Public summary – Theodoros Rizopoulos

Cultivated meat (CM) highlights a promising alternative to the conventional livestock production, yet its future environmental performance remains highly dependent on input assumptions, process design choices, and upstream supply chain & energy system evolution.

This study presents a prospective life cycle assessment (LCA) of a large-scale CM production facility, based on a detailed process model developed in SuperPro Designer (SPD) as the basis for the life cycle inventory (LCI). The system boundary reflects the production system, encompassing a semi-continuous process, combining continuous cell expansion with batch differentiation, coupled with perfusion systems, with an annual output of approximately 7 kt of cultivated meat.

The ReCiPe2016 Midpoint H and Cumulative Energy Demand (CED LHV) methods have been applied, with a primary focus on four impact categories: global warming potential, land use, water consumption, fine particulate matter formation, and (non)-renewable energy consumption. These impacts are evaluated across four main cases defined by two metabolic scenarios, namely wild type and enhanced cell lines, each assessed at both the differentiated and undifferentiated biomass level.

Preliminary LCA iterations revealed modelling and assumption gaps in the system, that were validated with mass and energy balances, as well as feedback from industry experts. Improved media and perfusion strategies were also implemented, based on environmental and utility consumption metrics. Future scenario development highlighted clear environmental prospects, based on EU decarbonization goals, while raw material sourcing and composition (amino acids, recombinant proteins) revealed great uncertainty, that could be mitigated with more detailed system definition and supplier engagement.

A dynamic Excel-based LCA model was developed as part of the project, providing process design and LCA guidelines to the Cellular Agriculture community. The model links process modeling parameters and environmental impact databases of all elemental flows to the process inventories. The output of the model provides contribution analysis of each process step and type of elemental flow (raw materials, utilities, wastes, and emissions) for all the impact categories, with a user-friendly interface for scenario and sensitivity analysis. Benchmarking of CM with previous assessments is an additional feature in this model.

The results confirm that cultivated meat has strong environmental potential, performing substantially better than traditional beef in global warming potential, land use, and particulate matter formation, especially under improved metabolic and renewable energy scenarios. These results are, however, sensitive to proxy dataset selection, scheduling assumptions, and inventory completeness.