Frequently asked questions

Content

1. What is the current price of a hamburger made from cultured beef?

As production is not at scale yet, it is difficult to say. We expect the price to be in the 10 USD range per hamburger once the production is at scale, using the current technology. With improvements in the technology, which are already foreseeable, the price will come down further to competitive pricing with traditional beef. Eventually it may even become cheaper as less resources are required to culture beef than to produce it through livestock

2. When do you expect market introduction of a cultured beef hamburger?

3-4 years for the first introduction, most likely in restaurants and specialty stores. Another 2-3 years for supermarket introduction

3. What have you been working on since the launch in 2013?

   a. We have worked on 4 areas:
   b. Improving the protein content, most notable myoglobin, giving the meat its red color and heme-iron content. We have been quite successful in that.
   c. Culturing fat tissue. These are cultured from the same stem cells but follow a different path towards specialization. Fat adds taste and texture to meat. Of course, one wants to limit the amount of fat, which we can very precisely do.
   d. Eliminating serum from the culture medium. This has been reasonably successful but is not quite optimized yet. It is very important to eliminate serum from the culture medium as serum requires large numbers of animals (calves), is undefined and may carry diseases.
   e. Designing and optimizing culture methods that are scalable to industrial scale

4. Is cultured meat real tissue or just a heap of cells?

It is real tissue that under the microscope is indistinguishable from muscle fibers taken from a steak. The cells form that tissue through self-organization. They first merge into large, primitive muscle fibers (myotubes), then they spontaneously align and start to contract, thus forming a firm muscle fiber.

5. Are you culturing cells with antibiotics and fungostatic drugs?

No, we are able to culture without those agents. Our infection rate has not gone up and has stayed very low. We have also noticed that the cells grow better in the absence of antibiotics.

6. How long does it take to culture a hamburger?

It takes approximately 10 weeks, but we consider that an irrelevant question. The time depends on the replication time of a mammalian cell, which is 25-35 hours and on the subsequent time it takes for a muscle cell to mature, 3 weeks. A hamburger consists of 10 billion cells. From 1 cell to 10 billion cells takes 33 doublings x 30 hrs= 7 weeks. Including maturation into muscle fibers it is 10 weeks to make 1 hamburger. Since cell multiplication is

an exponential process, it takes 10 weeks + 30 hrs to make 2 hamburgers and 12 weeks to make 100.000 hamburgers, provided you have enough capacity to grow cells.

7. Can you make any type of meat, for instance a steak?

We are currently focusing on hamburgers because we rely on self-organization of the muscle cells to form muscle tissue or fibers. That process results in small tissues that are large enough for minced meat applications, which accounts for 50% of the meat market.
To make a full thickness steak one would need to impose a larger 3D structure to the cells to grow in. It is very important in such a structure that it contains a channel system to perfuse the nutrients and oxygen through the developing tissue and to remove waste from its metabolic activity. This technology is being developed, also in the medical field, but is not yet ready for large scale production.

8. What is the motivation for this cultured beef development?

The three main reasons are:

- Food security. Feeding 2 billion more mouths and accommodating the growing meat demand by increasing living standards in India and China, will put more pressure on crop-for-feed growing as well as breeding and raising livestock
- Environment. Especially cattle are major contributors to greenhouse gas emission, mostly methane. We can eliminate that source of GHG.
- Animal welfare. By decimating the livestock population we are slaughtering much less animals and can keep the remaining ones under humane conditions.

9. Will there be food shortage in the future?

If we develop and use all of the emerging technologies to grow food in a more efficient and environmentally sound way and we reduce post-harvest waste of food, we will have sufficient capacity to grow food for the growing world population AND for the increasing appetite for meat.

10. How does the process work?

Muscle specific stem cells (myosatellite cells) are taken from a cow through a harmless procedure, mostly resembling a blood draw. The stem cells are then isolated and allowed as myoblasts to proliferate tremendously so that we get trillions of cells from the small sample. After sufficient cells have grown, they are assembled in groups of 1.5 million cells to form small muscle tissues (2.5 x 0.1 cm) that are very similar as muscle fibers in a steak. From 10,000 of these fibers we make a hamburger patty by adding salt, breadcrumbs and some binder. In the near future we grow fat tissue separately and combine it with muscle tissue in the patty.

11. Do you need to purify the cells taken from the biopsy?

Usually we take a sample from a lean muscle. In that case, the cells are almost entirely muscle cells. We always check purity of cells by looking at a specific marker that only muscle

cells express, named CD56. If the cell population is less than 95% pure muscle cells, we can use the same marker, CD56, to purify the cells. In brief, this is done by adding magnetic beads that are covered with an antibody to CD56. Only cells with CD56 bind to the magnetic beads, which can then be extract by a magnet.

