

# IN VITRO AS AN ALTERNATIVE TO MEAT

Santhya Sivaruban,  
Niklas Utermann  
and Felix Vittori, 4e

Basel May, 2019

# Contents

1. Preface .....	2
2. Introduction .....	2
2.1 Background .....	2
2.2 Why and where is the technique used? .....	3
2.3 Alternatives to in vitro meat .....	3
3. Description of engineering technique .....	4
3.1 Application of method .....	4
3.2 Graphs and Figures .....	5
4. Interview .....	7
5. Discussion .....	8
5.1 Ethical aspects.....	8
6. Summary.....	9
7. References.....	10

## 1. Preface

Since we are all three meat lovers, but at the same time very ecologically thinking people, we have to look for alternatives to our beloved meat. We have tried many different things, but if we are honest with ourselves, nothing comes close to real meat. So we were all very excited when we heard about something known as Cultured Meat or In Vitro Meat. Therefore, we decided to expand our knowledge on this topic by researching and writing a biology term paper about this topic. What fascinated us most about this subject was that it is possible to grow something that our body produces, a muscle, in a petri dish. We thought that this would mean that we could consume meat without having to harm any animals or damage the environment.

Questions which we have in regard to this subject are as follows: How ecological is in vitro meat really? How does it compare to conventional meat? How does it compare to plant-based meat alternatives and when will it be accessible to the general population?

## 2. Introduction

### 2.1 Background

It all began with Mark Post, a researcher at Maastricht University and CSO of Mosa Meat, when a Dutch company to launch the first in vitro (which stands for meat in a jar) burger. In Vitro meat is, as the name suggests, meat produced in a Petri dish. This means that you can eat an identical piece of meat as you would normally eat without slaughtering cows. The first in vitro burger presented in 2013 cost an astonishing 250,000 euros. This entire project was funded by the co-founder of Google, Sergey Brin. Due to the remarkable scientific breakthroughs, the price has fallen considerably in recent years and now costs about 10 euros per burger. Later, new companies such as Memphis Meat or SuperMeat emerged and began working on new types of meat such as pork, duck or chicken. Mosa Meat is even working on adding fats to the meat so that we can consume different cell types that an animal has to offer. This could be a whole new way on how we view on meat consumption as a whole and can influence many environmental factors. But before this happens, in vitro meat must adopt the European Food Regulation. Here you have to convince the authorities that your product and your production are safe. To do this, you need to carry out studies. However, people who are willing to take the risks of participating in the studies represent a minority. Another challenge will be the adaptation of cell culture systems to industrial standards.

### 2.2 Why and where is the technique used?

The demand for meat is growing rapidly. As the world population will reach more than 9 billion people by 2050<sup>1</sup>, the Food and Agriculture Organisation of the United Nations estimates that the meat demand will increase by more than two-thirds<sup>1</sup>. We simply do not have enough space and water to increase meat production as we already use most of the agricultural land for livestock and suffer from water scarcity to which livestock contributes significantly. To be more precise, about 80% of our agricultural land is used for livestock and beef, for example, requires 15,415 liters of water per kg of meat<sup>2</sup>. The increasing demand for meat is leading to increasing mass deforestation, leading to the loss of biodiversity. In addition, another issue is agricultural run-off. Through rain and irrigation, pesticides, fertilizers and pollution leave the farms and run into oceans and rivers. This can eventually, inter alia, kill coral reefs and marine life.

