EUROGROUP FOR ANIMALS

Cultivated meat FAQs:

A guide for further discussion

February 2022

Overview cultivated meat

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Overview cultivated meat

Burger by ***Mosa Meat***

1- Introduction

This document gives an overview of answers to the most frequent questions or concerns about cultivated meat. Since its technological development is an ongoing process and the insights of its impact are still growing, this overview should be considered as a living document.

The major purpose of developing cultivated meat (or cultured meat or cell-based meat) is to provide a product that is identical to conventional meat. The narrative of cultivated meat advocates can be summarized as follows: **people will continue to eat meat, whether we like or not. In order to reduce the impact on animals and the environment –and to secure our food supply– we need to produce meat differently.** There is substantial arguments to support that narrative. To begin with, worldwide meat production and demand has never been as high as today. From the 1960s till near 2020 the worldwide meat volume has more than quadrupled.[1] Although the production of all major meat types have been increasing, poultry meat has the most spectacular rise: the annual number of slaughtered chickens reaches 70 billion, on a total of approximately 73 billion animals per year.

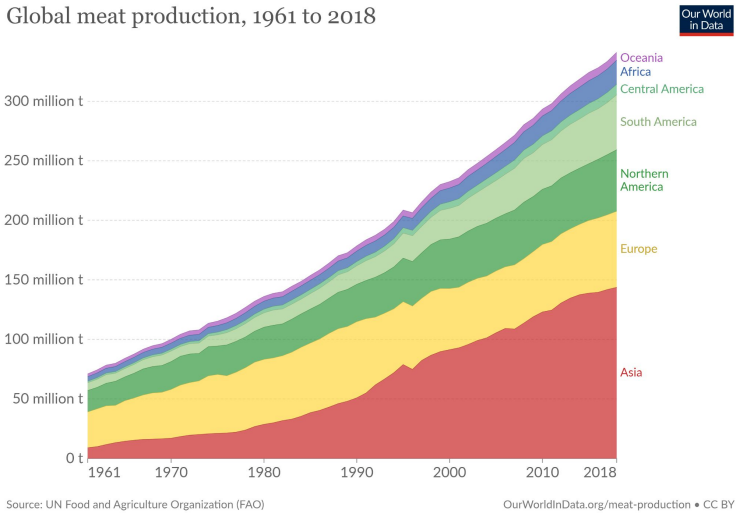


Figure 1*: Global meat production over time*

In particular the production growth in Asia could be called spectacular, but the increase has taken place on all continents. Moreover, the Food and Agriculture Organization (FAO) projects that world meat production will double by 2050.[2] Most of the increase is expected in developing countries, but even forecasts for the European continent are reason for concern: the overall meat consumption in the European Union is expected to decrease only from 69.3kg per capita in 2018 to 68.6 kg in 2030.[3]

[1] https://ourworldindata.org/meat-production#global-meat-production
[2] http://www.fao.org/ag/againfo/themes/en/meat/home.html
[3] European Commission. EU Agricultural Outlook. For markets and income 2018-2030.

Poultry meat consumption is even still expected to increase. However, this decline is largely compensated by higher exports due to the worldwide meat demand and European pork and poultry meat production is expected to increase further.

*Chicken sandwich by **SuperMeat***

The quest for cultivated meat includes the development of a product identical to meat as humans have always known it. If cultivation and slaughter deliver the same, why choosing a cruel product with a large environmental impact? Pat Brown, CEO of ***Impossible Foods***, claims that cultivated meat is unnecessary since plant-based alternatives might meet the demand for alternatives.[4] However, a report by consultancy AT Kearney confirms the idea of replacing meat by real meat.[5] The company has spoken with numerous experts from the food industry and concludes that cultivated meat in particular will be the major challenger in the food world. The analysis includes that classic vegan and vegetarian products have conquered their place, but do not convince the majority of consumers. This is due to the fact that meat is experienced as unique and tasty. Novel vegan products, like the ones of ***Impossible Foods***, approach meat more closely, but even more is expected from cultivated meat. The potential of cultivated meat would in the future surpass that of plant-based substitutes simply because it will have all the properties of conventional meat.

The report of AT Kearney predicts that global meat consumption will increase annually. However, the volume of conventional meat will decrease year after year as the substitutes will get better and more popular. The first expected revolution comes from novel vegan products. But when cultivated meat is ready for large scale production, it would overtake plant-based alternatives.

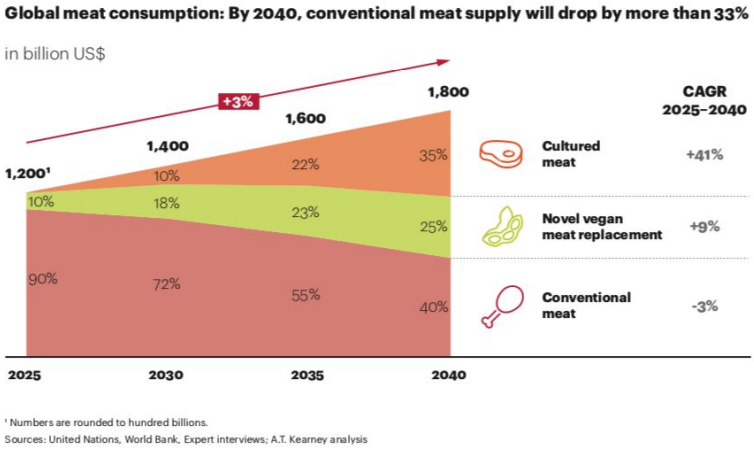


***Figure 2**: Forecast of the global meat market, according to the AT Kearney report*

Although the report is merely an estimation, it shows that food experts see a large potential in cultivated meat: the demand for both categories together could surpass the one for conventional meat by 2040. **Cultivated and plant-based meat are complementary, rather than competitors.** This is also shown by research on consumer attitudes. A study in Belgium commissioned by GAIA, for instance, demonstrates the

[4] Pat Brown has stated this multiple times, see for example https://thespoon.tech/sks-2020-impossible-foods ceo-on-cell-based-meat-its-never-going-to-be-a-thing/
[5] AT Kearney. How will cultured meat and meat alternatives disrupt the agricultural and food industry? (2019)

need for multiple approaches with respect to meat alternatives.[6] Almost half of respondents in the study indicated a positive attitude towards either cultivated or plant-based meat, but not both. Vegetarians are more likely to be positive towards plant-based products, while carnivores are more positive about cultivated meat. So different alternatives can helpfully co-exist to counter the ever increasing demand for meat.

Below in the document, several key aspects are discussed. The major advantage of cultivated meat is its disruptive potential, to reduce industrial farming dramatically and to remove animal suffering. The biggest challenge, however, is the upscaling of the production: although the first products are already commercialized, the technology is still in an early stage. The coming decade will determine to what extent cultivated meat will meet the expectations.

2- What is the actual status of the cultivated meat technology/landscape and when will it be available?

Short answer: Cultivated meat exists on an experimental level, not fully on a commercial level yet. The market introduction will happen slowly, from specialized restaurants pretty soon to large-scale commercialization after 2030. In December 2020, the first product (cultivated chicken meat) received an approval by the Singapore government to be commercialized.

Long answer: The development of cultivated meat already has a history. The first scientific advocate was Willem van Eelen (1923-2015), a physician and researcher that got inspired in the 1950s by stem cell technology for burns healing. Van Eelen spent his lifetime studying and thinking about the subject and was the first to file for a patent. Only in the late 1990s his ideas got considered as visionary and inspirational. In the early 2000s, two projects were carried out to produce cultivated tissue experimentally for food purposes, one funded by NASA and another by a team of bio-artists. In 2005, the Dutch government initiated the funding of some research projects on the topic. Cultivated meat still remained a theoretical concept until the first hamburger was developed in 2013 by Mark Post, financed by Sergey Brin (costing 250,000 dollars). This was still a purely academic project; in 2015, Mark Post founded the company ***Mosa Meat*** to develop cultivated meat for commercial purposes. In that same year, other pioneers started their research activities: ***Memphis Meats*** and ***Eat Just*** (US California), ***Integriculture*** (Japan) and ***SuperMeat*** (Israel). Since then, the number of companies entering the cultivated meat space grew exponentially. By the end of 2019, around 60 companies have emerged, which may be an underestimation, since it is difficult to do a follow-up worldwide.[7] In addition to the first hamburger in 2013 and the emergence of the first companies in 2015, other milestones in the field include:

- **2016:** ***Memphis Meats*** presents the first cultivated meat balls (at around 1,000 dollars per ball)
- **2017:** first Series A fundraising rounds

[6] Bryant & Sanctorum. Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years. Appetite (2021)
[7] State of the Industry Report: Cell-based Meat. Good Food Institute (2018)

2020: The first Series B raises more than 230 million dollars and first pilot scale facilities come online

Forecasting the future is harder than summarizing the history. During the presentation of the cultivated meat hamburger in London, the worldwide press was present to interview Mark Post. During some interviews he forecasted that cultivated meat would have been available by 2020. Also Josh Tetrick, CEO of ***Eat Just*** and one of the pioneers in this field, announced in 2017 (and repeated that several times in 2018) that by the end of 2018 he would have been ready to go to the market.[8] Obviously, they get reminded regularly about these prognoses by the opponents. In December 2020, however, the first commercialization of a cultivated chicken product got approved in Singapore.[9]

Thin Steaks by ***Aleph Farms***

Leaders of the cultivated meat space have become much more cautious in their prognosis. But there is more going on than just a wrong forecast. There are two major challenges for entering the market: upscaling of the production and the regulatory framework. The issue is no longer about creating prototypes, that hurdle has been overcome (see below to know more about the types of meat that have been cultivated already), as illustrated by the tasting events that these companies organize for journalists and NGOs.[10] Josh Tetrick insists on the fact that his company is truly ready, at least to deliver small amounts to a very selected group of restaurants. However, the regulatory framework and especially the lack of legal clarity in the US continues to slow down market introduction. In the European Union, clarity is available through the Novel Food Regulation and the first application is to be expected in 2021. Since some countries, like Singapore, have less stringent procedures concerning food technology, these are also coming into the crosshairs for market introduction.

Finally, the large scale commercialization of cultivated meat will not take place instantly. The process will include several steps, as Josh Tetrick explains regularly in the media and during symposia, based on his own experience with novel vegan products.[11] From prototypes to large scale commercialization, there are several intermediary stages where cultivated meat is to be consumed. A first stage includes the prototype leaving the laboratory and getting launched, in a single restaurant for instance. In the second stage, multiple restaurants and smaller retailers offer cultivated meat. Phase three means that a company's products are widely available through retail; in the final phase, products are available everywhere and at low cost. Based on discussions with several company leaders and talks during symposia, this last phase will not come into effect before 2030.

