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On Meat Substitutes

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On the front cover
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On Meat Substitutes

In recent years, much scientific research has been dedicated to developing meat substitutes based on animal or vegetable proteins produced in the laboratory using cell culture techniques. These methods avoid the environmental impacts of livestock farming without requiring consumers to change their eating habits.

Meat substitutes made from plant proteins have been on the market in several countries for years, while cultivated meat is not yet on the shelves—because of its production costs, it is not competitive with meat produced on farms, and there are still considerable technical challenges to overcome.

In the coming years, so-called cultivated meat (also known as synthetic meat or in vitro meat) could become an alternative for consumers, but its production and consumption pose crucial questions.

Can meat substitutes satisfy the growing global demand for meat without altering the balance of the planet, as industrial animal husbandry has done? Is the production of these substitutes actually more sustainable in terms of emissions? How can we prevent this new market from being co-opted by the multinationals that already control the food system? How should new meat alternatives be defined and regulated by law?

The global picture

In the second half of the 20th century, global meat consumption increased from 50 million tonnes in 1961 to over 300 million tonnes today[1]. This increase is due to the growing world population (which grew from 3 billion to 7.6 billion during the same period) as well as improved living conditions of part of the population.

In richer countries (USA, Australia, Europe), but also in places like Argentina, Brazil, and Mexico, meat consumption exceeds 80 kg per person per year on average[2], even though 26 kg per year is enough for a healthy adult.[3].

Where Meat Consumption Is Highest & Lowest
Total per capita meat consumption worldwide in 2014 (in Kg)

Meat consumption is very high but stable in Western countries; in fast-growing countries (China, India, Southeast Asia), on the other hand, it is increasing rapidly due to the westernization of lifestyles and the exit from poverty of large sectors of society.

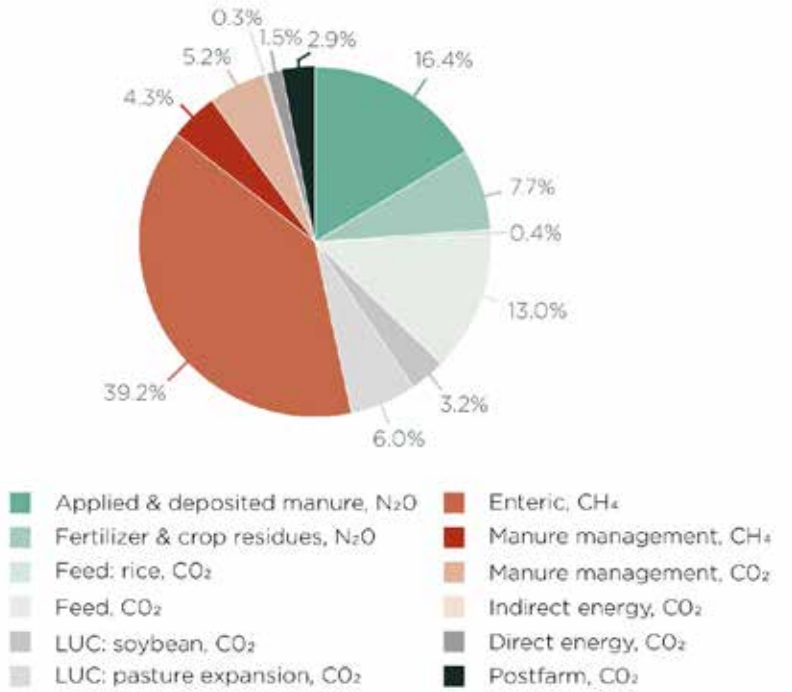
Taking into account the expected increase in the world population (11 billion people by 2050), the FAO estimates a possible increase of 75% in the demand for meat[4]. This forecast is also confirmed by the 5th report of the Intergovernmental Panel on Climate Change[5].

1 Our World in Data website; Meat consumption, health and the environment, H.C.J.Godfray, et all (2018)
2 Meat and seafood production and consumption, Hanna Ritchie and Max Roser, Our World in Data (2017)
3 World Cancer Research Fund and American Institute for Cancer Research: https://www.wcrf.org/dietandcancer/recommendations/limit-red-processed-mea
4 World Livestock 2011, FAO
5 IPCC Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty e Coninck, H. et al. (2018), 'Strengthening and implementing the global response'.

The global surge in demand for meat in recent years has seen a corresponding increase in industrial meat production, which has made it possible to put large quantities of meat on the market at low prices, taking advantage of the reduction in animal feed costs, the reduced need for labor, and the rapid growth times of new high-yield breeds.

The **concentration of power in the hands of a few large companies has also increased**, with a small group of multinationals now controlling the entire supply chain from animal genetics to feed production, pharmaceuticals to breeding, and slaughter to distribution. The number of farmers is gradually decreasing, but the number of animals per farm is increasing[6]. In the United States, the number of hog farmers decreased by 70% between 1992 and 2009, but the overall livestock population remained the same[7]. Today in the US it is possible to find farms (feedlots) with 100 thousand cattle (equal to the entire dairy cow population of Greece!), and globally the number of farms with over 500 thousand chickens or 10 thousand pigs continues to grow.

Industrial meat production is exerting tremendous pressure on environmental resources. The agricultural sector accounts for 24% of global emissions[8], and the livestock sector accounts for half of this (or 14.5% of total emissions[9]).



