Drivers of change

# Artificial meat and the environment

An appealing innovation with highly uncertain potential to reduce greenhouse gas emissions and enable more sustainable use of natural resources.

**Globally, the consumption of animal-based foods is expected to increase in the coming decades because of the combined effects of several global megatrends.** The global population increased from 2.5 billion in 1950 to 7.7 billion in mid-2019 and is expected to reach 9.7 billion people in 2050 (UN, 2019). Meanwhile, global economic development, urbanisation and globalisation are leading to the rise of a more affluent global middle class with changing eating habits (EEA, 2015). In particular, populations in Asia are shifting from traditionally vegetarian diets to those containing increasing amounts of meat and dairy products. Overall, the global demand for meat and dairy products is expected to grow by 73 % and 58 %, respectively, in the period 2010-2050 (FAO, 2011).

**As livestock farming is responsible for a significant share of environmental pressures and greenhouse gas (GHG) emissions, these projections are worrying.** Approximately 26 % of the planet's ice-free land is used for livestock grazing and 33 % of all croplands are used to grow animal feed (FAO, 2018a). Livestock supply chains are also estimated to be responsible for emissions of 7.1 gigatonnes of CO2 equivalent per year, representing 14.5 % of all anthropogenic GHG emissions (FAO, 2018b). Cattle (raised for both beef and milk) are responsible for about 65 % of these emissions, and about 44 % of livestock emissions are in the form of methane (FAO, 2018b).

**International organisations increasingly acknowledge the need to reduce emissions by the livestock sector** and a number of interventions are proposed (FAO, 2018b). For instance, the Food and Agriculture Organization of the United Nations (FAO) considers that possible interventions are 'to a large extent, based on technologies and practices that improve production efficiency at animal and herd levels', complemented by more circular and energy-efficient manure management practices and grassland carbon sequestration (FAO, 2018b). Other stakeholders are considering very different and innovative approaches to meeting the growing demand for meat. **One idea is to offer consumers a food product that is not traditional meat but has similar nutritional value and taste**. Combining environmental concerns with a rationale based on health benefits, animal welfare and business opportunities, laboratories and entrepreneurs are exploring **new and innovative sources of food for the 21st century**.

The term '**artificial meat**' appeared in the early 2000s and **referred originally to food produced from certain plants that, after transformation, would taste very similar to traditional meat**. The first wave of 'artificial meat' was made from soya beans, wheat or other kinds of legumes, cereals or fungi. In Europe, this trend has been largely popularised with the increase of vegetarianism and veganism (Hancox, 2018). **Today**, however, **'artificial meat' increasingly refers to meat produced by a new process, in which the meat is prepared from the stem cells of real meat from living animals**. Other names commonly used are 'in vitro meat', 'cultured meat', 'lab-grown meat', 'synthetic meat' or 'clean meat':

> In-vitro meat involves injecting muscle tissue from an animal into a cell culture, allowing cells to'grow' outside the animal's body.
>
> Lee, 2017

The stem cells, selected according to their reproduction rate, are put into a serum in which they start to grow and multiply. An edible scaffold is used to orient this growth and form a three-dimensional structure. A few months are sufficient to produce meat suitable for eating. The process is much quicker than traditional meat production, which often requires more than a year. Under ideal conditions, two months of in vitro meat production from a few muscle cells from a pig could deliver thousands of tonnes of pork meat.

**Although the technology is just emerging and is still subject to limitations, it is not science fiction**. In 2013, Mark Post, a professor at Maastricht University, presented the first cultured hamburger prototype and then created a company, Mosa Meat, with the aim of bringing the product to market by 2021 (BBC, 2013). Since then, many other start-ups and laboratories have started investing in this field (Cell Based Tech, 2019). At a country level, China even signed a USD 300 million deal with Israel to import laboratory-grown meat from three Israeli companies (EPRS, 2018).