Some companies are entering now the first stage of offering prototypes to a selected

[8] There are multiple articles and interviews about this forecast, he also announced it during symposia
[9] www.goodmeat.co and multiple media coverage
[10] GAIA visited Aleph Farms in September 2019 and brought 6 Belgian journalists to taste cultivated steak.
[11] An example is https://thespoon.tech/eat-justs-josh-tetrick-on-the-4-phases-of-bringing-cell-based-meat-to the-masses/

group of consumers, although they still need to complete regulatory approval. In August 2020, cultivated bacon developer ***Mission Barns*** announced that consumers could sign up to be one of 50 to 100 selected participants for public tasting.[12] Two San Francisco Bay area restaurants will be using the cultivated bacon to prepare meals for the participants. ***Mission Barns*** aims at introducing its product publicly, but also would like to collect feedback to improve. In November 2020, Israeli company ***SuperMeat*** announced the opening of a new restaurant in Tel Aviv called The Chicken.[13] The chicken meat on the menu is grown from cells in an adjacent pilot plant and it has the capacity to produce several hundred pounds of chicken meat per week. Again, the aim of the initiative is to collect feedback from consumers, who have to sign a waiver since the food product is not approved yet by the authorities.

3- Are animals used to produce cultivated meat and how?

Short answer: The only stage where animals are necessarily involved is when cells need to be obtained. Animal serum to grow cells is not to be used, all cultivated meat companies claim using animal-free media to grow cells. Despite mentioning the use of serum in the application for regulatory approval in Singapore, ***Eat Just*** claims that it is now ready to use a plant-based medium.

Long answer: There are two possible areas of concern where animals might enter the cultivated meat process: **1) collecting cells** and **2) feeding or structuring compounds.**

Cell sources

Overall, there are two possible methods for obtaining cultivated meat: primary cells isolated from the tissue of an animal or using cell lines.[14] The first option involves a biopsy from a donor animal that technically can be alive or recently slaughtered. Companies often refer to taking cells – under local anesthesia – from living herds.[15] The second option is based on a method that decreases the dependency on tissue samples dramatically. Cell lines are 'immortalized' and often include the use of embryonic stem cells. ***Aleph Farms*** uses cells from an embryonic structure that is derived through similar techniques as in animal agriculture today, such as embryo transfer.[16] Theoretically, no repeated cell collections are needed using this method, but keeping the stem cells in a stable condition is challenging.

Serum and other animal compounds

cells in vitro. Even during safety routine screenings of food products, to detect for contami-

[12] https://www.forbes.com/sites/jennysplitter/2020/08/03/mission-barns-bacon-tasting/#7b3700f83c9b
[13] https://www.fastcompany.com/90572093/at-the-first-lab-grown-meat-restaurant-you-can-eat-a-cultured chicken-sandwich
[14] Stephens et al. Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. Trends in Food Science and Technology (2018)
[15] For example https://www.mosameat.com/technology
[16] This information was provided during the Cultured Meat Symposium in San Francisco, 2020

nants, serum is standard material for using bioassays. The serum is nutrient rich and contains growth factors that enhance the proliferation of cells. Despite the fact that obtaining serum involves much animal suffering – blood of a living unborn fetus is slowly drawn from the heart and this might take up to five minutes[17] – its use in laboratories was never really questioned, until the idea of cultivated meat got mainstreamed. It would be absurd to solve an ethical issue (conventional meat production) with another ethically questionable practice (using bovine fetal serum to grow meat). Therefore, all companies state that they do not want to use serum.[18]

There are also other reasons, in addition to ethical ones, to exclude it. One is about food safety: the risk of contamination by viruses, bacteria of fungi is higher with animal-based media than with animal free media, so for manufacturers there is a technical rationale behind avoiding the use of animal products. More in general, commercialization of cultivated meat would be at stake using serum: consumers that are positive about cultivated meat according to research (see below about consumer acceptance), are aware of ethical concerns and they would very unlikely accept it, knowing that animal suffering is involved after all. An even more decisive argument is an economical one: fetal serum is obtained for laboratory purposes, which happens on a much smaller scale than the production of meat. The availability of serum is far too small and expensive to feed a meat production process. 500 ml of serum currently costs as much as 1,000 US dollars. Moreover, the serum is a by-product of the slaughter of pregnant cows and since cultivated meat is to replace conventional meat (partially), the availability is even supposed to decrease. In fact, cultivated meat has highlighted the widespread use of serum in laboratory facilities and creates an opportunity to develop plant-based and cruelty-free substitutes.

*Bacon by **Higher Steaks***

Nevertheless, it is challenging to develop good serum-free alternatives. For biopharma applications there have been some serum-free media for a while, but pricing of pharmaceuticals is rather value based and production costs are not as important as in the food industry. Most cultivated meat companies appear to develop in-house formulations that are fit-for-purpose and should be food-grade, possibly in collaboration with companies like Merck. The formulation of serum-free media include basal media with **1) water and salts, 2) compounds like glucose, amino acids and vitamins that are produced through fermentation, chemical synthesis or processing (hydrolysis of crops or fungi)** and **3) added factors through precision fermentation (proteins like growth factors)**. At this point there is little transparency on the exact formulation, since it is part of the intellectual property that is protected. And since these new growth media are not available yet on a large scale, it

[17] Jochems et al. The use of fetal bovine serum: ethical or scientific problem? Alternatives to Laboratory Animals (2002)

[18] All companies stress in the media, during symposia and during personal discussions that the use of animal serum is out of the question.

is expensive and contributes highly to the cost of cultivated meat production. Moreover, it seems that during the development process, fetal serum might be used in the lab, for instance to compare effectiveness between animal free medium and serum.[19]

Serum-free media are also commercially available and used in the pharma industry. The team of Mark Post has published a scientific article on the efficacy of these media, compared to fetal serum.[20] In this study, seven commercially available alternatives were tested and cell growth was monitored for six days. Three animal-free supplements, which serve to promote cell growth, were also tested. Three of the seven commercially available alternatives produced significant cell growth, but none turned out to be particularly nutritious for cells. The supplements tested were inadequate and hardly promoted the growth of the cells. In a recent paper published in the journal Nature Food, leading cultivated meat brand ***Mosa Meat*** revealed how they managed to replace Fetal Bovine Serum and achieve muscle differentiation without genetically modifying the cells in any way (for more info on these step, see **Figure 3 on page 13**).

Eat Just received regulatory approval from the Singapore authorities for 'chicken bites', but the application included the use of animal serum. CEO Josh Tetrick states that the application dates from 2 years before, and by then the plant-based medium to be used was not ready yet. ***Eat Just*** claims the plant-based growth medium is ready for commercialization. In the cultivated meat community, there is discussion about this. **Was it good to move as fast as possible or would it have been better to perfect first the plant-based alternative for serum, prior to filing application?**

Fetal serum is not the only possible animal compound involved in cultivated meat development. The most important example is the 'scaffold', the structure that carries the cells. To mimic the original environment and 3D structure in the body, the scaffold is necessary for cell adhesion and tissue development. Animal-based structures, like collagen and gelatin, show good properties for parameters like cell adhesion. However, as is the case for serum, companies are working on animal-free substitutes. ***Aleph Farms*** seems to work with a scaffold based on textured soy.[21] However, there are multiple options in the running, including mycelia and starch.[22]

*Thin Steaks by **Aleph Farms***

[19] Since fetal serum is standard, its use is required to replace it. Several scientific articles mention the use of fetal serum in the research phase
[20] Kolkmann et al. Serum-free media for the growth of primary bovine myoblasts. Cytotechnology (2020)
[21] Ben-Arye et al. Textured soy protein scaffolds enable the generation of three-dimensional bovine skeletal muscle tissue for cell-based meat. Nature Food (2020)
[22] Post et al. Scientific, sustainability and regulatory challenges of cultured meat. Nature Food (2020)

4- What kind of products are already cultivated and what else could be potentially cultivated?

Here is a list of the most active companies and the kind of products they are developing. All of them already made prototypes:

Company Name	Country of Origin	Type of cultivated meat
Aleph Farms	Israel	**Beef (steak)**
Because Animals	Canada	**Mouse and rabbit (pet food)**
BlueNalu	US (California)	**Fish (multiple species)**
Cubiq Foods	Spain	**Chicken (fat)**
Finless Foods	US (California)	**Bluefin tuna**
Future Meat Technologies	Israel	**Chicken**
Gourmey	France	**Foie gras**
Higher Steaks	UK	**Pork**
Integriculture	Japan	**Foie gras**
JUST	US (California)	**Chicken**
Meatable	Netherlands	**Beef**
Memphis Meats	US (California)	**Beef, chicken, duck**
Mission Barns	US (California)	**Duck, chicken, pork (fat)**
Mosa Meat	Netherlands	**Beef**
Mzansi Meat	South-Africa	**Beef**
New Age Meats	US (California)	**Pork**
Peace of Meats	Belgium	**Duck (fat), foie gras**
Shiok Meats	Singapore	**Shrimp**
SuperMeat	Israel	**Chicken**
Vow	Australia	**Kangaroo, alpaca, goat, lamb**
Wild Earth	US (California)	**Mouse (pet food)**
Wild Type	US (California)	**Salmon**

The possibilities are nearly endless. Companies also aim for less obvious products like leather and silk. The Australian start-up ***Vow*** even develops a library of cell lines for more exotic species like lion. A criticism may be that this could create an unwanted demand for slaughter meat from certain species. On the other hand, there is already a great demand for game meat (think of wet markets and bush meat), both legal and illegal. Cultivated meat might also offer a partial solution for this.

Foie Gras by ***Gourmey***

Bacon by ***Higher Steaks***

5- How does it work? How long does it take to produce? How much can you produce? And how scalable is it?

Short answer: The upscaling of the technology is the challenge of the coming decade. Due to the exponential growth process of cells, the prospect is that cultivating meat will be much faster than conventional meat production.

Long answer: Figure 3 (see next page) shows in summary the different steps in the cultivated meat process.[23]

Since mass production of cultivated meat is not available yet, it is difficult to give exact numbers on production volume and time. However, there are some straightforward calculations available, mostly provided by cultivated meat companies.