---

<sup>1</sup> <https://www.mosameat.com/benefits>

<sup>2</sup> <https://www.theguardian.com/news/datablog/2013/jan/10/how-much-water-food-production-waste>

These are some of the reasons why we must either find a more sustainable alternative or reduce our meat consumption. A possible alternative would be cultured meat, as its production is expected to consume 96% less water and 99% less land<sup>1</sup>. In addition, cultured meat does not require chemicals such as pesticides. Also cultured meat seems to be a better alternative as the production of conventional meat faces several other problems. The animal agricultural sector is responsible for 15% of global greenhouse gas emissions and 75% of the recent deforestation of the Amazon region.<sup>3</sup>

In addition, livestock contributes to global warming by emitting uncontrolled gases such as methane, which is a greenhouse gas about 20 times more potent than carbon dioxide.<sup>1</sup> In total, conventional meat accounts for 14.5%-18.5% of global greenhouse gas emissions.<sup>4</sup> Furthermore, over 70 billion animals are reared and slaughtered every year. Most animals suffer from inhuman conditions. For example, they are forced to live in the narrowest places, and since these places are not sterile, antibiotics are used for disease prevention in animals.

Excessive use of antibiotics also poses a threat to human health, leading to problems such as the more rapid spread of antibiotic-resistant bacteria. However, cultured meat is produced in a closed and sterile environment and is therefore free of antibiotics. With cultured meat, it is not necessary to use any artificial growth hormones or any kind of genetic modification. It generates up to 96% less greenhouse gas emissions,<sup>1</sup> helps us to reduce significant environmental impacts and avoid unethical livestock farming.

Cultured meat is not yet commercially available. Despite the progress made, there are still some hurdles to be overcome to bring cultured meat onto the market. One of the problems is the cost of each stage of the process. Although production prices and costs have fallen sharply and are expected to continue to fall steadily to around 8.9 euros by 2020<sup>5</sup>, companies are still working on cultured meat products to cost as much as one of the cheapest conventional meat products on the market. Other problems include cell culture media, scaffolding and bioreactors. In cultured media, which serve as food sources for cell lines and stimulate cells to grow and divide, an animal-based serum is often used to grow the sample of cells. Since the extraction of an animal serum is very controversial and expensive, poses a risk of pathogen contamination and raises massive ethical issues from an animal welfare point of view, work is now underway to either replace this serum with a herbal alternative or perhaps even remove it completely. The scaffolding is of great importance as well as it is responsible for the production of meat in the right shape and proportion. The first cultured meat products consisted only of muscle cells. However, a realistic cultured meat product must contain the appearance, texture and taste of a conventionally produced meat product. While scientists are working on it, engineers need to develop large bioreactors that are necessary to produce enough cultured meat to make it commercially available on a large scale. Despite these problems, cultivated meat is expected to be widely available in the coming years.

## 2.3 Alternatives to in vitro Meat

The most common alternative is conventionally produced meat from animals. However, there are numerous problems with meat from animals, as mentioned above. Therefore, alternatives to conventional meat, such as plant-based and insect-based alternatives, have emerged.

As consumers become more aware of where their food comes from and some want to reduce their animal intake, the demand for plant-based meat alternatives is growing. Some established consumer choices such as vegan meat-like foods made out of quorn, seitan, tofu and others have gained popularity in recent years. Plant-based meat alternatives are usually much less resource consuming.

