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ASCANIUS - ASsessing eConomic and eNvironmental Impacts of Cheese Making ResidUeS Treatments Using Comparative LCA and LCC Methods.

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Abstract

Cheese whey (CW) is one of the main by-products generated by the dairy industry and is characterised by high organic load, large volumes and management challenges. The agri-food sector accounts for approximately 10% of greenhouse gas emissions in the European Union, with dairy production representing an important contributor to environmental impacts (EEA, 2022). Approximately 10 L of whey are generated per kilogram of cheese produced (Asunis et al., 2021), creating environmental and economic concerns, particularly for small and medium-sized dairy plants (Pires et al., 2021). CW contains valuable organic matter and nutrients that can be recovered through different valorisation pathways (Asunis et al., 2020). This study presents a preliminary comparative Life Cycle Assessment (LCA) of two alternative CW management strategies in the Province of Trento (Italy), a region characterised by a cooperative dairy sector and non-intensive livestock farming systems. The assessment was conducted within the “ASCANIUS”-PhD project, which aims to evaluate the environmental and economic implications of cheese-making residue treatment options and support circular bioeconomy solutions. Two scenarios were compared using a functional unit of 1 t of CW. The benchmark scenario considered anaerobic digestion (AD) of CW for biogas production, followed by combined heat and power generation and agricultural application of the digestate solid fraction as a soil improver. The alternative scenario evaluated whey powder (WP) production through concentration and spray-drying processes, with the resulting product assumed to substitute milk powder in the animal-feed industry. The assessment was performed using the Environmental Footprint 3.1 method, accounting for the environmental benefits associated with energy, nutrient and product recovery through substitution of conventional products and processes. Preliminary results highlighted markedly different environmental profiles between the two valorisation pathways. The AD scenario achieved the highest climate change mitigation potential and fossil resource savings due to substantial energy recovery from biogas and associated avoided impacts. However, higher eutrophication impacts were observed, mainly related to nutrient emissions from digestate management. In contrast, the WP scenario showed lower energy recovery but higher material valorisation through production of a feed ingredient. Nevertheless, the concentration and spray-drying stages resulted in high energy consumption, reducing overall environmental credits compared with AD. Results indicate that environmental performance is strongly influenced by the type of recovered resource: energy-oriented valorisation through AD maximises climate and fossil resource benefits, whereas product-oriented valorisation through WP enhances material recovery but requires greater process energy inputs. Overall, the findings highlight important

trade-offs between energy recovery, nutrient recycling and material valorisation, providing a basis for future assessment of integrated dairy biorefinery systems. These preliminary findings provide useful insights into the environmental implications of alternative whey valorisation pathways and may support future decision-making aimed at improving resource efficiency and circularity within the dairy sector.

Keywords: Cheese whey, Life Cycle Assessment (LCA), Anaerobic digestion, Whey valorisation, Circular bioeconomy

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