Mosa Meat states that it takes about 10 weeks to make a hamburger.[24] And since cell growth is exponential, theoretically it could take 12 weeks to produce 100,000 hamburgers during production on industrial scale. In comparison, it takes 18 months to raise cattle for slaughter, which only delivers approximately 1,500 burgers. From one biological sample of one gram it is possible to produce 10,000 kilograms of beef, reaching a multiplication factor of 10 million. That would mean that 150 cows could sustain the current meat demand. Again, this is theoretical and not empirical. It is very possible that the final process will be slower, will have a lower yield or will depend on technological aspects such as the reactor and scaffolds. But the gap between current meat production and the prospective cultivated meat process is so large that is safe to conclude that producing cultivated meat will become much faster than through raising and slaughtering animals.

*Pork belly by **Higher Steaks***

[23] Figure 3 is derived from the State of the Industry Report on Cell-based Meat (2019) by the Good Food Institute
[24] See website of Mosa Meat - Frequently Asked Questions

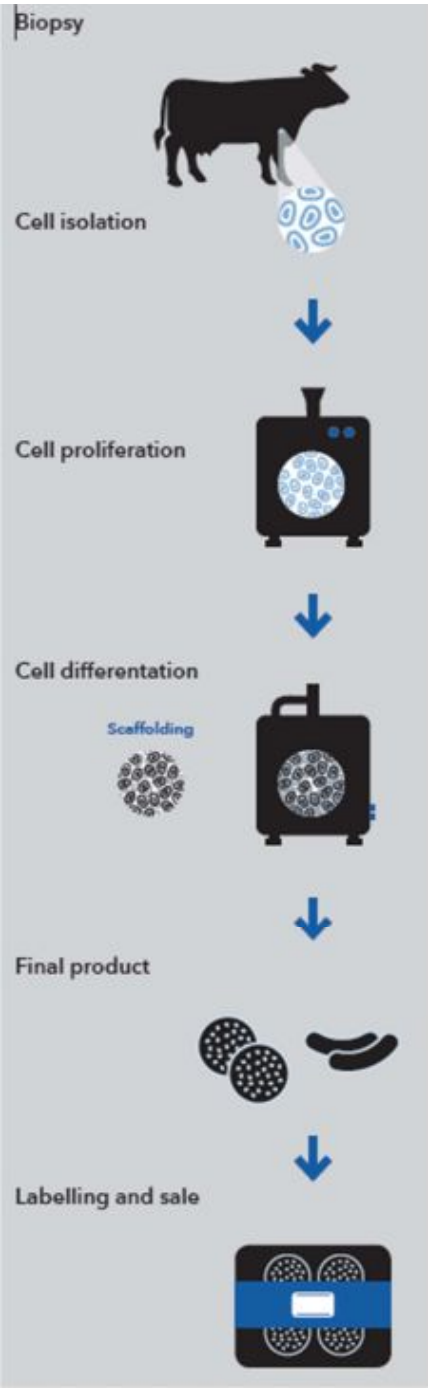


Figure 3: *The cultivated meat process*

Biopsy
A biological sample is taken, for instance through a biopsy from a muscle of interest (to obtain myosatellite cells).

Cell isolation
The right cell type(s) are selected and isolated, becoming the master cell bank. The master cell bank serves as a basis to develop working cell banks that can be used for further cultivation.

Cell proliferation
To start production, a vial from a working cell bank is taken and the cells are multiplied in a series of bioreactors of increasing volume. This so called 'seed train' is a small-scale proliferation. Next, the cells are moved to the largest proliferation tank, where they multiply until maximum cell density is reached.

Cell differentiation
A certain percentage (for instance 50 percent) is removed from the proliferation reactor and seeded onto a scaffold in a perfusion reactor for differentiation and maturation.

Final product
The matured cells are harvested from the perfusion reactor, washed and prepared for further processing and manufacturing to a final product.

Labelling and sale
The final product is labelled according to legislation.

6- Is cultivated meat truly 'meat'? What about labelling? How will consumers be able to distinguish between cultivated animal products from animal sourced products?

Short answer: Yes, as long as cultivated meat has the same characteristics and nutritional value as conventional meat.

Long answer: The name 'meat' is culturally and individually determined. In the past, meat used to be rather a general term for simply food. And, even today, asking consumers living in the same region whether certain products are meat or not, would provide a variety of answers. A steak is definitely meat, but nuggets and hybrid products could be a matter of debate. Some people do not even consider chicken meat as true meat.

Even legislation is not uniform on the definition on meat. According to the US Code of Federal Regulations, muscle tissue of tongue, diaphragm, heart and esophagus are considered as meat; lip, snout and ears are not. The European Food Hygiene Law uses an entirely different definition: all edible parts of animals, including blood, are considered as meat (but for an exhaustive list of animals).

There is, however, a modern scientific definition of meat. The American Meat Science Association published an article on the question whether cultivated meat is truly meat or not.[25] In the abstract of the article, the following is stated: **'Meat is the edible tissues from an animal consumed as food.'** This broad definition is specified further in the article:

'For the American Meat Science Association (AMSA), meat is skeletal muscle and its associated tissues derived from mammalian, avian, reptilian, amphibian, and aquatic species commonly harvested for human consumption. Edible offal consisting of organs and non-skeletal muscle tissues also are considered meat.'

This means that all kinds of tissues of all kinds of animals are meat, except for species like snails and insects. On the question about cultivated meat, the AMSA came to the following conclusion:

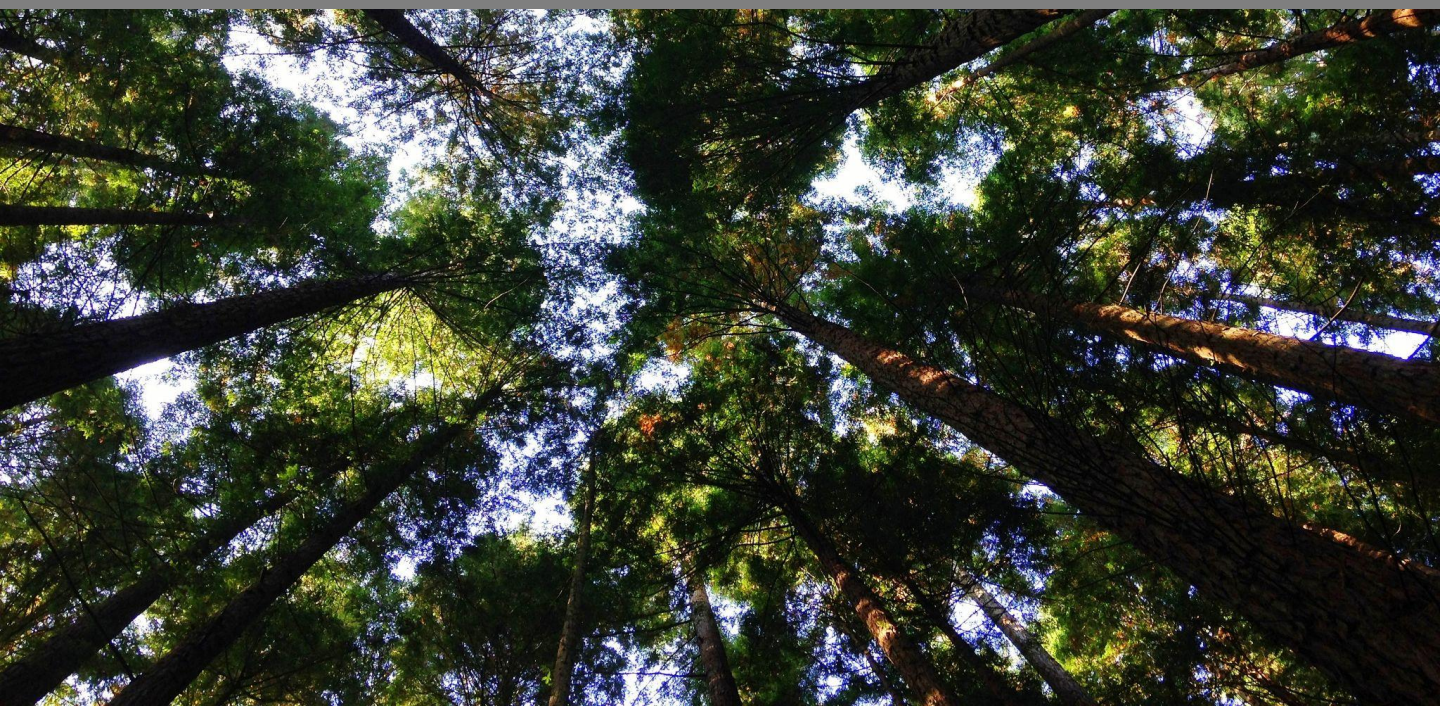
'Ultimately to be considered meat, in vitro meat must be originally sourced from an animal cell, be inspected and considered safe for consumption, and be comparable in composition and sensory characteristics to meat derived naturally from animals. In particular, the essential amino and fatty acid composition, macro- and micronutrient content and processing functionality should meet or exceed those of conventional meat.'

Obviously, cultivated meat is derived from animal cells and it needs approval for consumption. The challenge is to make it as (or even more) nutritious as its conventional counterpart. Although companies claim on a regular basis that their products do have the same composition as conventional meat, they will need to prove this by publishing their data and accept independent analyses.

[25] Boler & Woerner. What is meat? A perspective from the American Meat Science Association. Animal Frontiers (2017)

As we see for plant-based meat and dairy, the debate about definitions is mainly political. In October 2020, the European Parliament rejected amendments that proposed a ban on the use of meat denominations for plant-based products. However, further restrictions on plant-based dairy labels, were voted.[26] We might expect a strong lobby force against recognizing cultivated meat as 'meat', once it enters the market. An important argument from that lobby probably will be the fact that the origin of meat is important information for consumers and labelling cultivated meat as 'meat' might confuse. On the other hand, if a cultivated and conventional product are truly identical, allergen concerns make it imperative to inform consumers that it is actually meat, and that the product is labelled accordingly. The debate about the legal nomenclature of cultivated meat is still at an early stage.

7- What is the expected environmental impact of cultivated meat?



Short answer: Cultivated meat has a lower environmental impact than conventional meat, especially concerning land use. However, the type of energy used in the bioreactor to cultivate the cells determines largely its climate impact.

Long answer: The very first scientific article on the environmental benefits from cultivated meat was published by Tuomisto & Teixeira de Mattos (2011).[27] The results are very encouraging:

- **7 - 45%** less energy consumption than (European) beef, pork or mutton (although poultry still scored better on this parameter).
- **78 - 96%** less greenhouse gases than beef, pork, mutton or poultry - **99%** less land use than beef, pork, mutton or poultry.
- **82 - 96%** less water use than beef, pork, mutton or poultry.