---

<sup>3</sup><https://core.ac.uk/download/pdf/38629617.pdf>

<sup>4</sup> Source: New York Times

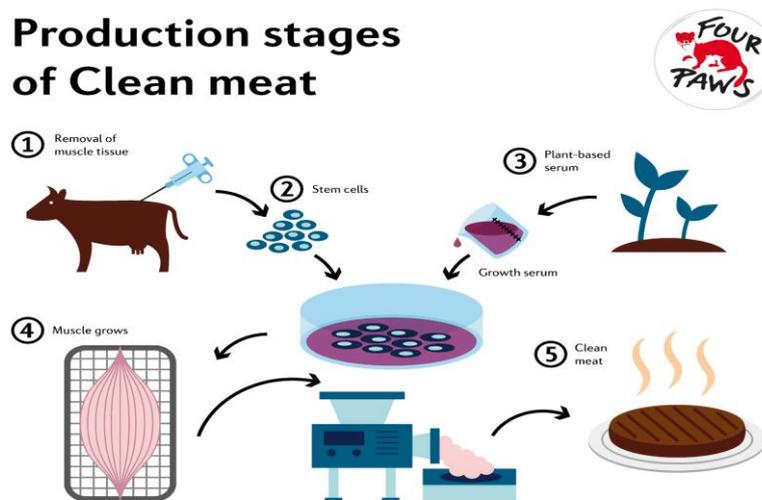
<sup>5</sup> <http://cleanmeat.org>

Impossible foods states that their vegetable burger consumes 96% less land, 87% less water and 89% less emissions.<sup>2</sup> Today, there are many companies that produce vegetable meat alternatives that many people can-not distinguish from meat. The problem with vegetable meat is the general acceptance by consumers, as these plant-based alternatives are usually not considered as „real“ meat. However, this could be a more sustainable and ethical alternative for our future. Insect-based alternatives are also a rich source of proteins. Although food neophobia is high here, when more sustainable harvesting practices are used, insect-based alternatives are seen as a good opportunity not only for us, but also for the pet food industry, to significantly reduce their environmental impact.

### 3. Description of engineering technique

#### 3.1 Application of method

Cultured meat is produced using tissue engineering techniques. The production of cultured meat consists of several steps (see picture 1). First, a tissue sample is taken from the muscle of an animal under anesthesia. A small biopsy is then performed to separate adult muscle stem cells, so-called myosatellites, from the sample. Satellite cells are cells that are activated in response to injury or stress and can regrow muscle cells. It is precisely this behavior that scientists use to grow muscle cells that eventually produce meat. They also differentiate sufficiently from other cell types and nevertheless have an acceptable proliferation rate (= cell multiplication rate), which is why they are frequently used.



Picture 1: The different Production stages of Cultured meat

In the second step, these cells are introduced into a growth medium that promotes tissue growth. This medium is usually a serum containing all the necessary nutrients, hormones, oxygen and naturally occurring growth factors to simulate the environment in the animal's body. This enables these cells to multiply as if they were inside an animal's body. The most common type of serum that scientists use to nourish the cells is fetal bovine serum (FBS), a nutrient-rich and protein-rich fluid derived from the blood of cow fetuses. Scientists are now trying to replace this serum with an animal-free media formulation or perhaps even remove it completely. The growth medium with the satellite cells is then placed in a bioreactor that is able to supply the cells with the required energy. This is where the growth takes place and the cells multiply until we receive trillions of cells.

In the next step, the satellite cells are starved with a different culture medium without the growth factors, which is why they differentiate themselves into muscle cells. More precisely, the satellite cells first differentiate into myoblasts and then into myocytes. These myocytes will then align naturally and merge into myotubes, which are primitive, multinucleated muscle fibers. The myotubes are then placed in a gel consisting of 99% water, which helps the cells form muscle fibers by promoting final differentiation. The innate tendency of the muscle cells to contract together with the tension produced by the gel causes the myotubes to further merge and bulk, eventually growing them into a small strand of muscle tissue. Thousands of muscle fibers are then combined and formed into a piece of meat as we know it. This meat can then be seasoned, cooked and eaten as boneless processed meat. Although many companies apply this basic principle, the process differs slightly depending on the manufacturing location.

### 3.2 Graphs and Figures

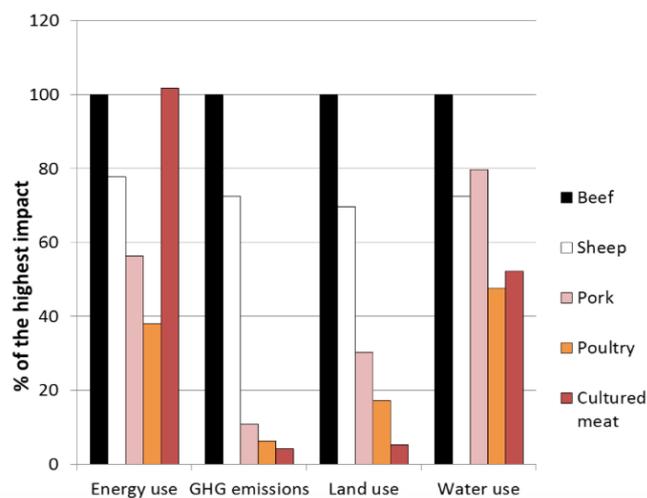


Figure 1: Comparison of environmental impacts of cultured meat with European livestock