Livestock contributes with 14,5% of Green Houses Gases emissions caused by humans-made GHG emissions
Of this 14.5%

- Enteric fermentation from ruminant animals contributes nearly 40% of livestock GHGs
- Emissions related to manure contribute around 25%
- Production of animal feed contributes around 13%
- Land-use change for livestock contributes nearly 10%
- Post-farm emissions (processing & transport from farm to retail) contribute only 2.9%

Public opinion is also increasingly sensitive to issues such as animal welfare, which is clearly lacking in intensive farming, and to the health risks of excessive consumption of meat and animal products.

The meat industry is therefore trying to change how it is perceived.

6 Meat Atlas, Facts and Figures about the animals we eat, Heinrich Böll Foundation and Friends of the Earth Europe (2014)
7 USDA Hog Production from 1992 to 2009: technology, restructuring and productivity growth (2013)
8 http://www.fao.org/3/a-i6340e.pdf
9 Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. and Tempio, G. (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organisation.

The new meat

For many years the market has offered high-protein meat replacements made from plants (tofu, seitan, quorn, and other products made from legumes) or insects, but now we are on the verge of a scientific turning point with the introduction of so-called "second generation" meat substitutes.

In addition to the way they are obtained, another aspect that differentiates second generation substitutes from first generation ones type of is the consumers that they target, namely people who are sensitive to the negative narrative that increasingly surrounds meat consumption and would like to eliminate it from their diets for ethical and environmental reasons, but are unable or unwilling to give up the taste and texture of meat.

Depending on the origin of the raw product (plant or animal cells), the new meat-like products can be divided into plant-based meat and cultivated meat[10].

- **Plant-based meat**

The plant-based origin of the raw product meat is produced using vegetable cells from legumes or cereals—soy, peas, wheat—assembled together with other ingredients thanks to innovative cellular farming techniques.

What makes these product different from the plant-based meat substitutes that have been on the market for years is the extraordinary extent to which they resemble meat from farmed animals, in terms of taste, texture, appearance, and cooking experience: The burgers sizzle during cooking, secrete a liquid that looks and tastes like blood, and have a crust on the surface just like conventional burgers.

The ingredients used in the production process are mostly of vegetable origin (extracts of beet, turmeric, sunflower or coconut oil, xanthan gum, fibrous parts of carrot or bamboo...), but preservatives, thickeners, and dyes that are not always of natural origin are also used. Some producers also use genetically modified yeasts in the production process or in the extraction of proteins and other substances from plants.

An oft-cited example in this regard is leghemoglobin or heme (SLH), a substance that produces a liquid similar to blood. Heme is naturally present in the blood of people and animals, and also in some plants, and is used to transport oxygen to cells. Producing a natural heme from soy or other legumes would require very large amount of plants and therefore a lot of soil. But it can also be obtained in the laboratory thanks to a process of genetic engineering: A DNA sequence (from soy root cells, for example) that codes for heme is inserted into a yeast strain, allowing it to produce this molecule naturally during the subsequent fermentation process.

Vegetable-based substitutes are commercially available in the form of sausages, hamburgers, meatballs, and steaks.

Cellular agriculture also uses vegetable proteins to produce gelatin, casein, albumen, milk, and collagen. These products can also be obtained from simple bacteria, fungi, algae, or yeasts that are genetically modified and then fermented.

10 Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture, Neil Stephens, Lucy Di Silvio, Illtud Dunsford, Marianne Ellis, Abigail Glencross, Alexandra Sexton (2018)

Ingredients that may be found in a meat replacement product:

- Soy protein concentrate*
- Maltdextrin*
- Natural flavors including "smoke"
- Hydrolyzed corn or soy protein*
- Caramel color
- Pea protein isolate
- Leghemoglobin (soy)*
- Gum Arabic
- Cellulose
- Soy protein isolate*
- Carrageenan
- Autolyzed yeast extract*
- Oleoresin paprika (color)
- Potassium chloride
- Xanthan gum*

* Ingredients which may be derived from genetic engineering

• Cultivated meat

Cultivated meat, on the other hand, uses animal stem cells that are multiplied in vitro or in bioreactors with biotechnological processes typical of regenerative medicine (the same used to produce cells, tissues, and organs useful in human transplantation). Via these processes, it is possible to obtain meat similar to that from of real animals[11].

The cells used to initiate cell culture can be obtained by biopsy from live or slaughtered animal muscles; alternatively, cell lines (stem cells) are produced by genetic engineering or gene editing methods, or by induced or spontaneous mutations.

The cells reproduce in liquids that contain the nutrients necessary for tissue growth. This step may require fetal calf or horse serum, chicken embryos, collagen, etc., depending on the cell species and type of tissue being produced.

Other inorganic and organic components (antibiotics/mitotics, carbohydrates, salts, micronutrients, amino acids, vitamins, flavor preservatives, colors, and other additives and processing aids) can be added to these liquids.

Meat substitutes from animal cells also need ingredients (heme or thickeners such as xanthan gum, i.e. E415) obtained from genetically modified microorganisms[12].