[26] https://www.eurogroupforanimals.org/news/meps-reject-veggie-burger-ban-support-dairy-ban
[27] Tuomisto & Teixeira de Mattos. Environmental impacts of cultured meat production. Environmental Science and Technology (2011)

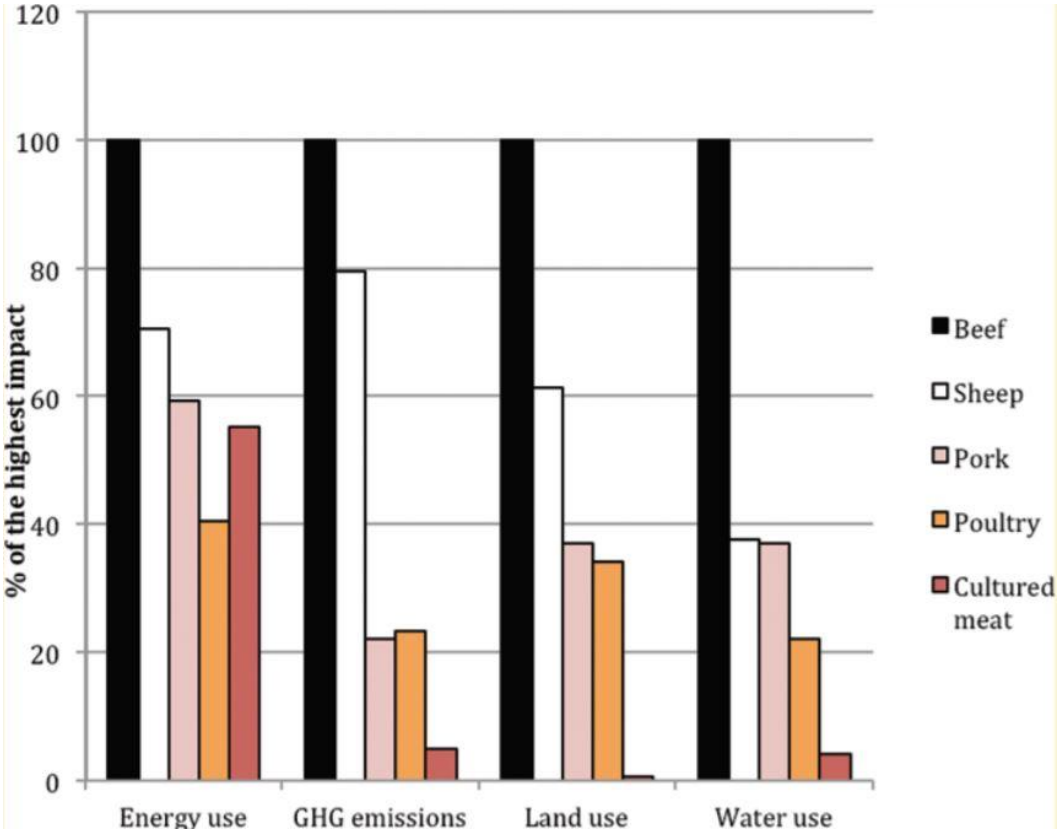


Figure 4: *Environmental impact of different meat types according to Tuomisto & Teixera de Mattos (2011)*

The research has a high uncertainty, since there was/is no large scale production process for cultivated meat yet and life cycle analyses are based on many assumptions. The assumptions could be beneficial to cultivated or conventional meat, the authors tried to equilibrate well. However, there are three major issues with this first assessment:

- the use of a Cyanobacteria hydrolysate as a source for nutrients, which would be environmentally friendly but not an obvious technical option
- the absence of an energy source to heat/cool the reactor
- taking rainwater into account for water consumption of conventional meat

Although the results above are still cited often, the authors made a kind of follow-up amendment through a new publication (not peer reviewed).[28] They made new calculations based on more likely assumptions: **(1) the use of plant-based media (wheat or corn) instead of Cyanobacteria, (2) remodeling the bioreactor (especially adding the use of heat)** and **(3) considering only the direct water consumption in calculating the water footprint.** These adaptations have an impact, but, according to this study, cultivated meat still scores very well on environmental parameters.

[28] Tuomisto et al. Environmental impacts of cultured meat: alternative production scenarios. Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (2014)

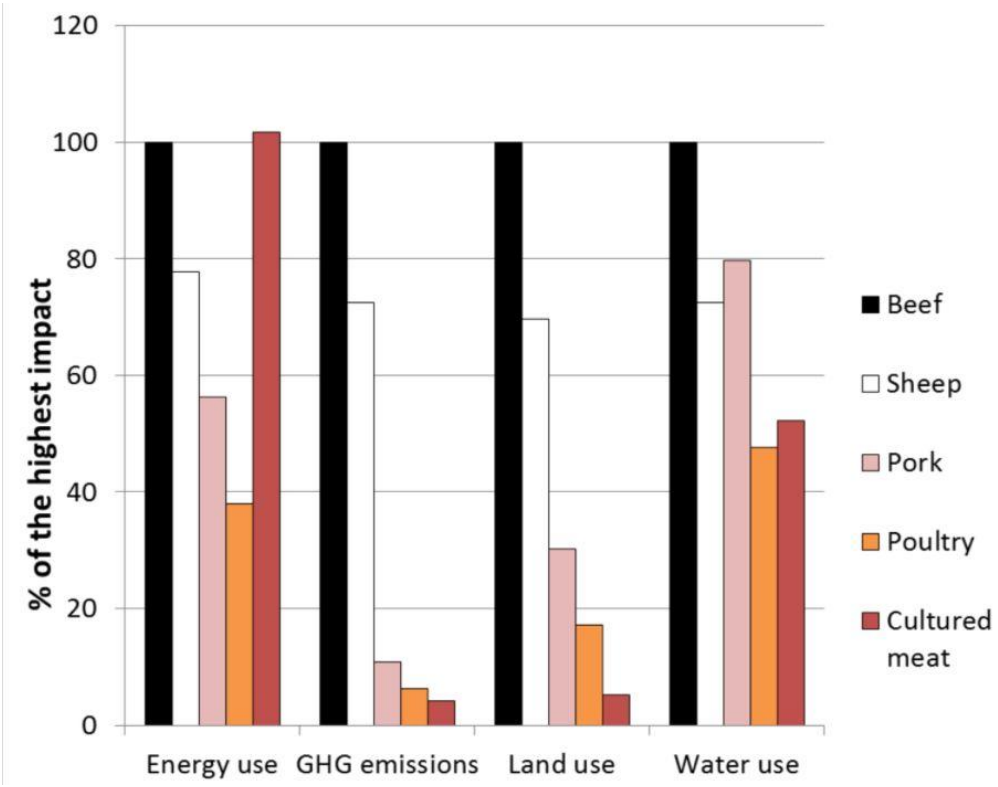
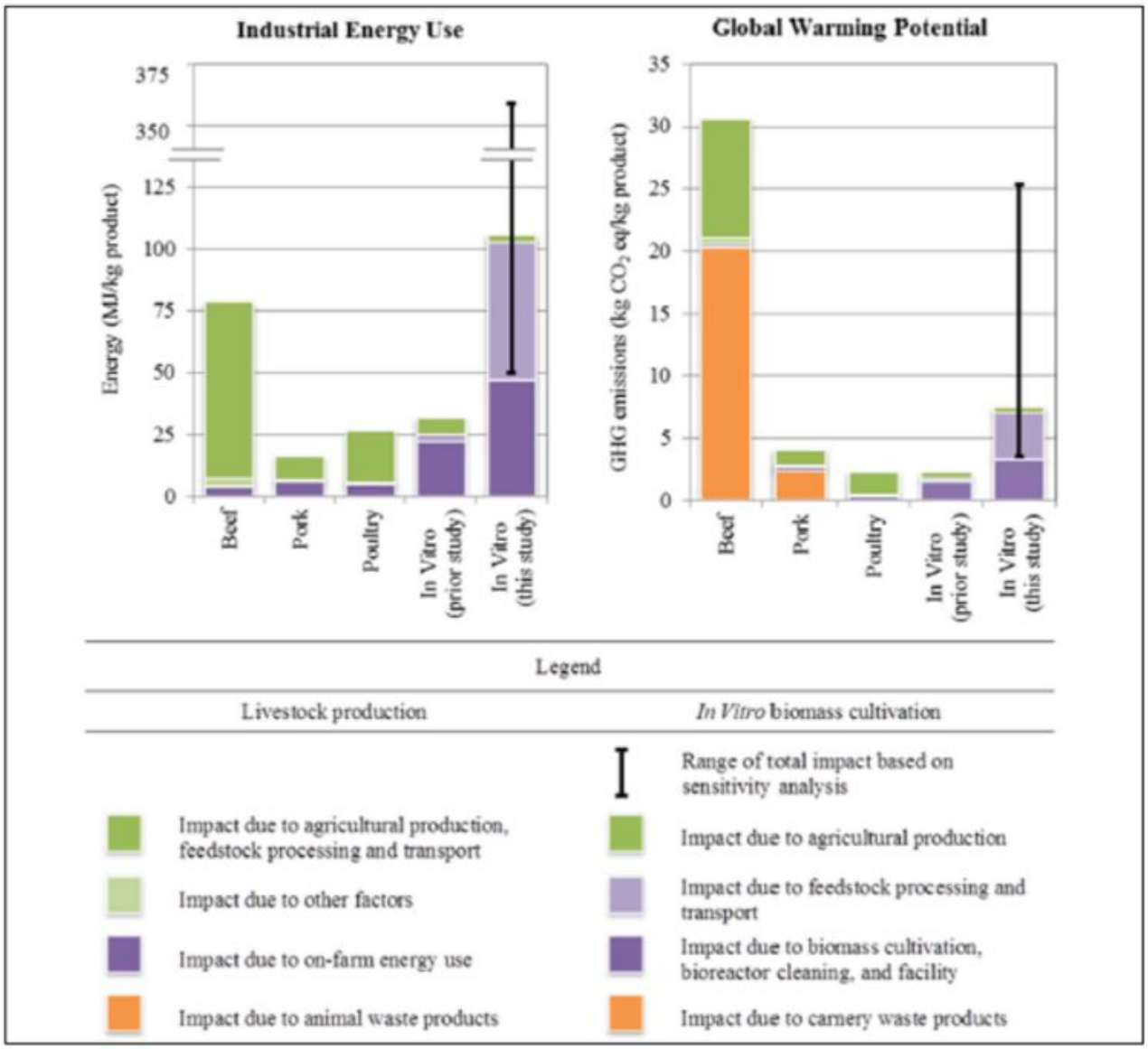


Figure 5: *Environmental impact of different meat types, according to Tuomisto et al. (2014), so with different assumptions and conditions compared to Tuomisto & Teixeira de Mattos (2011)*

A more thorough research was done by American researchers.[29] A benefit of their approach is that more details are revealed compared to the former study. A downside is that the lack of upscaling is even more evident and the results become less beneficial for cultivated meat.