In the first figure the direct comparison between livestock meat and cultured meat can be well observed in different aspects. In terms of land use requirements and the emission of greenhouse gases, cultured meat seems to have the smallest impact. However, cultured meat also seems to have the highest usage of energy and a higher usage of water compared to poultry. Even though cultured meat has the highest energy use, the carbon dioxide intensive processes used to produce cultured meat, can be replaced by processes that make use of renewable energy. This shows that it is a more sustainable alternative to conventional meat.

Figure 2 and figure 3 (seen on next page) compare the GHG emissions and the land use of cultures meat with animal and plant-based protein sources, which are also seen as a more sustainable alternative to cultured meat. Cultured meat seems to be at the same level as plant and animal-based protein sources with the lowest land use and global warming potential. As shown above, pulses seem to be the plant-based protein source with the smallest carbon footprint but has larger land use requirements than other meat substitutes, which have a higher carbon footprint.

Regarding animal-based proteins beef seems to have both the highest land use as well as the highest global warming potential compared to all the protein sources listed in figure 2 and figure 3. However, poultry seems to have the smallest global warming potential and land use compared to all other types of meat listed above. In general, poultry seems to be the meat type with the lowest impact on the environment. However, other important aspects such as unethical livestock farming or the use of antibiotics is not considered in these figures.

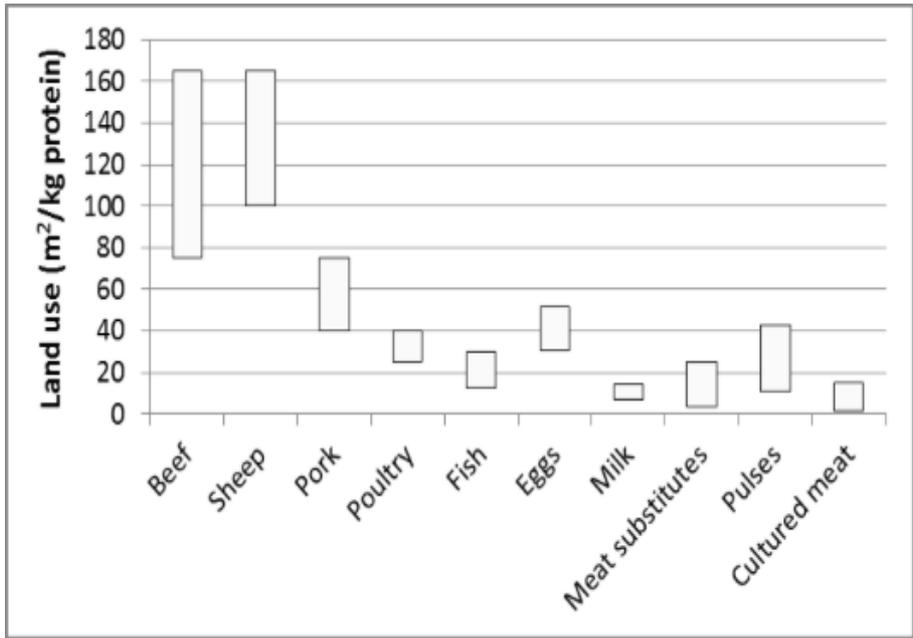


Figure 2: Comparison of environmental impacts of cultured meat with European livestock meat