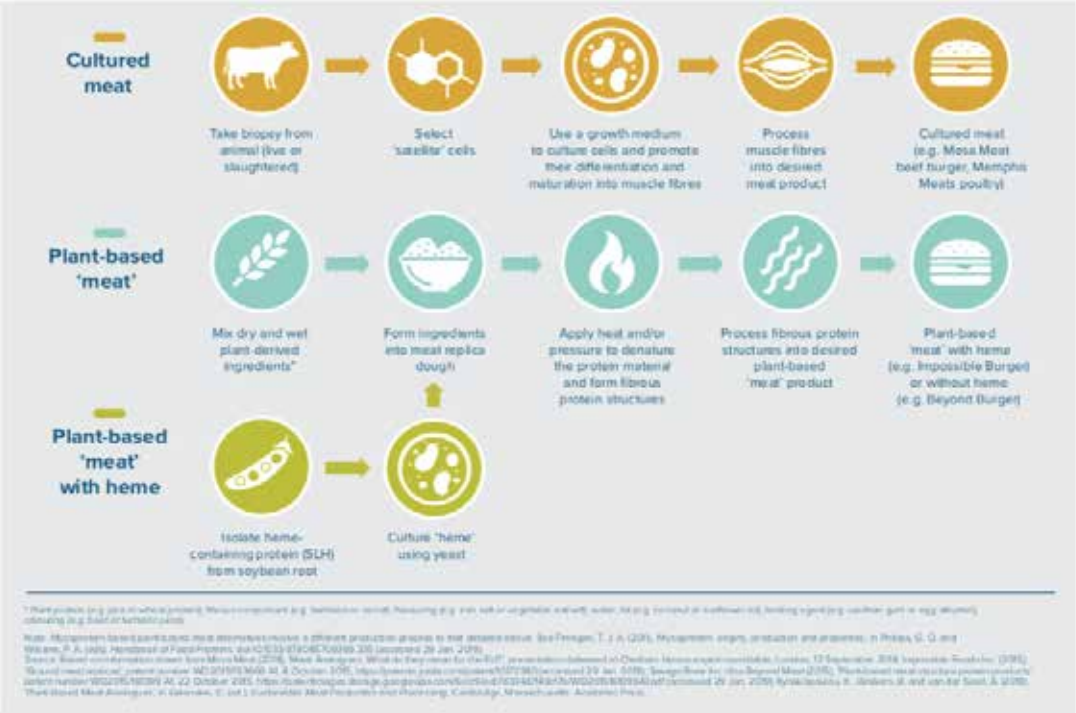
11 Enhanced Development of Skeletal Myotubes from Porcine Induced Pluripotent Stem Cells, Genovese, Domeier, Prakash, Telugu, & Roberts (2017)
12 Critical questions on laboratory-created animal product alternatives. Friends of the Earth (2018)

The consumer is not aware of all these additives because the law does not currently require the disclosure of additives used in the production process for cultivated meat (similarly to lack of legal obligation to indicate the type of feed given to a farmed animal—this is information that the consumer may want, but the law does not require that it be on the label).

As already mentioned, cultivated meat can be reproduced in vitro or in a two-stage bioreactor[13]. In the latter, starter cells grow rapidly in suspension in the first phase, and are then moved into a container where they differentiate into muscle tissue, fat, and connective tissue. A kind of scaffolding is then required to allow nutrients and oxygen to flow through the cell layers and produce thin layers of tissue. This process requires large energy inputs.

The meat obtained with these techniques is "biologically equivalent," i.e. molecularly and genetically identical, to meat from farmed animals, and able to provide an experience roughly equivalent to the real meat for the consumer, unlike other meat substitutes made with soy, beans, mushrooms, etc[14].

Cultured meat and plant-based "meat" production processes



According to the Dutch food technology company Mosa Meat, about 1,000 tonnes of muscle tissue can be obtained from just a few bovine cells[15].

For cultivated meat to become a viable alternative to meat from farmed animals, it will be necessary to be able to produce it in enormous quantities but companies still have to solve some important technical problems.

The cost of the substances used to grow the cells is very high (80% of the production costs) and the possibility of recycling the growth fluids in order to reuse them several times is being studied.

Other problems are linked to the nature of the cells used at the beginning: Embryonic stem cells reproduce quickly, but many tend to develop independently in non-muscular cells, while adult muscle cells, which are more controllable, grow more slowly and the costs are therefore higher[16].

It is necessary to find adequate "scaffolding" on which cells can take shape, and to find available cell lines, possibly deposited at public "banks." The Norwegian Center for Stem Cell Research in Oslo plans to use a grant from the Good Food Institute to support the construction of a repository of cell lines of agricultural importance, a sort of "frozen farm" able to provide, on request, cell lines of the most widespread breeding species[17].

Another difficulty is the space in which to host the large laboratories where cells can be reproduced and grown (and this means high costs).

13 A container capable of guaranteeing an adequate environment and the functions necessary for nourishment - but also movement and stimulation - useful for cell growth. The largest existing bioreactor has a volume of 25,000 liters (about one hundredth the size of an Olympic swimming pool) which Mark Post has estimated can produce enough meat to feed 10,000 people (The artificial meat factor, the science of your synthetic supper, Tom Ireland on Science Focus, May, 23, 2019).
14 Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture, Neil Stephens, Lucy Di Silvio, Illtud Dunsford, Marianne Ellis, Abigail Glencross, Alexandra Sexton (2018)
15 https://www.mosameat.com/technology
16 Production of animal proteins by cell systems. H.P.Haagsman, K.J.Hellingwerf, B.A.J.Roelen, Utrecht University (2009)
17 https://www.nature.com/articles/d41586-019-00373-w

Costs must also be reduced in order to create profit for other actors in the food chain (logistics, marketing, trade) to develop the market.

Then there is the question of flavor, which still needs to be improved and made more similar to that of meat obtained from farmed animals. So far, this is only possible with the use of additives. The sensory quality of the meat of farmed animals is related to the type of animal breed, their feed, the quality and variety of forage, their living conditions, and processing and maturation done by butchers; it is impossible for in vitro meat to perform on a similar level. However, according to some, this is a minor problem, and consumers are already accustomed to industrial meat products whose flavors rely on the use of additives[18].

