Environmental Sustainability Assessment of Valorizing Orange Peels Waste in Animal Feed Production

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Waste valorization through different technologies for animal feed production has emerged as an efficient strategy arising from awareness of the need for sustainable development in terms of the safe reuse of waste biomass. Production of high-value secondary feedstuff for dairy sheep from waste orange peels has been suggested as a sustainable option to guarantee the long-term competitiveness and sustainability of the livestock sector. To this end, a valorization process that includes the saccharification of the orange peels and the aerobic fermentation of the liquid part of the hydrolysate was recently suggested as an innovative process (Figure 1). However, the environmental benefits and impacts of this valorization strategy are uncertain. In this study, the environmental impacts of turning waste orange peels into high-value secondary feedstuff for dairy sheep were quantified through life cycle assessment (LCA). The valorization process was modeled for the identification of the most influential stage/s and the evaluation of potential impacts on the environment. The functional unit used for LCA was set as 1 ton of orange peel processed and ReCiPe 2016 Midpoint (I) method was used as the impact assessment method.

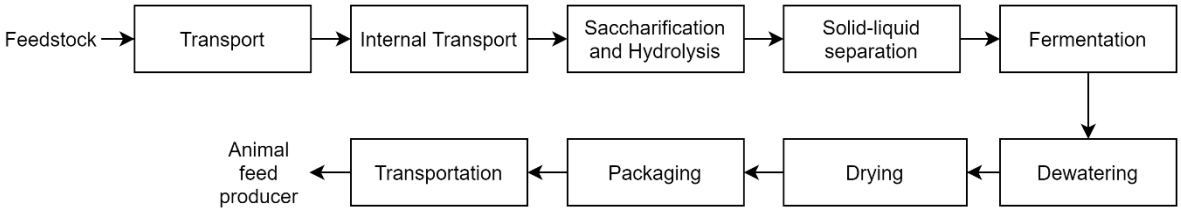

Figure 1. Valorization process flow chart

Figure 2 presents the normalized impacts of the valorization process. As can be depicted, this valorization process causes the highest impact on the freshwater ecotoxicity category followed by marine ecotoxicity while the impacts on the categories of global warming, ozone depletion, ionizing radiation, ozone formation, fine particulate matter formation, terrestrial acidification, land use, and mineral resource scarcity are negligible. The second most critical group of impact categories are freshwater eutrophication, human non-carcinogenic toxicity, terrestrial ecotoxicity, and human carcinogenic toxicity.

The process step of saccharification-hydrolysis appeared as the most critical environmental hotspot throughout the entire life cycle of the valorization process, with contributions higher than 70% in the most impact categories. The next critical contributing process step is fermentation with a contribution higher than 15% in the impact categories of freshwater ecotoxicity and marine ecotoxicity. The use of enzymes in the saccharification-hydrolysis process step appeared as the main contributor to the impacts of this process step. The environmental burdens caused by the use of enzymes originates are due to the commercial production process of the enzymes. Even though the temperature of the saccharification-hydrolysis step is 50 °C, the electricity consumption was found not to dominate the impacts. For the stage of fermentation where a temperature of 30 °C is maintained, electricity consumption is with a remarkable environmental impact.

The freshwater ecotoxicity potential of the whole process was estimated to be 6.7 kg 1,4-DCB, while that of marine ecotoxicity was 2.0 kg 1,4-DCB (Table 1). The freshwater eutrophication potential of the process was also remarkable with a value of 0.076 kg P eq. Yet, the valorization process was found to have relatively lower impacts on the other categories. The global warming potential was estimated to be 128 kg CO_2 per 1 ton of orange peels processed.

These results demonstrate the critical role that enzyme consumption plays in the proposed valorization process and require the optimization of enzyme use.