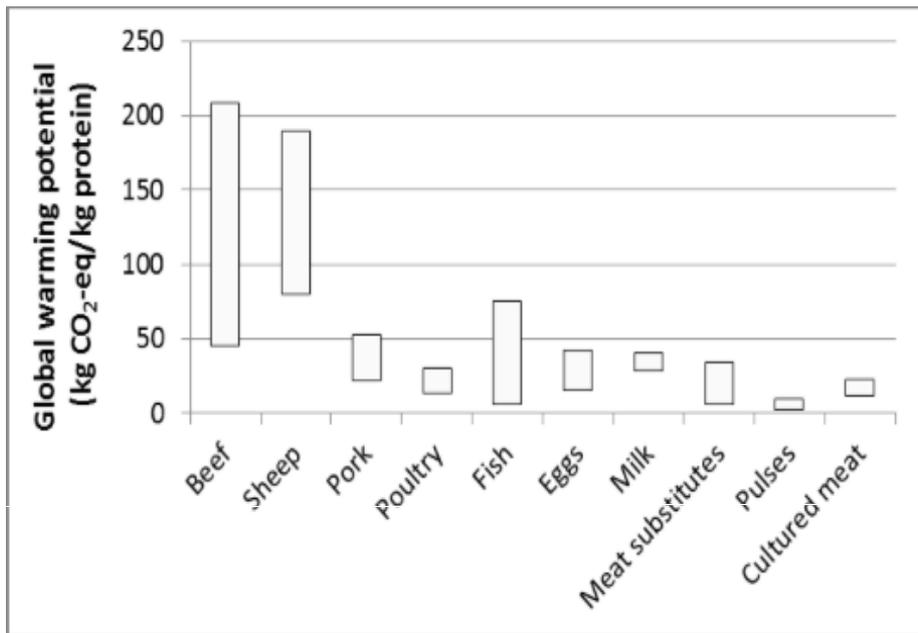


Figure 3: Comparison of GHG emissions of cultured meat with animal and plant based protein sources

## 4. Interview

The following questions were answered by Markus Hardegger, Head of the Genetic Resources and Technologies Department in the Federal Ministry of Economics, Education and Research (WBF) and the Federal Office for Agriculture (BLW). The answers were translated and adapted. The sense of the answers has been taken over.

### **Can in vitro meat prevail over meat? (price, social)**

Too complicated a question, since no one knows the future. There are several points that in vitro meat must meet in order to be successful. The taste, which must be very similar to the taste of normal meat, the price and the delivered values. In vitro meat can certainly score points with low green-house gas emissions. How much more the consumer is willing to pay for it cannot be said.

### **Will in vitro meat replace normal meat?**

I'm sure in vitro meat will find its niche. This means that a group of consumers will certainly replace normal meat with in vitro meat. For example in raw meat dishes. How large this group will be is uncertain.

### **Will in vitro meat prevail over other meat alternatives?**

This depends on the classification that consumers make in terms of taste and price or economically discussed by the price-performance ratio.

### **Could in vitro meat be part of the solution to climate change?**

You can already produce energy ecologically today (hydropower, photovoltaics, wind). More important is the reduction of greenhouse gases during in vitro production compared to production with animals (methane, ammonia, CO<sub>2</sub>, water, etc.).

### **When will in-vitro meat be available to regular consumers in Switzerland?**

This won't be the case for some time. It strongly depends on the success of American start-ups.

### **Is cultivated meat safe?**

I'm quite sure that the safety of in vitro meat is high. Certainly, better than the safety of meat from farm animals.

### **Is in vitro meat "real" meat?**

Yes, it is possible for cell cultures to become muscles nowadays. Muscles are "real" meat.

### **Does cultivated meat have the same nutritional values?**

Approximately yes. Proteins form the muscle fibers and are therefore the main component of the meat respectively the nutritional value.

### **Does in vitro meat have the same texture and taste?**

I cannot say as I have never tried it. Theoretically, it is not possible to make the texture and taste 100% identical. However, I think that it will be possible to reach a point where the normal consumer will not recognize any differences.

