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# Is cultured meet environmentally sustainable?

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# Introduction

To satisfy the increasing demand for food from a growing human population, expected to exceed 9 billion by 2050 (Chriki & Hocquette, 2020), cultured meat (also called in vitro, artificial or lab-grown meat) is presented as a promising alternative to conventional meat for consumers who seek to be more responsible towards the environment without changing their diet (Chriki & Hocquette, 2020; Merck Group, n.d.; Robbins, 2020; Skye, 2021; The Guardian, 2011). To produce cultured meat, muscle tissue is grown in a laboratory setting. First, muscle stem cells (called "myosatellite" cells) are extracted from an animal and grown in a highly-processed raw calorie source (medium). Then, the tissue is fed, multiplied, shaped and structured in bioreactors to become what consumers can consider similar to a meat product and would typically be used for burgers or nuggets (Robbins, 2020). While cultured meat requires a small tissue sample, the cells can be taken from a living animal, so the process does not require killing animals (Pathak, 2021).

The questions that this paper addresses are: Assuming that all uncertainties and challenges regarding human health and safety (a priority), economics, regulations and other matters are resolved, are there possible adverse impacts on the environmental sustainability that have to be considered at the design phase? What is the outcome of a full life cycle assessment (LCA) of cultured meat compared to conventional animal meat? Is there a risk that environmental impacts, currently perceived as negligible, could eventually lead to adverse consequences on the environment if production reaches a large scale? Chriki and Hocquette (2020) produced a review of various issues related to cultured meat, upon which this paper is largely based.

**1.**

# Expected impact on the environment

Regarding environmental issues, the main anticipated advantage of cultured meat is lower greenhouse gas emissions (GHG) because much less conventional farming for livestock, ruminants in particular, will be needed. However, this is a matter of controversy (Chriki & Hocquette, 2020; Robbins, 2020) because cultured meat can have an impact on the environment and the climate through its energy consumption; primarily electricity use during production itself, but also electricity and heat use in upstream production of the medium (Skye, 2021; Tuomisto & de Mattos, 2011).

Researchers began as early as 2010 to conduct LCAs of cultured meat (see Tuomisto & de Mattos, 2010). In a study conducted in 2011 by the University of Oxford (see Tuomisto & de Mattos, 2011), an LCA approach was adopted for assessing the environmental impacts of large-scale cultured meat production. In this research, nutrients and energy to grow muscle cells were provided by cyanobacteria hydrolysate. The results showed that "in comparison to conventionally produced European meat, cultured meat involves approximately 7–45% lower energy use (only poultry has lower energy use), 78–96% lower GHG emissions, 99% lower land use, and 82–96% lower water use depending on the product compared" (Tuomisto & de Mattos, 2011). The researchers conclude that despite high uncertainty, the environmental impacts of cultured meat production may be significantly lower than those of conventional meat production.

A complete comparison between cultured and conventional meat production will require considering other factors. Additionally, a comparison with other meat substitutes, especially plant-based alternatives, will also need to exhibit net benefits (Chriki & Hocquette, 2020).

**2.**

# Prospective LCAs of cultured meat

Acknowledging the multitude of LCAs for cultured meat, but the limited number of environmental impact studies on actual cultured meat production, the Global Food Institute and Nova Institute published in 2019 a review and gap analysis of three LCA studies of cultured meat (see Scharf et al., 2019). According to the study, "all analysed studies [LCA] are based on hypothetical production processes and simulation models as, currently, no largescale production facility of clean meat exists. Hence, all studies heavily rely on assumptions, literature and calculations based on mathematical formulas". The report provides a number of recommendations for future LCAs. Regarding the goal and scope of a relevant LCA, the authors recommend that "the LCA approach shall be selected depending on the goal and scope of the study. One can distinguish

