Assessing the sustainability and socioeconomic implications of cultured cattle meat through a Multiregional Inputâ€“Output Approach. Special Session: Sustainable Strategies for Reducing COâ‚‚ and Non-COâ‚‚ Greenhouse Gas Emissions

Topic: Sustainable Strategies for Reducing COâ‚‚ and non-COâ‚‚ Greenhouse Gas Emissions (II)
Author: Cristian Soria ValcÃ¡rcel
Co-Authors: Ã•ngela GarcÃ-a-Alaminos, Guadalupe Arce, Marina SÃ¡nchez, Nuria Gomez

The meat industry is one of the largest contributors to global greenhouse gas (GHG) emissions, accounting for 14.5% worldwide. Beef production alone is responsible for 41% of tropical deforestation and occupies 370 m2 per 100g of protein. In terms of water, 42 kL is used per 100g of protein. Experts highlight the need for dietary change, particularly reducing meat consumption through plant-based or synthetic substitutes. Plant-based alternatives have gained popularity but still fall short in replicating the protein value, texture, and taste of traditional meat. Cultivated (lab-grown) meat, however, offers similar protein standards and nearly identical sensory attributes to conventional meat.

Recent impact studies on cultivated meat mainly use Life Cycle Assessment (LCA), which evaluates environmental impacts and resource use from raw materials to waste. However, to the best of our knowledge, no studies have comprehensively analyzed total emissions by jointly considering both direct and indirect emissions across the entire value chain using a multi-regional input-output (MRIO) model. The objective of this study is to assess the overall sustainability profile of cultured meat by evaluating key impact categories identified in previous research, explicitly accounting for both direct and indirect contributions, and comparing them with conventional production.

To address these gaps, we applied an MRIO model to simulate the systemic consequences of replacing conventional beef production with cultured meat. Unlike LCA approaches, the MRIO methodology captures intersectoral and international linkages across global value chains, allowing a comprehensive evaluation of emissions, employment, water consumption, and land use. The analysis incorporates environmental extensions and decomposes impacts across production rounds using a Taylor series expansion of the Leontief inverse. The empirical application relies on the EXIOBASE database, which provides high-resolution data on sectoral interactions and environmental stressors. Two final demand vectors are constructed to represent the production of one ton of cattle meat and one ton of cultured meat, assuming nutritional equivalence. For cultured meat, the input structure is based on techno-economic data from large-scale production scenarios, adjusted to reflect recent cost estimates and industrial assumptions. For cattle meat, the demand vector is derived from the intermediate consumption structure of the meat processing sector in Spain.

The results reveal significant trade-offs between the two production systems. Cultured meat substantially reduces agricultural emissions, particularly methane (CHâ„), nitrous oxide (Nâ„O), and ammonia (NHâ„ƒ), due to the elimination of enteric fermentation and manure management. As a result, total GHG emissions measured in COâ‚‚ equivalents are approximately 28% lower than those of conventional beef. Additionally, cultured meat reduces land use and water consumption, highlighting its potential to alleviate pressure on natural resources. However, these environmental gains are partially offset by higher energy-related emissions. Cultured meat production is more energy-intensive, leading to higher COâ‚‚ emissions from combustion processes. This reflects a structural transition from biologically driven emissions to industrial, energy-dependent processes. Consequently, its sustainability depends on energy decarbonization and improvements in production efficiency.

From a socioeconomic perspective, the transition implies a restructuring of labor markets. Low-skilled employment declines, particularly in livestock farming, while high-skilled jobs increase in biotechnology and engineering. Although total employment may rise, this raises concerns about

worker displacement and the need for reskilling, especially in rural regions. Also, the MRIO decomposition highlights the importance of global value chains. For cattle meat, impacts are concentrated in domestic production stages, whereas cultured meat impacts are more distributed across upstream industries and foreign regions supplying key inputs.

Preliminary conclusions suggest that cultured meat could reduce the environmental footprint of meat production, particularly in land use and non-COâ‚‚ emissions. However, its benefits depend on technological progress, energy decarbonization, and supply chain optimization, as well as policies ensuring a just transition.