### **What potential do you see in cultivated meat?**

Personally, I see potential in raw meat dishes, such as steak tartare, for reasons of product safety, as in vitro meat has to be produced sterile.

## 5. Discussion

The progress that can be made with in vitro meat is quite clear: less greenhouse gas emissions compared to the production of conventional meat, less use of antibiotics in animals, fewer killing and torture of animals and many more. Of course, all these problems would not be completely solved. Even if in vitro meat were to replace all meat production, dairy products would still be in production. And the dairy industry causes exactly the same problem. With the exception of the non-breeding of animals for the purpose of subsequent slaughter. In addition, cultured meat also has its problems, which must be solved or minimized. An example of one of these problems is the animal serum with which the cells grow.

Although in vitro meat still has some problems to solve, in our opinion this alternative is still better than the way the meat industry works today. As mentioned earlier, not all problems with cultured meat are solved. However, they are minimized to a certain extent to which it is acceptable. Another question that arises is what it looks like compared to other meat alternatives.

The first point is that it is possible to emit even fewer greenhouse gases if the carbon-intensive process of producing cultured meat is replaced by processes that use renewable energies. Therefore, the CO<sub>2</sub> footprint of cultured meat depends on the used energy source. A further point to consider is the use of water, which is very high in in vitro meat and thus also contributes to water scarcity. Whether in vitro meat production manages to reduce water consumption and starts to make use of renewable energy, will determine the sustainability of in vitro meat. A great potential of in vitro meat is that it is very little dependent on agriculture and does not require much space. Whether in vitro meat is a more sustainable alternative than plant-based meat alternatives cannot be generally said. However, there is great potential for cultured meat that, which is why in theory it is very sustainable. Whether this potential can be transferred to practice cannot be predicted.

Future research steps include the creation of more diverse meats with the addition of fats that appeal to larger consumer groups. This will lead to an increase in production, which will hopefully lead to a reduction in conventional meat production. However, in order to achieve a large-scale production of cultured meat, it is necessary to find and choose the configuration of the bioreactor that offers a suitable physiological environment. Costs, water consumption and energy efficiency must also be reduced.

The meat is expected to be available in America by 2021.

### 5.1 Ethical aspects

Cultured meat solves or at least minimizes many ethical problems associated with the production of conventional meat. Almost no animals are injured during production and fewer animals are kept in captivity. There would be no need for forced feeding and excessive use of antibiotics, which would ultimately benefit human health, as the likelihood of bacteria becoming resistant would be lower. These animals would also not have to be kept in the narrowest places, which are not sterile. Not only can this be avoided with cultured meat, but there would also be fewer forced pregnancies and no need to raise animals just to kill them as quickly as possible to eat their meat. In general, animals could lead their lives in a more natural way without the use of chemical substances under more natural circumstances.

But even cultured meat has its ethical disadvantages. Scientists today use an animal-based serum to cultivate the cell sample. An example of an animal-based serum would be fetal bovine serum, which is a fluid obtained from the blood of cow fetuses by injecting a needle directly into the heart, which then sucks out the blood of the fetus until it finally dies. This method is very unethical, which is why alternatives are being tested to replace this serum with a herbal alternative.

Another disadvantage is that people who have worked in the meat industry can lose their jobs. Cultured meat is also not produced in a natural way, which could have a negative impact on customer acceptance. Finally, it is important to note that no long-term studies with cultured meat have yet been carried out, which is why it might have some negative long-term effects.

## 6. Summary

In vitro meat is produced by the painless collection of a sample of muscle cells from a living animal. The scientists then extract stem cells from the sample and cultivate them in a growth medium that promotes tissue growth. The resulting muscle tissue can then be cooked and eaten.