Producers and financial supporters

"We think of it as meat made a better way [...] Meat today basically is made using prehistoric technology, using animals to turn plants into this very special category of food [...] But to your typical consumer [...] the value proposition of meat has nothing to do with its coming from an animal."[19]

Pat Brown, CEO of Impossible Foods

The world's first hamburger made from in vitro meat from a culture of bovine muscle cells was made in 2013 by Prof. Mark Post's team at Maastricht University in The Netherlands. It was financed by Sergey Brin, co-founder of Google, with an investment of $325,000[20]. Much of that share was used to build the laboratory. Prof. Post said it would take 10 years and a lot of money to produce large quantities of meat, improve its quality, and lower production costs enough to make it truly competitive.

In late 2018, an Israeli laboratory announced that it had produced a small steak (more difficult to produce than minced meat) at a unit cost of $50, still too high for the market[21].

But while cultivated meat is not yet on the market, plant-based meat substitutes are having great success, thanks in part to support from large distribution chains. The value of this market in 2018 was $4.63 billions and is expected to rise to $6.43 billions in 2023[22].

Europe, currently the biggest market for these products, consumed the world's largest share in 2017 (39%), but the Asian market is the fastest growing[23].

Today, among the well-known companies actively pursuing the idea of putting second-generation meat substitutes on the market are the American Mosa Meat (linked to Mark Post) and the American Memphis Meats, which produces in vitro meat (in the form of meatballs and beef, chicken, and duck bites) thanks to 22 million dollars invested by Bill Gates, Richard Branson (Virgin Group), and the multinationals Cargill (the first food multinational to invest in cultivated meat) and Tyson Foods, among the main protagonists of industrialized animal husbandry in recent decades and a leader in the meat market[24].

Bill Gates is also investing in the company Impossible Foods to finance cultivated meat as well as eggs produced without hens. Open Philanthropy, Temasek, Khosla Ventures, UBS, GV (Google Ventures), Viking Global Investors, and Horizon Ventures also believe in this Silicon Valley company challenge/ project. Impossible Foods has obtained total investments of 300 million dollars[25].

The US start-up Modern Meadow has produced demonstrative "steak chips" made from cultured muscle cells combined with a hydrogel and cultured skin.

Another US start-up, Finless Foods, is working on aquaculture and to obtain proteins from the genetic engineering of algae, from which it develops shrimps.

The same goes for Geltor for gelatin products, Perfect Day for milk, and Clara Foods for egg whites[26].

18 The to-do list for "clean" meat. Melody M.Bomgardner. C&EN Whitepapers (2018)
19 https://www.cbinsights.com/research/future-of-meat-industrial-farming/
20 A Lab-grown burger gets a Taste Test. Henry Fountain. New York Times (2013)
21 World's first lab-grown steak revealed – but the taste needs work. Carrington, D. Guardian, (2018)
22 PR Newswire (2018), 'Meat Substitutes Market 2018 – Global Forecast to 2023', News provided by Research and Markets, 23 March 2018,
23 Meat Analogues. Considerations for the EU, Antony Froggatt and Laura Wellesley (2019) Chatham House The Royal Institute of International Affairs
24 https://www.fairr.org/article/plant-based-profits-investment-risks-opportunities-sustainable-food-systems/
25 Impossible Foods just raised 75 million dollars for its plant-based burgers. Connie Loizos. Campfire (2017)
26 From lab to fork. Critical questions on laboratory-created animal product alternatives. Friends of the Earth (2018)

In Israel such companies as SuperMeat, Future Meat Technologies, and Meat the Future, which benefit from funds from a $300 million trade agreement signed in 2017 between Israel and China. China has stated that it wants to cut its meat consumption in half, and the production of cultivated meat would be part the strategy to achieve this goal[27].

There are also a number of university laboratories with an interest in the sector: The New Harvest Cultivated Meat Advocacy Group has funded the work of researchers at the University of Bath, University of Ottawa, Tufts University, and North Carolina State University.

A research group called Shojinmeat[28] is active in Japan and, in 2018, the Japanese government participated in the funding of a start-up called Integriculture, known for producing a "cultivated" foie gras[29].

In 2016 the American consulting firm FAIRR, which has a network of investors whose turnover is worth a total of 6.5 trillion dollars, invited companies to invest in alternatives to plant-based meat, listing in a dossier the many and growing investment risks to which industrial livestock farming is subject. First and foremost are the risks linked to the excessive use of antibiotics and the outbreak of a pandemic linked to intensive livestock farming. FAIRR invited operators to ensure safer and more reliable production from the point of view of health and the environment[30]. The founder of FAIRR, Jeremy Coller, a private equity investor linked to the University of Tel Aviv, is at the forefront of studies on meat substitutes.

