project was performed throughout a power-interest grid. The power-interest grid is enormously valuable to rank the stakeholders based on their authority and concern regarding the various phases of the production. Throughout this template, ZER0-E collected the opinion of all partners in the project. According to the results obtained, the main targets of the S-LCA in the project are the Consumers, Society and Value Chain Actors. Conferring to the experts' opinion, the final consumers have the highest interest and power due to its capacity to decide if they know about the social aspects associated to typical products consumed daily. Similarly, the Value Chain Actors have shown high interest because of its involvement into the processes which can represent a relevant risk over their health and safety.

During the second period of the project, the LCA will target the final biobased products and their application in their specific industrial contexts and the comparison with their fossil-based counterparts. Additionally, subsequent techno-economic and social assessments will be addressed, and results will be presented in future publications.

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