two approaches: attributional and consequential. An attributional approach is recommended to evaluate and/or compare processes or products. Moreover, this approach allows to identify the most impacting process parameters and the technical optimisation potential. In contrast, an evaluation of the (societal) consequences of the technology can be better performed in a consequential approach. The typical target audience here is policymakers. In order to provide feedback for the industry, an attributional approach is the most suitable. Moreover, a so-called prospective LCA might be suitable. This includes scale-up data as well as potential changes of the circumstances". The authors also emphasize that prospective LCAs are suitable and necessary to address questions like "what will happen?", "what can happen?" or "how can a specific target be reached?". They recommend that "a hypothetical scale-up and optionally an outlook into a future technosphere can be included (e.g., changes in the energy mix and transportation, feedstock provisions). This is especially relevant in comparative studies as a comparison on lab-scale may cause premature and potentially wrong conclusions".

A study from CE Delft published in February 2021 (see Odegard, 2021) used primary data from multiple cultured meat companies and associated companies in the supply chain, and compared several future production systems expected to be in place by 2030. The study concluded that cultured meat could offer environmental gains compared to conventional meats (beef, pork, chicken) and that it uses much less land than conventional meats. Moreover, it also has a much lower carbon footprint than beef and is comparable to the global average footprints for pork and chicken when produced using conventional energy, provided at least 30% of the energy used is produced sustainably. When using sustainable energy, cultured meat has a lower carbon footprint than ambitious production benchmarks for all conventional meats.

**3.**

## Food safety and potential risks for human health

Health and safety aspects may need to be considered even before environmental aspects. Cultured meat is a new product, and there is incomplete knowledge regarding its impact on human health. Chriki & Hocquette (2020) showed at least four aspects to consider when evaluating potential health safety hazards:

First, advocates of cultured meat claim that it is safer than conventional meat, based on the fact that it is produced in a fully controlled environment. In contrast, conventional meat is produced from living animals and health and safety conditions may not be optimum. Cultured muscle cells are not confronted with various pathogens such as intestinal pathogens like E. coli, Salmonella or Campylobacter, three pathogens that cause millions of episodes of illness each year. Perfect health and safety control are not always possible. Contamination occasionally happens at slaughter, and incidents may occur during industrial production of chopped meat.

Second, cultured meat may be considered safer because it is not produced from animals raised in a confined space. There is no risk of an epidemic outbreak and no need for costly vaccinations against diseases like influenza. However, it is possible to argue that incidents may also occur with cells that live in high numbers in cultured meat incubators. There are uncertainties regarding the consequences of cultured meat on public health, as in vitro meat is still a new product. It may not be possible to control the cell culture process perfectly and some unexpected biological mechanisms may occur. For instance, given the significant number of cell multiplications, cell line dysregulation is likely to occur (as takes place in cancer cells). When in vitro meat is consumed, this may have unknown potential effects on the muscle structure and possibly on human metabolism and health.

Third, the abuse of antibiotics as a growth promoter in some countries and antimicrobial resistance are two significant problems in the case of livestock, which are absent in the case of cultured meat. The controlled environment and close monitoring can help stop any signs of infection. However, one cannot rule out that antibiotics would be added to prevent or stop early contamination.

Finally, it has been suggested that the nutritional content of cultured meat could be controlled in the production medium, which could be a highly desirable goal to improve nutrition standards. For example, the ratio between saturated fatty acids and polyunsaturated fatty acids can be easily controlled, and saturated fats can be replaced by other types of fats, such as omega-3 (although there is a risk of higher rancidity). However, new methods are being developed in conventional livestock farming as well to increase the content of omega-3 fatty acids in meat.

4.

## Animal welfare and economic aspects

In addition to evaluating environmental and human health aspects, cultured meat can also be evaluated for its impact on animal welfare, which is a matter of concern in some parts of modern society. Although the process of producing cultured meat needs animal muscle samples, the number of slaughtered animals can be reduced dramatically.