The most striking result is the high energy consumption. The reasons are mainly the production of medium and the use of the bioreactor. However, greenhouse gas emissions are still much lower than for conventional beef, however with a large uncertainty. A lower energy use but higher global warming potential for conventional meat has to do with N2O and methane from the animals and their manure, which cause a greater greenhouse effect than CO2. Again, land use is minimal, even lower than for chicken. The result for eutrophication is also positive compared to conventional meat. The study points out that nutrient use is more efficient for cultivated meat, since redundant animal tissue is not produced (like bones and organs). It is important to emphasize that the conditions for the cultivated meat calculations in this study are not favorable. For example, greenhouse gas emissions for cultivated meat were calculated on the basis of an energy mix where one third of the production would come from coal, which is the most polluting energy source.

[29] Mattick et al. Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States. Environmental Science and Technology (2015)


Industrial Energy Use
Energy (MJ/kg product)
375
350
125
100
75
50
25
0
Beef
Pork
Poultry
In Vitro (prior study)
In Vitro (this study)
Global Warming Potential
GHG emissions (kg CO_2 eq/kg product)
35
30
25
20
15
10
5
0
Beef
Pork
Poultry
In Vitro (prior study)
In Vitro (this study)
Legend
Livestock production
In Vitro biomass cultivation
Range of total impact based on sensitivity analysis
Impact due to agricultural production, feedstock processing and transport
Impact due to other factors
Impact due to on-farm energy use
Impact due to animal waste products
Impact due to agricultural production
Impact due to feedstock processing and transport
Impact due to biomass cultivation, bioreactor cleaning, and facility
Impact due to carnery waste products

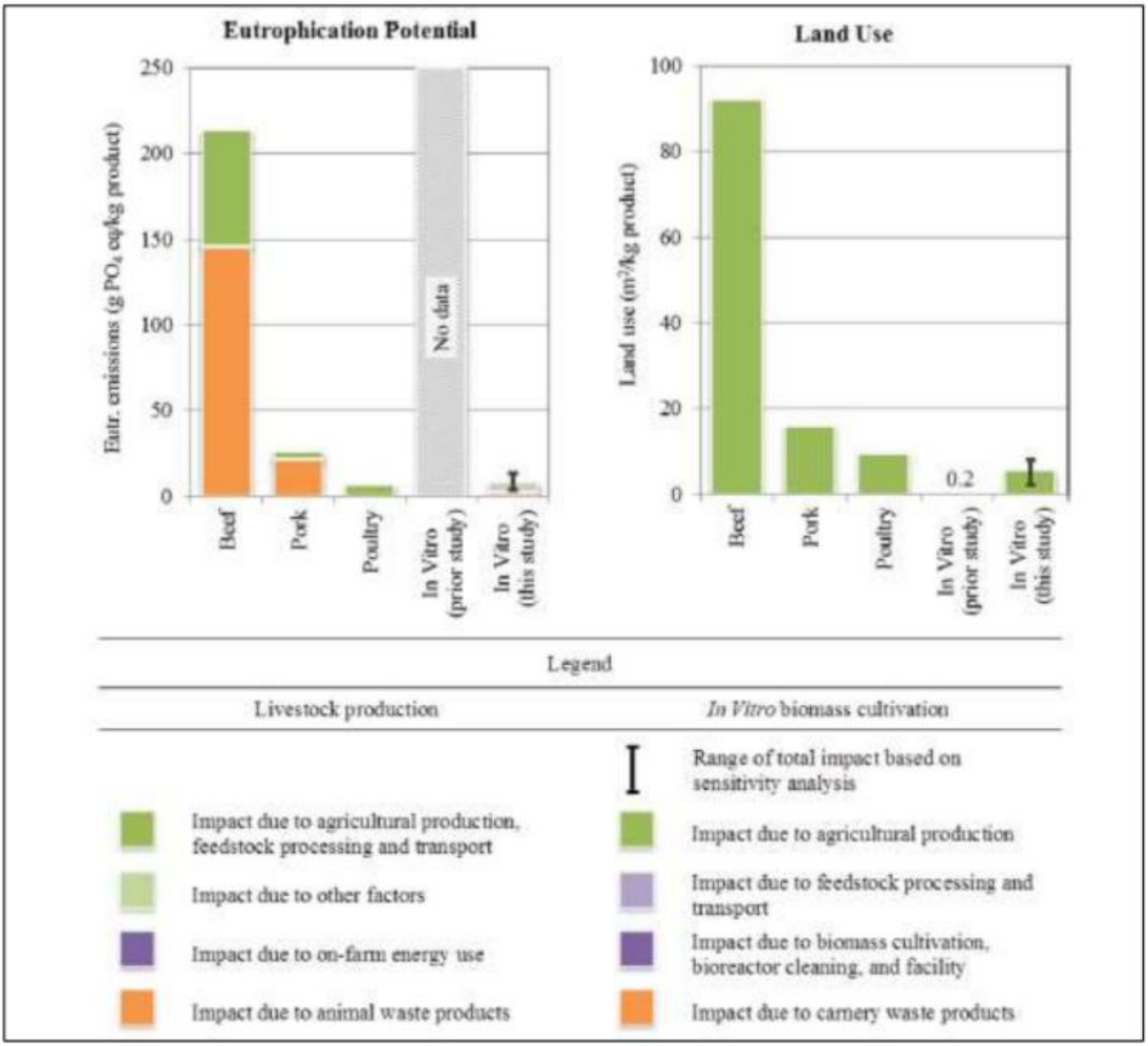


Figure 6 and 7: *Environmental impact of different meat types, according to Mattick et al. (2015)*

The following research has gotten the most attention, which is quite problematic.[30] The study focuses on greenhouse gas emissions during beef production, conventional or cultivated. However, there are methodological problems because of the considered timespan and that it does not take the shift away from fossil fuels into account. Former studies calculated CO2 equivalents, which are based on the global warming potential over 100 years and is the scientific standard (by the UN Intergovernmental Panel on Climate Change for instance). The authors of this study, on the other hand, used the impact over 1000 years and calculated on the basis of simple modeling what the impact would be of conventional and cultivated meat over that period. The impact is high: conventional meat production exhausts CH4 and N2O (direct emissions from animals and manure) that have a high global warming potential for 100 years; but CH4 and N2O have a shorter lifespan than CO2 and therefore have less impact over 1,000 years than over 100 years. Cultivated meat would only emit CO2 because industrial energy is consumed (assuming that fossil fuels are used). CO2 has a lower global warming potential than the other gases, but it is more stable and its presence in the atmosphere lasts longer (so it becomes more important over a period of 1,000 years). It might be interesting to look at a perspective of 1,000 years. However, it is problematic to consider industrial energy production based on the present fuel mix. Since the authors use the data of former studies (like the one of Mattick et al., 2015, which considers an energy use that consists of 33 percent of coal), this becomes very relevant. The European Union aims for a total decarbonization by 2050, therefore it is very unlikely that industrial energy will depend for 1,000 years on fossil fuels.

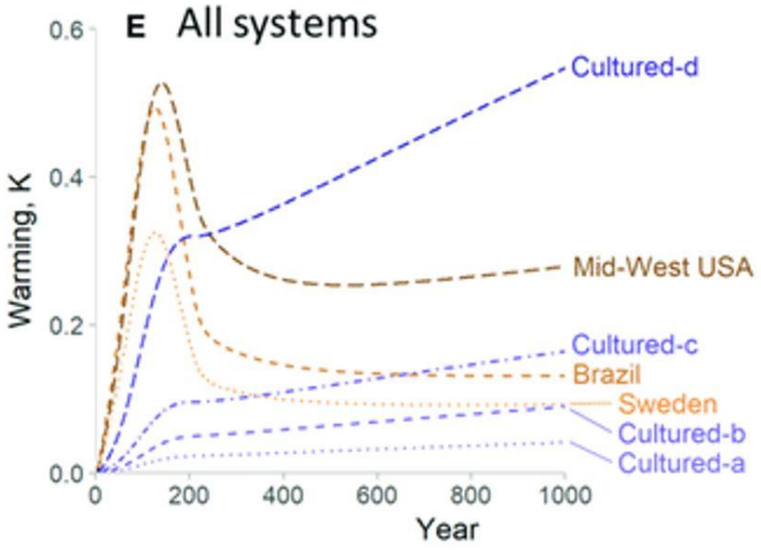


Figure 8: *Global warming potential for different meat production systems, according to Lynch and Pierrehumbert (2019)*

Interestingly, even with these unfavorable conditions, cultivated meat scores well. Two scenarios even score better than the 'Sweden' model, which is based on an organic farm that has the lowest footprint for conventional energy, according to the modeling. Only one scenario scores worse than all conventional meat production systems: 'Cultured-d', which is based on the very unfavorable conditions by Mattick et al. (2015). This is a worst case scenario based on 1,000 years of fossil fuel use. This unrealistic Scenario determined (and still determines) the headlines about the study. Considering a timeframe of 100 years, even by using fossil fuels, 'Cultured-d' scores better than the orga-

[30] Lynch & Pierrehumbert. Climate Impacts of Cultured Meat and Beef Cattle. Frontiers in Sustainable Food Systems (2019)

nic 'Sweden' model.[31]

In conclusion, cultivated meat seems to score much better than conventional meat in terms of environmental impacts, although there are still multiple uncertainties. Land and water use are particularly important factors in defense of cultivated meat. Cultivated meat even competes with plant-based products considering these parameters. Indirect effects can further increase the positive impact of cultivated meat: if only a fraction of the land is still needed for production, more space is available for reforestation and biodiversity can increase (both on land and at sea). Nutrients are processed more efficiently via cultivated meat, which greatly reduces the need for animal feed.

Cultivated meat also seems to be positive in terms of greenhouse gas emissions, although much will depend on the way of upscaling and the energy sources. Energy consumption is a justified point of attention, to be tackled through decarbonization of the energy system. GAIA and the Good Food Institute commissioned a study to learn more about the impact of sustainable energy use on cultivated meat production by 2030.