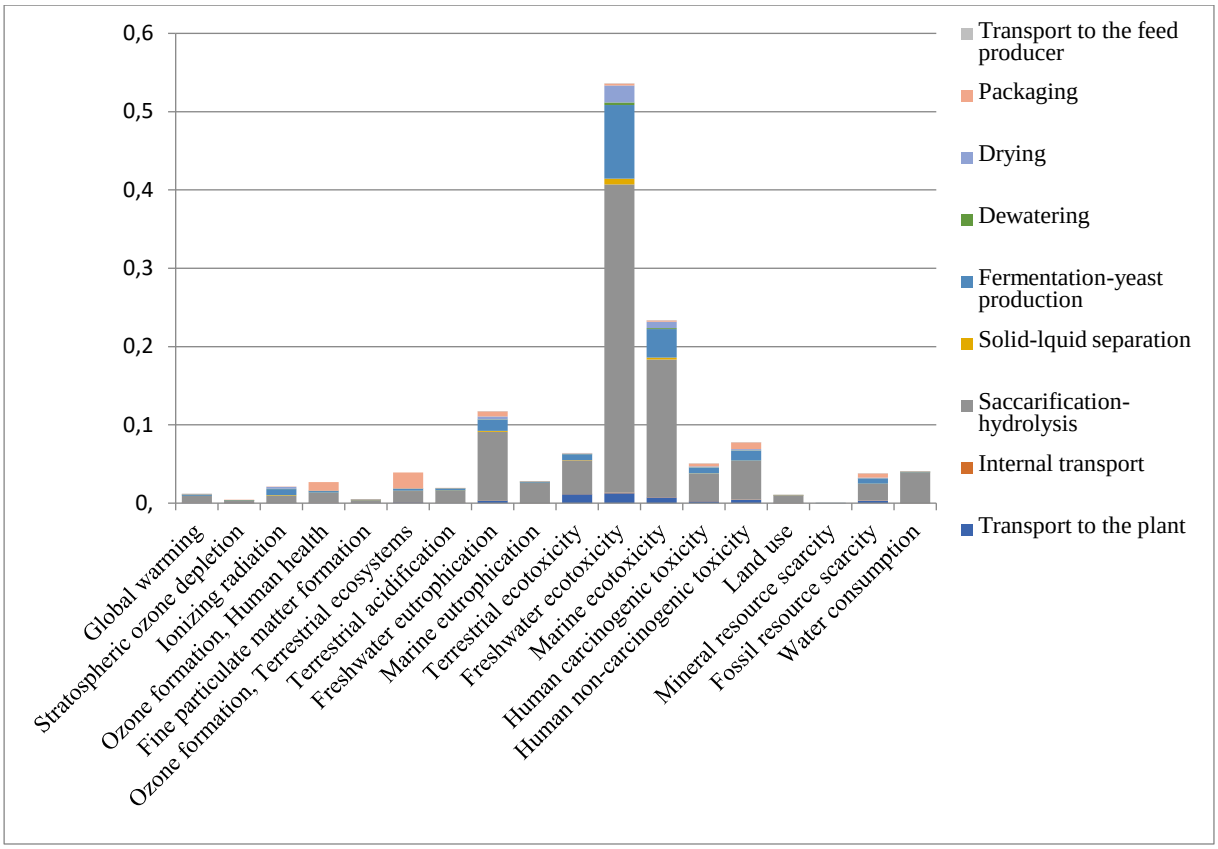

Figure 2. Normalized impacts of different process stages

Table 1. Impacts of the Valorization process on different categories

Impact category	Unit	Total
Global warming	kg CO2 eq	128
Stratospheric ozone depletion	kg CFC11 eq	0.000254
Ionizing radiation	kBq Co-60 eq	9.8
Ozone formation, Human health	kg NOx eq	0.56
Fine particulate matter formation	kg PM2.5 eq	0.01
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.69
Terrestrial acidification	kg SO2 eq	0.79
Freshwater eutrophication	kg P eq	0.076
Marine eutrophication	kg N eq	0.126
Terrestrial ecotoxicity	kg 1,4-DCB	427
Freshwater ecotoxicity	kg 1,4-DCB	6.7
Marine ecotoxicity	kg 1,4-DCB	2.0
Human carcinogenic toxicity	kg 1,4-DCB	0.503
Human non-carcinogenic toxicity	kg 1,4-DCB	3.9
Land use	m^2a crop eq	64
Mineral resource scarcity	kg Cu eq	0.51
Fossil resource scarcity	kg oil eq	37.3
Water consumption	m^3	11

References

Andrianou, C.; Passadis, K.; Malamis, D.; Moustakas, K.; Mai, S.; Barampouti, E.M. Upcycled Animal Feed: Sustainable Solution to Orange PeelsWaste. Sustainability 2023, 15, 2033. https://doi.org/10.3390/su15032033.