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Sustainability of meat substitutes: plant analogues, microalgae, insects and cultured meat (#371)

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Introduction

The lack of protein sources in several parts of the world is triggering the search for locally produced and sustainable alternatives. Insects, microalgae and plants are recognized as a potential solution. Industry of cultured meat is dynamically developing through investments from meat companies and venture capitals. The production of various meat substitutes (based on plants, microalgae and animal-based biomass) aims to reduce the environmental impact caused by livestock and find safe and reliable supply alternatives. This study outlines the comparative analysis of meat substitutes' environmental performance in order to estimate the most promising options.

Methods

The study relies on attributional and consequential Life Cycle Assessment modelling for the estimation of the most impacting types of meat substitutes. It considered "cradle-to-gate" meal life cycle with the application of ReCiPe and IMPACT 2002+ methods. Inventory was based on literature and field data. Consideration of functions and functional unit (FU) variations were included. Results of meat substitutes (high-moisture intermediates or fresh meat) LCA were compared to conventional benchmark meats (beef, pork, chicken). LCAs are followed by sensitivity analyses, which identify the most promising directions towards sustainable production of meat analogues and estimate the magnitude of impact reductions if those directions are to pursue by the industry.

Results

Results showed the highest impacts for cultured meat (based on own study and recent publications), which was in the upper impact level of beef. The highest impacts of meat culturing were associated with production of culture media. Even with more progressive scenarios of culturing meat on cyanobacteria-produced media, the impact of cultured meat is very high (Figure 1). Microalgae-based meat analogues had lower environmental impact than beef, such intermediates were not competitive against pork and chicken (autotrophic microalgae grown in food grade conditions). Heterotrophic cultivation of microalgae on industrial side-streams or underutilised but safe organic matter has a potential to result in more sustainable meat substitutes comparable in impact to analogues based on insects, plants or chicken. Legal requirements for treating insects as livestock animals increase the impact of insect-based meat substitutes (need to grow insects on animal feed) to the levels of lower impact range of chicken. Similarly to microalgae, environmental impact of insect can be improved if they are grown on wastes or food industry side streams. Plant-based meat analogues were the most environmentally beneficial type of meat substitutes (nutritional properties are not similar however). The results were very sensitive to the changes of FU. Midpoint impact category results were the same order of magnitude as some previously published work, although wide ranges of possible results and system boundaries made the comparison with literature data challenging.

Conclusion

The results of the comparison were highly dependable on selected FU. Therefore, the proposed comparison with different integrative FU indicated the lowest impact of plant-based meat substitutes (which corresponds to other studies). Analyses of insect meat substitutes corresponds with other findings in the literature, indicating insect-based intermediate as more sustainable than fresh chicken meat. Insect-based meat substitutes have a potential to be more sustainable with the use of more advanced growing and processing techniques. Contradictory to other publications modelling of culture meat production on industrial level and analysis of economic and environmental efficiency of cellular meat production indicated its lower efficiency in terms of resource use (higher price and higher environmental impact) comparing to conventional beef production. Upscaling of cultured meat production and identification of reliable and cheap cultured media would make it environmentally competitive to the upper impact boundaries of beef. The consequential LCA indicated that transforming organic residuals into meat substitute biomass could result in lower environmental impacts if composting or anaerobic digestion (as a waste treatment technology) is avoided.

Notes

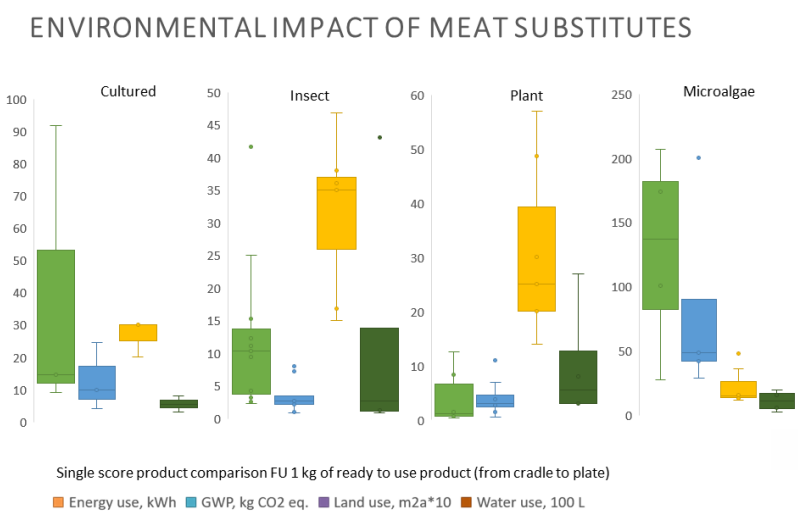

Figure 1.
Environmental impact of meat substitutes

Notes