8- If there is no conventional meat production, what about grasslands and the valorization of plant-based by-products? Will rural landscapes be empty? And will traditional breeds get extinct?

Short answer: The concept of cultivated meat only affects the slaughter of animals, not the use of them. It is perfectly possible to develop a model where animals have an ecological purpose and fulfill a function of living cell stocks at the same time. Moreover, with the rise of cultivated meat, the focus might shift from high productivity (leading to physical anomalies in animals) to breeding that is more diverse and humane.

Long answer: Since mass production via industrial farming is necessary to meet the high demand for meat and involves uniformity, there is a tendency of loss of local breeds and the takeover by transboundary breeds (breeds that are used worldwide independently of the environmental conditions). According to FAO in 2007, one farm animal breed is lost every month and industrial livestock production is the major cause for that.[32] Transboundary breeds have a low effective population size, which means they show low genetic diversity and high inbreeding. In conclusion, the greatest endanger for the diversity of (domesticated) animals is industrial farming itself. Moreover, breeding over the past decades has been focused on productivity (yield for meat, milk, eggs, offspring, etc.), which led to numerous physical anomalies in the animals.

Foundation made an estimation of the 'safe operating space' for the EU livestock.[33] The

[31] For more details, see 'Mattick et al. Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States. Environmental Science and Technology (2015)' and 'Lynch & Pierrehumbert. Climate Impacts of Cultured Meat and Beef Cattle. Frontiers in Sustainable Food Systems (2019)'
[32] FAO. The State of the World's Animal Genetic Resources for Food and Agriculture (2007)
[33] The RISE Foundation. What is the Safe Operating Space for EU livestock? (2018)

RISE Foundation is a think tank on agriculture and was established in 2006 by the then Commissioner for Agriculture, Rural Development and Fisheries, with the support of the European Landowners' Organization (ELO) and the Friends of the Countryside (FCS). Its report looked into the minimum number of ruminant livestock units needed to ensure the conservation of permanent pastures in the EU. The results show that all European countries, except five (Romania, Lithuania, Bulgaria, Latvia and Estonia), would have to reduce their livestock dramatically for just maintaining permanent pastures. Moreover, the deforestation of the Amazon rainforest shows that the increasing beef demand globally has dramatic ecological consequences and is a major cause of biodiversity loss: 80 percent of the deforestation is due to change to grassland for cattle.[34] In conclusion, a limited number of animals that graze is more compatible with cultivated meat production than with industrial farming.

Another argument related to ecology is that monogastrics (especially pigs and poultry) are able to convert non-edible by-products. Therefore, animal agriculture and meat production play a vital role in circular economy and are an efficient way of producing proteins and micronutrients. The common reference given for that reasoning is an article by Mottet et al.[35] It is also used in FAO reports (the first author is affiliated with FAO) and contains material to counter the fundamental critics on meat production. For instance, the publication emphasizes that:

- most feed comes from non-edible (by-)products, namely 86%
- the conversion of feed to food is (on average) better than mostly claimed - animals provide manure and add to fertility of soils

Unlike the argument of grazing, this needs to be countered, since it implies that the large-scale production of meat would be beneficial.

The numbers for feed-to-food conversion (or FCR, which identifies the amount of feed to produce a kilogram of food) in the literature vary between 6 kg and 20 kg of grain per kg of beef and shame conventional meat production for being inefficient and malign to the planet. The publication by Mottet et al. tries to nuance that, by emphasizing that the upper bound concerns beef and in certain conditions (namely beef lots). According to their analysis, that is only 13% of the worldwide production.

The publication identifies whether there are co-products that are not human-edible, but that are drivers for land-use and therefore compete with food. That is the case for soybean cakes (with an economic fraction allocation of 72%).

The publication of Mottet et al. clarifies: In the FCR data for OECD countries (like EU countries), we see that FCRs for cattle vary according to production system:

- Mixed systems for cattle (the most common) FCR = 53 kg feed/kg final product - FCR for grazing = 67
- FCR for feedlots = 62

[34] Nepstad et al. Interactions among Amazon land use, forests and climate: prospects for a near-term forest tipping point. Philosophical Transactions of the Royal Society (2008)
[35] Mottet et al. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate (2017)

Obviously, these are high numbers of feed needed to produce meat. Given that even grazing systems happen in conditions of intensity, for instance the fattening stage before slaughter, these numbers are relevant. However, the everlasting critic pro meat production is that grass and by-products after food production are not edible by humans, so there is no competition with food production. Therefore, the FCR data based on human-edible feed and soybean cakes (since they drive land use) are the most relevant:

- FCR for mixed systems = 7.6
- FCR for grazing = 5.5
- FCR for feedlots = 45.4

These numbers show that feedlots consume a very high number of edible compounds but also that a large amount of human-edibles are used in grazing systems.
Regarding pigs and poultry: in the same FAO scientific publication, the distinction is made between backyard, intermediate and industrial production. But the production volume of the first two is negligible, compared to the industrial volume.

- For pigs (industrial): FCR = 29
- For broilers: FCR = 26

Considering only human-edible feed and soybean cakes, as calculated above for cattle, the results are:

- For pigs (industrial): FCR = 24.1
- For broilers: FCR = 24.0

Meat burger by ***Mosa Meat***

Clearly, there is no efficiency argument here, since high amounts of human edibles are consumed to produce meat. Interestingly, although the production volume is very low, backyard pigs and chickens appear to be efficient protein converters. The reason for that is that these small-scale systems – and only these – match with the purpose of converting waste streams into protein instead of using human edible feed. It means also that this model might be interesting to produce tissue that delivers cells to cultivate. Like for grazing, small groups of animals are more compatible with cultivated meat than with industrial farming. Moreover, non-edible by-products could be used for medium production to cultivate the cells into meat.

[34] Nepstad et al. Interactions among Amazon land use, forests and climate: prospects for a near-term forest tipping point. Philosophical Transactions of the Royal Society (2008)
[35] Mottet et al. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate (2017)

			Total protein production[a] (Mt/year)	FCR1 Kg DM feed/kg protein product[1]	FCR2 Kg DM human edible[b] feed/ kg protein product[a]	FCR2 meat Kg DM human-edible[b] feed/kg meat[c]	FCR3 Kg DM human-edible +soybean cakes[d]/kg protein product[1]	Protein FCR1 Kg protein feed/ kg protein product[a]	Protein FCR2 kg protein from human-edible feed[b]/kg protein product[a]	Protein FCR3 Kg protein from human-edible +soybean cakes[d]/ kg protein product[a]
Non OE-CD	Cattle & buffaloes	Grazing	5881	195	1.6	0.9	1.9	20	0.2	0.3
		Mixed	13,615	171	4.8	3.1	5.6	16	0.5	1.0
		Feedlots	374	99	37.1	7.9	39.6	16	3.5	4.8
	Small Ruminants	Grazing	975	221	0.4	0.1	0.5	20	0.0	0.1
		Mixed	1250	190	0.5	0.2	0.6	17	0.1	0.1
	Poultry	Backyard	942	78	2.1	1.5	8.8	16	3.5	3.5
		Layers	6960	20	15.5	–	16.6	4	2.9	2.9
		Broilers	8496	26	18.6	3.5	24.7	6	5.2	5.1
	Pigs	Backyard	3800	574	0.6	0.1	7.8	11	3.3	3.7
		Intermediate	2441	35	18.8	3.8	24.4	7	4.9	4.9
		Industrial	2937	27	19.1	3.9	23.9	6	4.6	4.6
OECD	Cattle & buffaloes	Grazing	5053	67	4.7	3.9	5.5	8	0.5	0.9
		Mixed	7404	53	6.4	6.0	7.6	7	0.7	1.2
		Feedlots	1152	62	44.3	9.4	45.4	6	4.1	4.7
	Small Ruminants	Grazing	242	132	3.2	0.8	3.5	16	0.4	0.5
		Mixed	409	111	2.8	0.9	3.2	13	0.3	0.5
	Poultry	Backyard	18	59	0	0	1.0	10	0.5	0.5
		Layers	2259	18	13.8	0	15.7	3	2.9	2.9
		Broilers	4686	26	18.8	3.6	24.0	6	5.1	5.0
	Pigs	Backyard	99	57	0	0.0	1.4	7	0.6	0.7
		Intermediate	180	35	21.1	4.3	25.1	6	4.5	4.5
		Industrial	5428	29	20.0	4.0	24.1	6	4.4	4.4
World	Ruminants	All	36,355	133	5.9	2.8	6.7	2	0.6	1.0
	Monogastrics	All	38,246	30	15.8	3.2	20.3	14	2.0	4.2
	All	All	74,601	80	11.0	3.1	13.7	10	1.3	2.6

Figure 9: *Feed conversion ratios for different meat production systems, according to Mottet et al. (2017)*

9- Is cultivated meat GMO or GMO-free?

Short answer: It can be both. Especially in Europe, companies aim consciously for non-GMO cultivated meat – according to their communication on symposia, in the media and to us directly. However, based on information from patent applications, we may assume that this might be different in other continents over time.[36]

Long answer: The reality is rather complex. The definition of a GMO or 'genetically modified organism' in Europe is described in the Directive 2001/18/EC: **"an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination"**. The definition of GMO food is described in Regulation (EC) 1829/2003: "food containing, consisting of or produced from GMOs". The Directive 1830/2003 specifies that a product may contain traces of GMOs and does not need labelling below 0.9 percent, if this is technically unavoidable.

Every word in these definitions matters. The statement "produced from GMOs" means derived from GMOs. And whether or not a food has been produced "from" or "with" a GMO depends on whether or not material derived from the GMO is present in the food.[37] Food produced "with" a GMO, for instance through processing aids, does not fall under the scope of GMO regulation. This is important since certain compounds in growth media for cultivating meat may be produced recombinantly, such as growth factors. This is similar to the use of the recombinant enzyme chymosin for cheese production, as an alt-

[36] Based on information received from Elliot Swartz, senior scientist at GFI US
[37] Deckers et al. Genetically Modified Micro-Organisms for Industrial Food Enzyme Production: An Overview. Foods (2020)

ernative for the original rennin derived from stomachs of calf. Its use has been accepted for decades and no opposition or concerns have emerged.