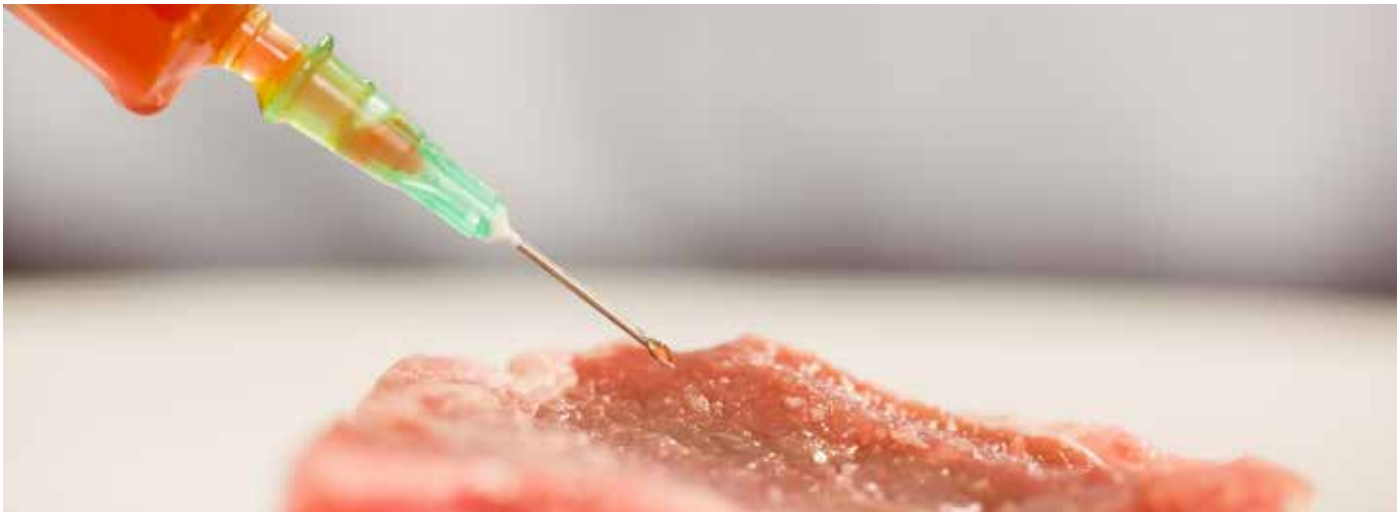
An updated review of the current producers and/or laboratories that are doing research can be found in the report produced in 2019 by Chatham House[31].

Environmental effects of alternative meat consumption

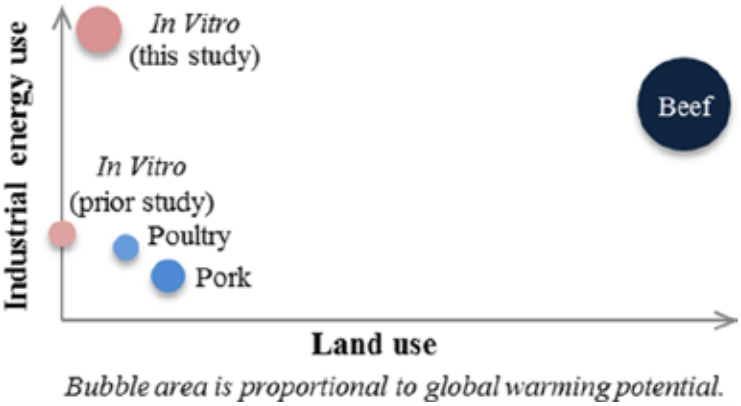
According to a life cycle analysis (LCA), cultivated meat would need less water (minus 82-96%), produce less greenhouse gases (minus 78-96%), use less energy (minus 7-45%), and involve less land use (minus 99%) than conventional beef, pork, sheep, and poultry production.

Only conventionally reared poultry would consume less energy than meat grown in a laboratory. In addition, the production of cultivated meat would free up a lot of land now used for the cultivation of cereals and legumes for animal feed[32]. However, these much-quoted data have in fact already been corrected by the authors of the study themselves, who state that the results of their environmental analyses still have a high level of uncertainty and that much research is still needed[33].

A study by some American researchers has reported significant energy consumption. According to their LCA calculation, cultivated meat would have a higher global warming potential than pork or poultry, but would still be lower than beef, while maintaining significant (and obvious) savings in land use[34].



27 China signs $300m deal to buy lab-grown meat from Israel in move welcomed by vegans. Rachel Roberts. The Independent (2017)
28 The Science Behind Lab-Grown Meat. Elliot Swartz (2017)
29 Japan part of 2,7 million investment in new clean meat brand. Anna Starostinetskaya. VegNews (2018)
30 FAIRR (2018), Plant-Based Profits: Investment Risks & Opportunities in Sustainable Food Systems and FAIRR (2016) Factory Farming, Assessing Investments Risks
31 Meat Analogues. Considerations for the EU, Antony Froggatt and Laura Wellesley. Chatham House The Royal Institute of International Affairs (2019)
32 Environmental impacts of cultured meat production. H.L. Tuomisto, M.J.T. de Mattos University of Oxford (2011)
33 Environmental impacts of cultured meat: alternative production scenarios. Hanna L. Tuomisto, Marianne J. Ellis, Palle Haastrup (2014)
34 Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States. C.Mattick, A.E.Landis, B.R.Allenby, N.J.Genovese (2015)



Da: Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States (2015)

Another study hypothesized the replacement of 50% of the meat consumed globally with various alternatives and calculated the related savings in terms of land use. The alternatives would be to reduce meat consumption and replace it with a vegetarian diet and the consumption of insects, vegetable-based substitutes, and fish from aquaculture. The solution that allows the least land use is to reduce meat consumption and replace it with vegetables (-55%), while replacing it with cultivated meat would only lead to savings of 29%. Classic substitutes (tofu, tempeh, etc.) or insects would lead to a reduction in land use of 35% and 34%, respectively[35].

The hidden costs of alternative meats

"We have a simple mission: to replace the need for animals as a food-production technology globally, by 2035."

Pat Brown, Founder and CEO of Impossible Foods[36]

Advocates of "new meat" point the finger at livestock farming, emphasizing its environmental impact, but do not suggest that consumers eliminate meat from their diets (as vegan activists do), nor do they call for an effort to reduce consumption and buy sustainable meat (as Slow Food and other associations, including Greenpeace, do[37]).