## Overall implications (non-environmental)

If the technology develops as expected, the significance of artificial meat will largely depend on its acceptance by consumers (Hocquette, 2016; Johnson et al., 2018). Controversies similar to those encountered for genetically modified organisms (GMOs) will most probably occur, although the parameters and boundaries differ. Some polls run in the United States indicate a rather negative, or at least suspicious, perception of artificial meat at present. Indeed, 48 % of respondents would not 'purchase foods that look and taste identical to meat, but are based on ingredients that are produced artificially', while 33 % would (MSU, 2018). However, another survey shows a strong interest in trying in vitro meat (65 %) but much less in eating it on a regular basis (30 %) (Wilks and Philips, 2017).

Several factors can work against the acceptance of artificial meat, notably its high price, the 'unnaturalness' of the product, scepticism about the taste and concerns about the safety of associated production processes (Hocquette, 2016). Today, production costs are simply too high for artificial meat to be affordable. As an order of magnitude, the first hamburger grown by Maastricht University in 2013 cost EUR 250 000. However, production costs are falling and companies such as Mosa Meat expect the production cost of a hamburger to fall below EUR 10 by 2020, which would start making them competitive (Le Monde, 2019). What remains costly in production processes is the use of fetal bovine serum (an animal by-product offering optimal conditions for growth) in the culture medium, which stimulates the growth of stem cells. Finding an alternative is one of the main research topics at present.

If artificial meat were to become mainstream, it could have a number of significant impacts on society and the economy. From a health perspective, in vitro production could offer ways to control the composition of meat and make it healthier (Post, 2012). 'Animal products are the human diet's primary source of saturated fat, which is linked to health problems such as heart disease and strokes' (EPRS, 2018). The fat content of laboratory-grown meat could be set to recommended levels, and unhealthy saturated fat could be replaced with healthier omega-3 fatty acids. Additional healthy ingredients such as vitamins could even be included in the meat (Bhat et al., 2014).

Antibiotics are widely used in livestock to prevent disease, which puts humans at higher risk of infection from antibiotic-resistant microbes (Sachan, 2016). Artificial meat would not be so dependent on the use of antibiotics, as meat would be grown in sterile conditions from the stem cells of healthy animals (i.e. those not being treated with antibiotics). A similar reasoning could apply to the use of hormonal substances for growth promotion, which are sometimes used to raise bigger animals in some non-EU countries (the EU has largely prohibited their use). However, growth hormones could also be used in the culture medium for artificial meat. Adopting stricter control procedures during in vitro production processes, compared with many existing factory farms and abattoirs, could lead to a decrease in zoonotic and food-borne diseases.

Artificial meat production would also lead to better welfare for animals. The need to raise fewer, but very healthy, animals to provide high-quality stem cells would lead farmers to secure better living conditions for their livestock (i.e. larger spaces, fresh air, natural food). These different implications are still very debatable but 'they address the expectations of today's society perfectly' (Hocquette, 2016), which helps to explain the current hype around this technology. As for other emerging technologies, 'proponents of artificial meat have understood very well the issues and have developed a convincing communication strategy around them' (Hocquette, 2016).

The wider uptake of artificial meat consumption may also have some negative implications. From a socio-economic perspective, the agricultural sector could be badly affected by reduced employment in livestock farming. This could be particularly detrimental to farmers, and associated households and communities, who would not be able to meet this new demand or to shift their activities towards other form of agricultural production. Chemical and pharmaceutical firms could also be affected financially because of a decreased use of fertilisers and medicines and they might, therefore, resist the change. Another concern relates to the use of animal-based serum during in vitro meat production, as it involves the risk of contamination at a larger scale (Orzechowski, 2014). As for many technologies, rebound effects could be observed. In particular, ‘a perception that cultured meat is healthier than agricultural meat could lead individuals to overconsume fat and protein at the expense of a healthy and balanced diet’ (Mattick et al., 2015). Artificial meat also raises other questions such as ‘do meat alternatives need to resemble meat?’ or ‘is it cannibalism if we eat lab-grown human meat?’ (Forbes, 2019).

## Implications for the European environment

Today, artificial meat is generally perceived as an environmentally friendly alternative to livestock farming. One extensively cited study by Tuomisto and de Mattos (2011) has been particularly influential in the emergence of this viewpoint (Mattick et al., 2015). This anticipatory life-cycle analysis (LCA) shows that, ‘in comparison to conventionally produced European meat, cultured meat involves approximately 7-45 % lower energy use (only poultry has a lower energy use), 78-96 % lower GHG emissions, 99 % lower land use, and 82-96 % lower water use depending on the product compared’ (Tuomisto and de Mattos, 2011). However, these results remain subject to huge uncertainty, as the assumptions about this emerging technology, its associated production processes and related systemic effects are ‘plausible scenarios’ rather than projections.