Whether cultivated meat should be labeled as GMO or not, is important. According to a recent Eurobarometer, 27 percent of European citizens claim they are concerned about genetically modified ingredients in food or drinks.[38] Although substantial quantities of GMO feed are imported, very little GMO food is produced or marketed in the European Union.[39] Former surveys show even higher percentages of concern, but this might be due to the type of questions. A survey of 2010 showed that 66 percent of the EU population was worried – distributed between 50 percent in the Netherlands and 84 percent in Lithuania – and the concern had increased compared to 2005.[40] GMO always ranks among the top concerns on food safety in the European Union.

An acceptance study shows that consumers in France and Germany are much more critical on cultivated meat if it would be a GMO product.[41] To the question whether there is willingness to replace part of conventional meat with cultivated meat that was not genetically modified, around 90 percent of the participants in the questionnaire responded positively; in the case of GMO cultivated meat, those numbers dropped to below 50 percent (Germany), or even below 30 percent (France).

Clearly, a GMO path would make it more difficult for cultivated meat to be accepted in Europe. However, without knowledge of cell biology and without tissue engineering techniques, it is not possible to cultivate cells to meat. That does not mean that legally there is genetic modification involved.

Stacked sausages by ***New Age Meats***

Cells obtained from an animal may show different properties depending on their type. Embryonic stem cells are an interesting type since their proliferative capacity is indefinite, which means that theoretically they can be kept forever as a source for cultivated meat.[42] Embryonic stem cells can still differentiate into all kind of cell types. The downside is the difficulty to obtain and to culture them. ***Aleph Farms***, who specifically aims for the European market, works consciously with embryonic stem cells to avoid any GMO discussions. ***Aleph Farms*** claims that it uses a naturally pluripotent cell line (cells

[38] Eurobarometer on Food Safety in the EU (2019)
[39] https://ec.europa.eu/commission/presscorner/detail/en/MEMO_15_4778
[40] Special Eurobarometer 354. Food-related risks (2010)
[41] Bryant et al. European Markets for Cultured Meat: A Comparison of Germany and France (2020)
[42] For more info: Ben-Arye & Levenberg. Tissue Engineering for Clean Meat Production. Frontiers in Sustainable Food Systems (2020)

that are still to be differentiated).[43] These cells are obtained from the inner cell mass of a very early embryonic structure and are kept stable due to the right environment (i.e. certain media conditions).

Another method is taking cells from an animal tissue sample. Muscle tissue contains myosatellite cells that are responsible for muscle repair. These are adult stem cells and are already more specialized than embryonic stem cells. However, they still have a potential to differentiate into several cell types of interest for cultivated meat, such as skeletal muscle cells. These cells are less difficult to obtain or culture/control than embryonic stem cells, but they might be less obvious for developing all necessary cell types in cultivated meat. Moreover, these cells have a lower proliferative capacity. Therefore, when using myosatellite cells as a source for cultivated meat, it might become necessary to take regular biopsies from animals. The first hamburger of Mark Post was made via bovine myosatellite cells and it looks like ***Mosa Meat*** is still on that track.[44]

Other candidates as a cell type source for cultivated meat are mesenchymal stem cells, due to their abundance and ability to differentiate into multiple cell types of interest, and induced pluripotent stem cells (iPSC). The latter are interesting because they are rather easy to produce and have an indefinite capacity to proliferate. However, the part 'induced' means that matured somatic cells are reprogrammed to pluripotent cells and therefore genetic modification or gene editing is involved.

The matter of the indefinite capacity to proliferate – or 'cell immortality' – is not insuperable, but it is an important one for productivity reasons. Achieving an immortal cell line to produce cells for cultivated meat means that no repeated biopsies are necessary. Moreover, enough cells are needed to produce cultivated meat in a batch. Especially for adult stem cells (like the myosatellite cells), the limited proliferating capacity is a problem. The key problem is that the telomers (the ends or 'caps' of chromosomes) get shorter after each cell division. After a certain number of divisions, the proliferation simply stops — a phenomenon known as the Hayflick Limit.

There are methods to alter this process and immortalize the cell line, including modifying the genome and for instance induce an overexpression of telomerase − which is the enzyme that prevents telomere from shortening. It is important to stress that not every technique for obtaining mutations means that a GMO is obtained. 'Mutation breeding', especially used for plants, involves chemicals or radiation to induce random changes in the DNA; the offspring with the desired traits is then selected. Mutation breeding is exempted from GMO regulation since it has been used for such a long time and is now considered as safe.[45] Even about the latest techniques, such as genome editing (CRISPR-Cas for instance), there is wide discussion whether it should be exempt or not.[46] The view that they should not fall under the scope of GMO legislation is based on the argumentation that the new and very precise techniques deliver end products that are

[43] The claims are made during symposia and personal conversations.
[44] Based on presentations, conversations with Mark Post and recent publications like Verbruggen et al. Bovine myoblast cell production in a microcarriers-based system. Cytotechnology (2018)
[45] Briefing European Parliament: New Plant-breeding Techniques. Applicability of EU GMO rules (2019)
[46] EASAC and the New Plant Breeding Techniques. European Academies Science Advisory Council (2018)

very similar to the ones generated using conventional breeding techniques, or that similar changes could also occur naturally. Opponents argue that the products are in fact genetically modified. In 2018, the European Court of Justice published a ruling that genome-edited organisms fall under the scope of the GMO regulation.[47] Public and political discussions about this ruling are ongoing.

Meatball by ***Mosa Meat***

A rather simple technique without using mutating agents is spontaneous immortalization, where the accumulation of spontaneous mutations in a cell culture and selection of the target cells lead to an immortalized cell line. This technique is likely to be viewed from a regulatory standpoint as non-GMO. Other available techniques mostly involve genome-editing tools and seem to fall under the GMO regulation, at least in the European Union. Some methods are so called "footprint free," which permit changes to be made into cells without imparting permanent genomic changes. Other methods include modifications that can be undone: immortalization of cells can be performed via an ON/OFF system, where the cells in the master cell bank are immortal (ON) and the cells for growing cultivated meat are restored to their original genome state (OFF).

Finally, it should be added that there is also criticism on the process of cell immortalization: genetic mutation is a natural process and after a high number of cell divisions, important genetic alterations might occur in the cell line that might make the cells unfit for the purpose. This is an argument in favor of regular biopsies in animals.

Salmon nigiri by ***Wildtype***

At this point, there is little transparency on what exactly happens in the cultivated meat laboratories, although some insights on engineering methods being trialed can be gleaned from patents filed by companies. At a certain point, they will have to open up towards the regulators. So a lot still needs to be clarified about the engineering techniques in use. But we do know that in Europe there is pressure from society and the regulatory framework to avoid GMO cultivated meat.

[47] Worth mentioning is that this is basically the opposite conclusion that was reached in the US (USDA SECURE Act). For an overview: https://cspinet.org/news/biotech-blog-ramifications-exemption-and-self-determination provisions-usda%E2%80%99s-new-secure-rule

10- Is cultivated meat beneficial for public health?

Short answer: Yes, cultivated meat offers an opportunity to decrease antibiotic use and occurrence of zoonoses dramatically. Cultivated meat is potentially safer than the conventional counterpart.

Long answer: The cultivated meat production process has a great advantage over livestock: it is performed under sterile and closed conditions, so the risk of pathogens is far less. This is important because of a concern about antibiotic resistance and infectious diseases. After all, current meat production is by far the largest consumer of antimicrobial agents. Of all antibiotics sold in the United States, 80 percent are for use in animal husbandry; 70 percent of these are medically important to humans.[48] In the European Union steps are made towards a reduction, but the worldwide consumption of antibiotics is still expected to increase: globally by 67 percent in 2030 and even double in Brazil, Russia, India, China and South Africa.[49] Moreover, industrial farming is a breeding ground for pathogens and COVID-19 has made very clear to the wide world that zoonoses pose an existential risk. Studies in other sectors show that in sterile and closed conditions, the incidence of contaminations via bacteria and fungi is very low (less than 2 percent).[50] This aspect is also important considering foodborne illness. Due to the lack of enteric food pathogens, the risk for foodborne diseases is much lower and it potentially increases shelf lives and reduces spoilage (which means less food wasting).

Opponents of cultivated meat challenge the claimed avoidance of antibiotics, since they are of common use in laboratories, although in low levels. The team of Mark Post published a paper on the influence of antibiotics on the cultivated meat process: the use of antibiotics has been found to be negative for the cells.[51] Cell growth was stopped by 20 to 26 percent. No infections occurred during the experiments without antibiotics, sterile work was sufficient to avoid bacteria.

Another concern that sometimes shows up is the question whether cultivated meat might contain other, maybe toxic compounds. Scientifically, this is extremely unlikely. If primary cells originate from animals in good health, they are very likely to result in safe food products. Since compounds of animal tissues are functional, there is no reason to assume there might be silent pathways to produce toxic substances. The presence of allergens is, however, a reasonable concern. It is technically possible that cultivated meat would contain the same allergens as the conventional counterpart, but at a higher level. This simply needs to be cleared out by transparent analyses.

A final advantage of cultivated meat concerning public health is the absence of trace chemicals. Pesticides, antibiotics, veterinary drugs, heavy metals, among others, are a matter of concern for conventional meat. These residues are unlikely to appear in cultivated meat.

[48] Summary report on antimicrobials sold or distributed for use in food-producing animals. Food & Drug Administration (2014)
[49] Van Boeckel et al. Global trends in antimicrobial use in food animals. PNAS (2015)
[50] 13th Annual Report and Survey of Biopharmaceutical Manufacturing (2016)
[51] Kolkmann et al. Serum-free media for the growth of primary bovine myoblasts. Cytotechnology (2020)

Short answer: The acceptance studies of the past years show a worldwide positive attitude towards cultivated meat. Still, the proof of the pudding is in the eating.

Long answer: Since cultivated meat is not commercially available, only consumer intentions and opinions can be measured. Overall, the level of interest in cultivated meat seems rather high. Surveys with representative samples typically indicate robustly that between 20 and 40 percent of a population in a Western country is positive about cultivated meat or is willing to eat or buy it; around half of the population is ready to try it.[52] However, there is a variability among countries in Europe: **French consumers for example seem to be more critical – 44% would try cultivated meat – than in Germany where 58% would eat it**.[53] The survey in Belgium by IPSOS commissioned by GAIA even reveals differences in a country: in the northern, Flemish part, positive attitudes reach almost half of the population, while only one third shows enthusiasm in the southern, Walloon part.[54] Obviously, a lot depends on the exact questions: nuances between trying to eat, purchasing, replacing conventional meat, positive opinion, information or no information received yield different rates. It is important to stress that mostly there is a large undecisive group during surveys, participants that are neither positive nor negative. They may be considered as a target consumer group as well.