They simply propose a product that is similar to meat and that has a competitive price, less impact on the environment, and is "ethical".

If Pat Brown's vision comes true, what will happen to farm animals? Can agriculture do without them? Do the different forms of animal farming have the same impact?

Those who breed animals with respect for their welfare, producing quality meat and providing an important environmental service, could be overwhelmed by the hasty and successful marketing of cultivated meat.

Cultivated meat and, perhaps more so, imitation meat obtained from plant cells, could affect not only those involved in industrialized livestock farming (which is undermining the planet's resources), but also the most sustainable and virtuous breeders, already penalized by a market that excludes those who are not part of this intensive production system. The consequence could be a further loss of local animal breeds, traditional knowledge, and manual skills linked to the breeding and processing of meat and its derivatives, with serious consequences for the environment and cultural heritage.

A professor at the University of California in Davis, Alison Van Eenennaam[38], notes that nature has already developed a perfect bioreactor powered by clean energy (the sun), capable of converting cellulosic material into high quality proteins: cattle. Ruminants have evolved, together with the microbes in their rumen, to digest cellulose, an insoluble and inedible carbohydrate for humans, which is the main constituent of plant cells (grass). By grazing in often marginal environments impossible to convert to agricultural crops, where it would otherwise not be possible to exploit natural resources, they perform a dual service: they feed us and, if they are well managed, they take care of the balance of the landscape/territory.

Cattle and other ruminants have been selected over time for robustness and to adapt to heat, cold, humidity, difficult diets, water scarcity, mountainous terrain, and dry environments. They harvest their own forage on marginal soils to produce meat, milk, macro and micronutrients, fiber, leather, fertilizer, and fuel; they are used for transportation and draft power, and are a source of income and investment for millions of small farmers in developing countries.

35 Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? Alexander, P., Brown, C., Arneth, A., Dias, C., Finnigan, J., Moran, D. and Rounsevell, M. D. (2017), ", Global Food Security
Meat Alternatives: Life Cycle Assessment of Most Known Meat Substitutes, Smetana, Mathys, Knoch e Heinz (2015)
36 Impossible Food impact report 2019
37 https://www.greenpeace.org/international/publication/15093/less-is-more/
38 Lab-grown meat isn't as 'clean' as you might think, Alison Van Eenennaam, Genetic Literacy Project (2019)

Even in developed countries, ecosystem products and services produced by livestock go far beyond milk and meat, but these benefits, which are of global value, are not taken into account when assessing the impacts of small-scale livestock farming.

Van Eenennaam also notes that the calculations of the LCA of farms rightly consider the impacts generated by animal emissions, but do not account for the fact that giving up farming means abandoning areas that have no other uses, areas where grass would no longer be transformed into food for people (meat, milk, cheese) and where solar energy and photosynthesis would no longer be useful for humans.

The prairies are among the largest ecosystems in the world, occupying between 20% and 47% of the Earth's land surface depending on the data considered (it is difficult to acquire precise data due to the variety of sources, different sensitivities, and evaluation systems)[39].

According to one study, 20% is grazed[40]. Yet the contribution to human protein requirements of meat from grazing animals today is negligible: Only 13% of beef cattle and 6% of dairy cattle reared on the planet, plus a higher proportion of sheep and goats, is now raised entirely outdoors, with grass. The rest are given feed (often GMO) grown intensively, often on deforested land, using pesticides and fertilizers.

Milk and meat from ruminants provide 13 g of protein per person every day (the total amount of animal protein available daily at global level is 27 g per person), but unfortunately only 1 g of protein comes from grazing animals, which have a much smaller impact than industrial farming[41].

Grazing contributes to carbon storage in the soil. However, many forms of grazing-based livestock farming are at risk of disappearing in the coming years.

INDACO2, an environmental assessment agency, has carried out analyses on Slow Food projects and shown how extensive cattle breeding for meat and dairy produces significant savings (up to 83%) in CO2 emissions, compared to similar conventional operations, and this is without counting carbon uptake, i.e. the ability of plant systems on farms with adequate plant cover to store carbon in the soil. If we consider this aspect, it can be said that extensive livestock farming can fully offset its emissions and even boast a carbon "credit"[42].

Product	lower emissions compared to a similar "industrial" product	CO_2 emissions (t./year)	CO_2 soil storage (t./year)
Mountain pasture cheese	-83%	126	1.161
Eggs from meadow hens	-35%	20	63
Hay milk	-31%	48	239
Extensively reared meat	-30%	180	748

In conclusion, we can say that the environmental impact of intensive livestock farming and industrial meat production is very high and we must make an effort to decrease it in order to reduce the pressure on depleted natural resources. At the same time, it must be recognized that sustainable livestock farming models are possible that involve open-air grazing on otherwise unused land, respect high animal welfare standards, and create high-quality products. This heritage must be safeguarded for environmental, cultural, social, and gastronomic reasons.