More recently, another study analysing the long-term climate implications (up to 1 000 years) of cultured meat versus meat from cattle challenged some of these results. It differentiated more specifically the expected impacts on climate of different GHGs, namely methane ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$). Methane has a greater radiative forcing effect (i.e. effect on the atmospheric energy balance) but remains in the atmosphere for only about 12 years, while $CO_2$ persists for millennia. According to this study, artificial meat production is more energy intensive, so it could lead to more warming than cattle production if energy for in vitro production systems continues to be generated from fossil fuels (Lynch and Pierrehumbert, 2019). As for many technologies, much of the reduction of artificial meat’s climate impact depends on the use of renewable energy sources.

As livestock farming takes up a huge amount of land and water per calorie of food compared with crops, a shift towards artificial meat production could theoretically reduce pressures on water and land resources (Mattick et al., 2015). Based on a number of anticipatory LCAs, Stephens et al. (2018)

conclude that ‘cultured meat could deliver reduced water use, greenhouse gas emissions, eutrophication potential, and land use compared to conventional livestock meat production.’ One study shows that artificial meat could have ‘less environmental impact than beef, and possibly pork, but more than chicken and plant-based proteins’ (Smetana et al., 2015). However, these LCAs are speculative as they are ‘all based upon hypothetical models of what form cultured meat production might take’ (Stephens et al., 2018). Further monitoring of associated technological developments is needed to complement these speculative models.

Artificial meat production centres could be located in areas where water can be managed sustainably. More land could be used sustainably or even returned to wilderness, helping to increase biodiversity and protect endangered species (Bhat et al., 2014). On the other hand, there are areas that benefit environmentally from traditional forms of cattle and sheep breeding, such as mountain pastures during summer, especially in the Alps, Pyrenees or Carpathian Mountains. More generally, turning our back on livestock farming could have important implications for rural areas and local ecosystems, which remain hard to predict. Another question is whether artificial meat will further disconnect society from nature or increase our respect for it.

## Implications for environmental policy in Europe

Artificial meat production can potentially support the achievement of many social, economic and environmental goals emphasised in the EU’s Seventh Environment Action Programme (e.g. protecting natural capital), the bioeconomy strategy (e.g. slowing down land degradation) and the Sustainable Development Goals (e.g. improving food security), as well as promoting the transition to a low-carbon economy (EU, 2013; UN, 2015; EC, 2018).

However, artificial meat production remains an emerging technology at an early stage of development. At present, ‘the environmental impact of artificial meat is difficult to evaluate because it is based on speculative analyses’ (Hocquette, 2016).

Environmental policymakers should be involved in this technological development process to ensure that future artificial meat production processes are sustainable. This includes the need for more systemic assessments of this technology, based on LCA and monitoring, to mitigate unintended environmental consequences.
If the technology develops well, policies such as the common agricultural policy would be directly affected, necessitating support to farmers as they transition away from livestock farming.

This brief belongs to a series of ‘rapid assessments’ on the implications of emerging trends for the environment and environmental policies in Europe. The identification of the topic results from a participatory horizon-scanning process run by experts from the Eionet National Reference Centres on Forward Looking Information and Services (NRC FLIS) during the period 2018-2019. The brief was drafted with support from the European Environment Agency (EEA) and the European Topic Centre on Waste Materials and the Green Economy (ETC WMGE). It is conceived as a living document that should be enriched through interactions with other knowledge communities and stakeholders, and evolve according to technological developments.

Type of signal: **Weak signal**

Geographical scope: **Local, regional, national, European, global**

Origin of signal: **Technological**

Time horizon of expected significant impact: **Mid- to long-term**

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## Main related EU policies

- Common agricultural policy
- Common fisheries policy
- Environment action programme to 2030
- Bioeconomy strategy
- Directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms
- Horizon Europe

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