Yellowtail kimchi by ***BlueNalu***

In other continents, enthusiasm may be even larger, although drivers might differ from the ones in Western countries. The first study in Brazil, considered as a true meat culture, gives a first glimpse as only a few hundred people were surveyed in two specific cities. But the willingness to eat cultivated meat reached 64%.[55] Also in Asia, the continent with the highest meat consumption, it looks promising: a first study exposed that enthusiasm for cultivated meat is higher in China and India than in the United States. Interestingly, the context differs. Chinese are more attached to meat than Indians, but they are also more curious about new food and especially consider health and safety as important. In India, the ethical arguments in favor of cultivated meat are more decisive for wanting to eat it.[56]

In general, avoiding animal slaughter is the most commonly perceived benefit of cultiva-

[52] This is based on an overview that Chris Bryant provided. He is author of many of the scientific articles that have been published the past few years on consumer acceptance of cultivated meat
[53] Bryant et al. European Markets for Cultured Meat: A Comparison of Germany and France. Foods (2020)
[54] Bryant & Sanctorum. Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years. Appetite (2021)
[55] de Paula Soares Valente et al. First glimpse on attitudes of highly educated consumers towards cell-based meat and related issues in Brazil. PLOS One (2019)
[56] Bryant et al. A Survey of Consumer Perceptions of Plant-Based and Clean Meat in the USA, India, and China. Frontiers in Sustainable Food Systems (2019)

ted meat; the benefit to the environment is a robust second most important reason.[57] We have to keep in mind that this does not mean that these reasons are the most important drivers to purchase food: indeed, taste, price and convenience still dominate consumer behavior. However, animal welfare and environment, together with health, are increasingly important. It explains why flexitarians - who are concerned but not completely ignoring meat - are the category of consumers most looking forward to the arrival of cultivated meat.

Other robust results across country and cultural boundaries are demographic. For example, it is striking that women are on average more concerned about animal welfare than men, but that men are more positive about cultivated meat than women. The only exception so far is China, where women welcome cultivated meat more than men. Young and urban people also evaluate cultivated meat more positively than older and rural residents, just as higher education usually goes together with a more enthusiastic attitude. Such research is interesting, but we don't have to overemphasize it. Cultivated meat is something new and it is therefore logical that it scores better with consumer types who are more open to novelties. What's new today is tomorrow's normal. After all, informing consumers will also play a decisive role: people with prior knowledge about cultivated meat are clearly more positive about it than those who have never heard of it.

*Shrimp dumplings by **Shiok Meats***

Finally, an interesting publication shows the positive value of expectancy: in a Dutch study, participants were asked to taste two pieces of meat: one piece was presented as being from a slaughtered animal, while the other piece was supposedly cultivated meat (without knowing this prior to participating in the study). In reality, they were two identical pieces of meat, that is, from slaughtered animals. All 193 participants effectively tasted the so-called cultivated meat and they even liked it better than the other piece.[58]

[57] For more insight on perceived benefits, concerns and drivers, see Bryant & Barnett. Consumer acceptance of cultured meat: A systematic review. Meat Science (2018)
[58] Rolland et al. The effect of information content on acceptance of cultured meat in a tasting context. PLOS One (2020)

12- Will cultivated meat be as nutritious as conventional meat?

Short answer: Yes, it will be vital to pass the comparison with conventional meat. There are even opportunities to ameliorate the nutritional profile. However, cultivated meat developers still need to prove that their products are or will be as nutritious.

Long answer: As explained before (**section on the definition of meat page 14**), the nutritional profile must be similar or even identical to the one of conventional meat. Otherwise, the (scientific) claim that cultivated meat is actually 'meat', is questionable. Since the consumers with a positive attitude towards cultivated meat are flexitarians or carnivores (**see section on consumer acceptance page 29**), that claim is important.

Steak tartare by ***Mosa Meat***

Opponents or critics argue that it is not self-evident to substantiate this claim. In a paper by Belgian scientists, scientific hurdles are listed and the idea is challenged that cultivated meat would automatically contain the same micronutrients as conventional meat: post-mortem metabolism influencing tenderization and flavor development, iron content, the large variety of compounds present in conventional meat, etc.[59] On the other hand, there is an opportunity to even increase the nutritional value. Profiles of saturated fat, cholesterol, allergens to be removed, among others, could be altered. A published example of nutritional engineering concerns cells for cultivated meat that are able to produce beta-carotene (precursor of vitamin A). However, this implies genetic modification, so in a European context it might be avoidable.

13- Is cultivated meat halal/ kosher?

Short answer: It could be, but at this point there are no clear rulings yet. A lot will depend on the final production process that will need to be inspected by delegates from the religious communities. And it is very possible that there will be multiple contradicting rulings and religious labels, as is the case today for conventional meat.

Long answer: In a world with 1.8 billion Muslims, 1.1 billion Hindus, half a billion Buddhists and over 10 million Jews, the religious perspective on cultivated meat matters. In the absence of an exact precedent, cultivated meat is and will be a matter of debate among religious scholars. Although this debate might still last for a long time, in each religion there is room for acceptance of cultivated meat. It will require a lot of openness and transparency about methods and ingredients.

[59] Fraeye et al. Sensorial and Nutritional Aspects of Cultured Meat in Comparison to Traditional Meat: Much to Be Inferred. Frontiers in Nutrition (2020)

For Orthodox Jews, food must be kosher. Traditionally, meat is permitted for kosher consumption only when it is derived from a kosher species, which has been kosher slaughtered in accordance with strict regulations.

The same set of rules could count for cultivated meat.[60] The following rules would be important:

- the cells are extracted from a kosher species and the sample must contain an accepted cell type for cultivation (as blood for instance is not consumable)
- the growth conditions must be kosher (fetal serum would likely be unacceptable)
- the cells are derived from an animal after kosher slaughter

Although a much lower number of animals would be involved than with conventional meat, this still includes a killing step in the production process. Proper slaughter is essential according to orthodox views and taking flesh form a living animal is explicitly forbidden. Another view could be that cultivated meat is a non-meat derivative, like eggs and milk that should come from kosher animals but do not require slaughter. The most promising ruling option is that the process of cultivating meat is so different from growing conventional meat, that it may be defined as a new entity and could be kosher without much concern even about the source. Since the knowledge about micro-organisms (in or outside food) is more recent than Talmudic laws, this also required rabbi authoritative assessment. Basically, the ruling states that organisms that are not visible to the naked human eye are insignificant and therefore considered kosher; theoretically, that might count for cells too. As clarity will grow on the exact materials and processes involved in cultivating meat, authoritative rulings will emerge.

The fact that Israel is a major area for cultivated meat development, where 63 percent of Jews keep kosher at home and 82 percent do not consume pork products at all[61], offers an opportunity for great care concerning religious sensitivities.

For Islam, similar concerns and conditions exist on whether cultivated meat is halal. Cultivated meat could be halal if the cells used are from a halal-slaughtered animal and no serum is used in the production process.[62] Like for kosher, the origin of the cells matters greatly: it is very unlikely that cells from haram species, such as pigs, would be approved. Interestingly, the limited survey data appears to confirm that the Muslim population in acceptance studies on country level is rather positive about cultivated meat: 58 percent would eat cultivated beef, 68 percent would eat cultivated lamb or goat meat, and 49 percent would eat cultivated chicken, but only 28 percent would eat cultivated pork.[63]

Similar attitudes are to be observed in Hindu and Buddhist communities. Although no clear guidance is available yet for these religions, it seems that according to the available research for India and China, religion is not a hurdle (except for cultivated beef for Hindus). On the contrary, both religions promote compassion towards animals.

[60] Kenigsberg & Zivotofsky. A Jewish Religious Perspective on Cellular Agriculture. Frontiers in Sustainable Food Systems (2020)
[61] Pew Research (2016) at: https://www.pewforum.org/2016/03/08/jewish-beliefs-and-practices/
[62] Hamdan et al. Cultured meat in Islamic perspective. Journal of Religion and Health (2018)
[63] Bryant. Culture, meat and cultured meat. Journal of Animal Science (2020)

14- Will/can farmers play a role in cultivated meat production? What is the social impact of cultivated meat?

Short answer: Providing farmers a role in cultivating meat is technically possible. However, it is not self-evident. The broad social impact of cultivated meat is still to be investigated.

Long answer: The growing criticism on cultivated meat is not coming from big meat processors; it originates from concerns about farming practices. Farmer unions are expected to becoming a major opponent of cultivated meat, since the essence of growing animals for slaughter is challenged. Especially ***Mosa Meat*** and ***Aleph Farms***, two companies that are most active in the European space, are aware of the importance of farmer inclusion in the cultivated meat model.[64]

Sausages by ***New Age Meats***

Prof. Cor van der Weele is professor at the Wageningen University and has performed most of the early research on farmer attitudes and ways of inclusion. She organized focus groups to discuss concerns and opportunities, with citizens, stakeholders (such as feed producers) and farmers themselves. The central question during this research is whether cultivated meat could be part of a switch to a more circular agriculture and could farmers be actively involved. During discussions in focus groups with citizens, the concept of 'pig in the backyard' emerged.[65] Initial hesitance transformed to enthusiasm when new technology was mingled with traditional cultural ideals, the hope of guilt-free meat-eating and intimate relations with genuinely happy animals and the values of local production. The idea of the 'pig in the backyard' that could deliver a relationship with an animal and local food at the same time warmed participants considerably to cultivated meat. The focus groups with stakeholders and farmers ended in more diffuse conclusions: in general, farmers have a rather conservative attitude about their livestock and are suspicious towards new technology; however, a small minority of agriculturalists sees opportunities and some are even eager to start.[66] If some farmers succeed in taking a part in the cultivated meat process, it might serve as an example to others (like what happened in the organic agriculture).

The broad social impact of cultivated meat is still very unclear, though. For sure, cultivated meat will be disruptive, but will it be a net employer, like green energy is more labor-intensive than the fossil fuel industry? Answers still need to be provided to this question. Therefore, GAIA requested a study about this topic and asked a multidisciplinary research team in Paraná (Brazil) to investigate this. The results are supposed to be published in 2022.

[64] This is based on personal conversations and talks during symposia
[65] Van der Weele & Driessen. How Normal Meat Becomes Stranger as Cultured Meat Becomes More Normal; Ambivalence and Ambiguity Below the Surface of Behavior. Frontiers in Sustainable Food Systems (2019)
[66] These results are still to be published; the information is based on conversations and inputs from symposia.

Burger by ***Mosa Meat***

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