39 FAO, 2017. FAOSTAT http://www.fao.org/faostat/en/
40 Henderson, B., Gerber, P.J., Hilinski, T.E., Falcucci, A., Ojima, D.S., Salvatore, M. and Conant, R.T. (2015). Greenhouse gas mitigation potential of the world's grazing lands: Modeling soil carbon and nitrogen fluxes of mitigation practices. Agric. Ecosyst. Environ., 207, pp. 91-100. doi:10.1016/j.agee.2015.03.029
41 Grazed and confused? Tara Garnett, Cècile Godde et all. FCRN Food Climate Research Network, Oxford Martin Programme on the Future of Food, Environmental Change Institute, University of Oxford (2017)
42 INDACO2 e SLOW FOOD "Buoni per il pianeta, buoni per la salute" (2018)

Economic aspects

Being independent of climate, soil quality, and production area, cultivated meat—if available at low cost on the market—could theoretically provide access to a protein diet for a larger segment of the world's population.

It could also allow for a reduction in the prices of some products (primarily cereals) used for animal feed; cereals are the basis of the diet of many people in poor countries.

In some ways the effects would also be positive in terms of reducing food waste: Only the meat cuts required by the market would be produced and the problem of using the whole carcass of the animal would no longer arise.

The "normal meat production process" yields large quantities of by-products that cannot be used as food for humans (about 50-60% for a bovine animal): head, viscera, bones, hooves, intestines, cartilage, feathers, and glands. However, it is not entirely accurate to speak of this as waste, since it is possible to use all of a bovine carcass once you take into account pet food, biogas, hides and skins, prostheses for the medical and dental industry, additives for various types of industrial production, etc.

Ethical aspects

The obvious ethical aspects of cultivated meat should attract the interest of those who reject the consumption of animal meat[43]. A study has estimated that the number of animals whose slaughter could be avoided each year thanks to the use of cultivated meat is 7.5 billion in Europe and 9.1 billion in the USA[44].

Cultivated meat, however, cannot automatically be defined as cruelty-free, because cells are also taken from animals that have already been slaughtered.

The practice of extracting the serum used as a growth medium to develop the cells themselves is also objectionable for those who reject the slaughter of animals. It is taken from the heart of the calf fetus when the mother is slaughtered, causing pain and discomfort to the fetus[45].

But beyond some technical aspects, which could be solved with time, some people point out that human beings should develop the awareness that it is cruel, useless, and disgusting to feed ourselves with other sentient beings and to tolerate their suffering and death for a need that is not real and that can be eliminated by consuming food of vegetable origin.

According to this view, it is likewise absurd to eat a simulacrum of flesh and to dedicate financial resources and energy to a morally unacceptable food [46].

43 Vegetarian Meat: Could Technology Save Animals and Satisfy Meat Eaters? P.D. Hopkins & A. Dacey, (2008)
44 Farm Animal Statistics: Slaughter Totals. Humane Society of the United States (2015) and Agricultural Production Animals, Eurostat (2016)
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Health aspects

Cultivated meat, being produced in controlled and sterile environments, is less subject to biological risks, such as contamination or disease, which are frequent in industrial animal husbandry.

It does not contain antibiotics, the inappropriate use of which in world livestock farming systems is the main cause of antibiotic resistance, a source of great alarm in the world scientific community[47].

If we take plant-based meat into consideration, it tends to have a lower content of saturated fat, cholesterol, and calories and, often, a higher content of micronutrients such as zinc, calcium, and iron compared to conventional meat[48]. Theoretically, plant-based alternative meats could include additional healthy components and also lower overall calorie intake[49]. However, some consumers are concerned about excessive salt content and the wide use of additives.

Also, the biotechnological processes necessary to produce these substitutes often use genetically modified products/ingredients[50]. There is no data to show that there is no risk at all in the consumption of food obtained from genetically manipulated ingredients or adjuvants, especially with regard to the long-term transmissibility of such genes, nor is there scientific evidence of their harmfulness.

Only with time will it be possible to evaluate the effects of consuming GM products, although even assessing their consumption will be difficult, since the law does not require labels to indicate the presence of certain ingredients. Slow Food's opposition to GMOs is well known, and this issue has been at the center of important campaigns[51].

Producers are often hesitant to communicate information about their products, claiming the right to keep certain commercial information (CBI) confidential, and hindering reviews by independent institutions and associations.

Friends of the Earth denounced the government mechanisms that authorized the Impossible Burger in the USA. The US Food and Drug Administration (FDA) had warned Impossible Foods that evidence for the safety of a key ingredient in the Impossible Burger, leghemoglobin (SLH), was inadequate. SLH had never been introduced into the human diet before. The production of SLH with genetically modified yeast had, in fact, led to the production of 46 unexpected proteins, some unknown, which Impossible Foods did not identify and whose safety was not assessed.

Altering an organism at the genetic level can create unexpected changes in the organism itself, as well as in the products it generates. Alternative foods produced by genetic engineering may therefore present unexpected health risks due to off-target effects and genetic mutations. Safety assessments in some countries are inadequate and there is no mandatory regulatory control for these rapidly evolving new technologies[52].

The regulations of the United States Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the FDA do not address the health and environmental and safety impacts of new genetic engineering applications, editing techniques (e.g. CRISPR technology), and products derived from them.

Theoretically, such mutations could lead to the unexpected production of toxic by-products that could have an impact on human health, for example by causing allergic reactions in consumers[53].

Then there are the current rules of protection and control, which, in the context of the United States, are not sufficiently secure. Many guidelines are voluntary and the FDA leaves it up to the manufacturers to adopt them. One example is the procedure for obtaining "safe" (GRAS) status for food additives, which is only controlled by companies (meat substitutes contain many). The USDA has a control role only on animal health and inspection in slaughterhouses and production and packaging facilities[54].

The high level of secrecy regarding the ingredients and techniques developed to obtain products highly similar to conventional meat, the use of GMOs by some producers in certain phases of the production process, and the high level of processing and added ingredients necessary for these products negatively affect the judgment of many observers[55].