Furthermore, economic aspects must be considered in evaluating cultured meat with respect to sustainability. If conventional meat from livestock is progressively replaced with cultured meat, several services provided by livestock farming systems will be reduced or even disappear: besides supplying proteins for human nutrition, livestock provides essential income for rural populations, from meat, milk, eggs, wool, fibre, leather, and socio-cultural services such as when transhumance is attracting tourism, or when local products with a sense of terroir are protected with various labels (Chriki & Hocquette, 2020).

5.

## Regulation and norms

Another issue is uncertainty regarding regulatory frameworks. Cultured meat stands at the frontier between meat and non-meat (see Schneider for the US [2013] and Petetin for the EU [2014]). For example, regarding labelling, in April 2018, France banned the use of the terms “meat” and “dairy” in the communication about vegetarian and vegan products (as in “vegetarian-meat”). It has not been decided yet whether the term “meat” for cultured meat is authorised. In the US, several organisations are fighting over what cultured meat should be called, who tests for safety, and which governing body can regulate it (Chriki & Hocquette, 2020).

Finally, the nebulous status of cultured meat must be mentioned from a religious point of view. There is still some debate about whether cultured meat is Kosher or Halal (compliant with Jewish or Islamic dietary laws) (Chriki & Hocquette, 2020).

6.

## Costs

In their seminal study, Chriki & Hocquette (2020) remind that the first in vitro hamburger was produced in 2013 by Professor Mark Post, Maastricht University, for more than $300,000. This high cost was due to the fact that products and compounds traditionally used in medical science were used, and it was anticipated that the price would go down if production were to be scaled up. The cost of the cell culture medium used to produce cultured meat is currently quite high and, furthermore, may not be ecologically sustainable. However, researchers consider that raw materials from large-scale agricultural production could serve as inputs for cultivated meat. This would mean it might be possible to turn a waste product into food. This could be a positive contribution to circular economies, assuming this does not imply diverting agriculture waste from other uses, or that there would be a net benefit at the level of the system.

At the end of 2020, Mosa Meat[2], a Dutch company created by Post, announced the development of a serum-free medium. No cultured meat has yet been sold to consumers, and more applied research and experimentation are needed before an acceptable price level is reached. The Dutch government announced in April 2022 that it would invest 60 million euros in “cellular agriculture”[3] (Biotech Campus Delft, 2022).

In February 2021, Future Meats[4], a US company, announced that its technology had advanced to the point where it could produce a cultured chicken breast for US$7.50, and in June 2021, they opened the world's first lab-grown meat factory in Israel, where it produces cultured chicken for $3.90 per pound (Lavars, 2021). In comparison, the US average price between May 2021 and May 2022 for a pound of chicken was around $3.80, according to the US Bureau of Labor Statistics (n.d.). If the price difference for actual products becomes small, then serious considerations must be given to the other aspects previously mentioned in this paper.

[2] See mosameat.com/.
[3] See en.cellulaireagricultuur.nl/.
[4] See future-meat.com/.

7.

# Consumer acceptance

Many factors will strongly influence consumer acceptance. Some authors have demonstrated that consumers tend to strongly reject the name “in vitro” or “lab-grown” meat. This is confirmed in a study conducted by Siegrist et al. (2018), which concluded that participants have a low level of acceptance of cultured meat because it is perceived as unnatural, in contrast to so-called “vegetarian meat”, which consumers generally know is produced with plants. A recent survey indicates that potential consumers of cultured meat could be young, highly educated meat consumers who are concerned about the negative impacts of conventional meat on the climate and are somehow familiar with cultured meat (Bryant et al., 2019). However, it is unclear if consumers may associate cultured meat with vegetarian food in their search for alternative sources of proteins. In addition, more work is still needed to optimise the technical aspects of cultured meat production. Currently, it is also impossible to reproduce the diversity of meats derived from various species, breeds and cuts, which impacts consumer acceptance (Chriki & Hocquette, 2020). So in many ways, the jury is still out.

Regarding the specific question of what potential impact emerging technologies for cultured meat could have on environmental sustainability, researchers, technology developers and investors would be advised to consider prospective LCAs, which will become easier to carry out as actual products become available on the market.

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