Since many issues are associated with conventional animal agriculture, such as the excessive use of antibiotics and unethical livestock farming, a more sustainable alternative has been invented. With in vitro meat, we can help reduce the negative impact of conventional meat while feeding our growing population without sacrificing our beloved meat. While in vitro meat can minimize almost all ethical problems of meat, it cannot be predicted whether it is sustainable enough to replace meat, compete with other meat alternatives and be accepted by consumers.

Although the first in vitro burger was launched in 2013, it is not yet commercially available and will not be in the coming years, as in vitro meat still has some problems to overcome, such as improving the scaffolding to match the appearance, taste and texture of conventional meat. In short, in vitro meat has great potential to solve many problems, but its future is still very uncertain.

Our conclusion on this subject is as follows: In vitro meat is a better alternative to conventional meat and comparable to other meat alternatives, if not sometimes better. In general, it is difficult to compare in vitro meat with plant-based meat alternatives and say which is better, as they both have their advantages and disadvantages in different categories such as environment and human health. In addition, there are many different meat alternatives on the market, so it would be inadmissible to say that one alternative is in general better than the other. In vitro is by no means perfect, but it is as close as possible. It still has some hurdles to overcome. But it is safe to say that better for the environment and good for consumers as it has about the same nutritional value as conventional meat.

## 7. References

- ABC: <https://www.abc.net.au/news/rural/2018-05-06/vegan-alternative-plant-based-meat-grown-in-lab/9726436> 01.05.19
- Clean meat: <http://cleanmeat.org> 01.05.19
- Cleantech: <https://www.cleantech.com/alternative-proteins-cultured-meats-and-the-buzz-about-bugs/> 02.05.19
- Core: <https://core.ac.uk/download/pdf/38629617.pdf> 01.05.19
- Cultured beef: <https://culturedbeef.org/facts-about-cultured-meat> 02.05.19
- Draxe: <https://draxe.com/lab-grown-meat-food-technology/> 02.05.19
- Frontiers: <https://www.frontiersin.org/articles/10.3389/fsufs.2019.00005/full> 30.04.19
- Labiotech: <https://labiotech.eu/infographics/cultured-meat-infographic/> 30.04.19
- Mosa meat: <https://www.mosameat.com/benefits> 30.04.19
- Mosa meat: <https://www.mosameat.com/technology> 01.05.19
- Mosa meat: <https://www.mosameat.com/our-story> 01.05.19
- New harvest: [https://www.new-harvest.org/environmental\\_impacts\\_of\\_cultured\\_meat](https://www.new-harvest.org/environmental_impacts_of_cultured_meat) 30.04.19
- New harvest: [https://www.new-harvest.org/faq#/what\\_is\\_cultured\\_meat](https://www.new-harvest.org/faq#/what_is_cultured_meat) 01.05.19
- New harvest: [https://www.new-harvest.org/environmental\\_impacts\\_of\\_cultured\\_meat](https://www.new-harvest.org/environmental_impacts_of_cultured_meat) 01.05.19
- Scientific American: <https://www.scientificamerican.com/article/lab-grown-meat/> 01.05.19
- The Good Food Institute: <https://www.gfi.org/clean-meats-path-to-commercialization> 30.04.19
- The Good Food Institute: <https://www.gfi.org/why> 02.05.19
- Wikipedia: [https://en.wikipedia.org/wiki/Cultured\\_meat](https://en.wikipedia.org/wiki/Cultured_meat) 02.05.19
- Picture 1: <https://www.four-paws.us/campaigns-topics/topics/nutrition/clean-meat>
- Figure 1: [https://www.new-harvest.org/environmental\\_impacts\\_of\\_cultured\\_meat](https://www.new-harvest.org/environmental_impacts_of_cultured_meat)
- Figure 2: [https://www.new-harvest.org/environmental\\_impacts\\_of\\_cultured\\_meat](https://www.new-harvest.org/environmental_impacts_of_cultured_meat)
- Figure 3: [https://www.new-harvest.org/environmental\\_impacts\\_of\\_cultured\\_meat](https://www.new-harvest.org/environmental_impacts_of_cultured_meat)