47 A recent report by the Interagency Coordination Group on Antimicrobial Resistance (IACG) to the United Nations states that antibiotic resistance could cause 10 million deaths per year by 2050 and catastrophic economic damage such as that caused by the global financial crisis of 2008-2009. The consequences could reduce up to 24 million people in extreme poverty (No time to wait: securing the future from drug-resistant infections. Report to the Secretary-General of the United Nations, 2019).

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55 Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture, Neil Stephens, Lucy Di Silvio, Illtud Dunsford, Marianne Ellis, Abigail Glencross, Alexandra Sexton (2018)

Legal aspects and transparency in the marketing of meat substitutes

Only substitutes obtained from plant cell reproduction are available for consumption today, in many countries. But while we wait to see flesh-like hamburgers made from animal cells hit the shelves, the legal battle to be able to call alternatives from cell-based agriculture "meat" is already underway, and heated. There are many disputes and lawsuits pending, particularly in the United States, where the largest companies of plant-based alternatives (Impossible Food and Beyond Meat) are based.

Since 2015, some operators in the sector, in particular the Good Food Institute (involved in advocacy for alternatives to meat), have been arguing for the need to call cultivated meat "clean meat" because it is more attractive to consumers and able to focus attention on its being "clean" rather than "cultivated"[56]. This definition is contested by breeders' associations because meat obtained from animal husbandry would therefore be perceived, by contrast, as "dirty" meat.

"Synthetic" meat or "artificial" meat, on the other hand, are rejected by the cultivated meat industry because they imply an unwanted connection with the synthetic biology sector[57]. Memphis Meats uses the more neutral tern "cell-based meat."

These ambiguities and disputes regarding names substantially reflect the ambiguity about what this product really is, as well as the different political sensitivities of the various players about its positioning. Names are important and can be decisive in alienating or engaging consumers.

In the USA, where the livestock sector involves almost 2 million farms[58], the Cattlemen's Association (USCA) has already officially requested that the Department of Agriculture (USDA) prohibit the use of the name "meat" for products that do not come from animals, filling a legislative vacuum in some states that producers of alternative meat take advantage of. In the absence of a federal law, a dozen US states have already passed laws in recent months saying that the name "meat" can be used on labels only if the meat comes from an "animal born, raised and slaughtered in the traditional way"; some associations and companies that produce alternative meat and use "meat" on their packaging have sued[59].

In early March 2020, the USDA and the FDA launched a framework agreement to regulate the production of synthetic meat, as demanded by meat substitute producers in previous years.

A law is essential to reassure consumers about the safety of new meat, to maintain competitiveness with other countries at the forefront of research (Israel, The Netherlands, etc.), and to capture more investment in research, both private and public. A law—and a name to be put on labels—would prepare a market for these products. A federal law can also harmonize the legislative initiatives of individual states, which until now have favored breeders' associations, blocking requests to use the word "meat" for alternative products.

56 Clean meat consumer survey: Public is hungry for clean meat! Bruce Friedrich (2018) Good Food Institute
57 The to-do list for "clean" meat. Melody M.Bomgardner. C&EN Whitepapers (2018)
58 https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf
59 U.S. Cattlemen's Association (2018), 'Petition for the imposition of beef and meat labelling requirements: to exclude products not derived directly from animals raised and slaughtered from the definition of "beef" and "meat"' (2018)

In the European Union only a product derived from slaughtered animals can be called “meat”.

In October 2020 the European Parliament rejected a request from European meat industry representatives to make it impossible for producers of plant-based alternatives to use terms like hamburger, sausage, meatballs and steak for their products (a ban already in place in France). This decision means it will still be possible for producers to label vegetarian and vegan options with names like veggie burgers, vegetarian sausages, lentil meatballs or soy steaks.

In the past the demand to ban the names milk and butter for dairy substitutes made from plants was successful and the prohibition for this category of products is still in place, but times have changed and a different approach was chosen for meat. As the European Parliament has voted against an EU-level regulation, it will now be up to individual countries to decide how to regulate their markets and protect consumers.

This is not an insignificant matter: The name used for plant-based substitutes and cultured meat, and the labelling regulations for their marketing, can generate confusion in consumers about the origin of the ingredients used or their nutritional properties and influence their ability to make conscious choices. Slow Food has been campaigning for years for more clarity and complete information on food labels, even if this now means finding itself in uncomfortable company with those who, like the meat lobby, are using this argument to fight the initiatives of the vegan and vegetarian movements. The reasons for taking this position are however radically different: Slow Food prioritizes protection for consumers, who have the right to shop for products whose names correspond correctly to the ingredients used in the production process, just as they have the right to know all the details of the production chain. Clear and complete information is also in the interests of those virtuous producers who want to communicate the value of their products to consumers. On the contrary, the meat industry lobby have no interest in adding information to labels that might inspire consumers to make a deeper reflection on their choices.

More or less favorable regulations in terms of labelling and food legislation, supportive financing policies, public investment, and communication campaigns to persuade meat consumers to switch to alternatives will all play a role in determining the future of what is expected to be a great new business. According to a survey carried out in the US in recent months, 95% of those who buy a vegetable hamburger in a fast-food restaurant are regular meat consumers[60].

To go deeper:

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Our Meatless Future: How The $1.8T Global Meat Market Gets Disrupted. CBInsights (2019)

60 https://www.npd.com/wps/portal/npd/us/news/press-releases/2019/quick-service-burger-buyers-mix-it-up-between-plant-based-and-beef/

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