12. Do you need to slaughter the cow?

No, you don't. This could be kill-free meat. If one decides to slaughter the cow, you can harvest enough stem cells to provide a small country with beef for a year. This would for instance be attractive for Halal or Kosher beef preparation.

13. Can you make cultured meat from other animals?

You can make cultured meat from any animal that has muscle specific stem cells in the muscles. As far as we know that holds for all the common animals used for food such as mammals, birds and fish.

14. Why are you focusing on beef?

We are focusing on beef because cattle are the least efficient links in food production. Their conversion rate is 15% or lower, meaning that you need to feed cattle 1 kg of feed to get 150 grams of muscle out of it. Pigs are twice as efficient and chicken is even 4 times as efficient. Fish is the most efficient. That does not mean that working on other animals makes no sense. Pigs and chicken constitute a major part of meat consumption and they will probably rise in importance. There are also much more animals involved. For animal welfare reasons, replacing pigs and chickens with cultured meat variants is a very good idea. Biodiversity will benefit greatly if we develop alternatives for large scale fishing and fish farming.

15. What are the biggest challenges to develop cultured meat as a consumer product?

- scaling up production. This is a technical, financial and organizational challenge
- getting regulatory approval. In the EU, cultured meat will be handled as a novel food for which one has to provide ample safety data
- financing the start-up companies
- developing cultured meat that, besides the cells, contains no other animal components.

16. When will the cultured hamburger hit the supermarket?

It is always hard to predict when product development is finished. We are aiming for market introduction in 3-4 years. We expect it to be relatively expensive in the beginning and to drop in price so it can compete with livestock meat products in 2-3 years following introduction.

17. Is there a genetic difference between cultured meat and livestock meat coming from the same cow?

No, they are genetically identical. We do NOT genetically modify the cells.

18. Could in vitro meat be the solution for the ever increasing human demand for meat?

Yes, it could, but there will likely be more alternatives, such as vegetable based meat substitutes and other sources of proteins such a mycoproteins or insect proteins.

19. How big is the current meat consumption and how will that develop?

Meat consumption varies widely from continent to continent and country to country within continents. It is estimated by the WHO that 30% of land is used for livestock agriculture (70% of all arable land) and that in 2050, meat consumption will be 70% higher than it currently is. That would mean that we do not have enough land on the planet to increase livestock volume to match that demand.

20. What volume of beef can you make through cell culture?

This depends on the level of scaling the production. From 1 sample of less than 1 gram of muscle you could produce 10,000 kgs of beef, reaching a multiplication factor of 10 million. If you translate that into a reduction of cows, you end up with 150 cows for the entire world (we now host roughly 1.5 billion cows). For practical and genetic health reasons, one might want to have a much bigger herd than 150 cows. Obviously, these considerations assume that we can scale up production to meet global demand

21. Is cultured beef safe for human consumption?

Yes, it is. The tissue is practically the same as meat directly from livestock and will therefore be as safe for human consumption as regular meat. It will however in many countries has to be regulated as a “novel food”. That means that we will have to prove safety of the product. One of the first steps in safety testing is to show that cultured cells survive when exposed to the new product. This is of course inherently the case with a product that consists of cultured cells itself!

22. Can you make cultured meat healthier than the livestock product?

We probably can. The most obvious improvement would be to reduce the amount of fat tissue that we add. In addition, we are probably able to have the fat cells make more poly-unsaturated fatty acids (ω-3). This would have a beneficial effect on our cholesterol level, thereby reducing the risk of cardiovascular disease. The other health risk that is associated with eating red meat is colo-rectal cancer. The component in red meat that causes colo-rectal cancer has not been unequivocally identified yet, so unfortunately we cannot specifically focus on reducing the risk for colo-rectal cancer.

23. Will cultured beef be exactly the same as livestock meat?

It can be, provided that we feed the cells and tissues with all the necessary ingredients and vitamins that they require and do not produce themselves. Vitamin B12 is good example of an essential component that is NOT being produced by skeletal muscle cells but taken from the blood (or the feed, i.e. medium). Adding vitamin B12 to the medium is easy and cheap.

24. What changes can we expect after cultured meat is an accepted food?

Cultured meat intents to provide a sustainable, safe, environmentally friendly and animal friendly alternative to livestock meat. In addition to these benefits, it will change the way we think about meat. It will become a different product if we do not longer have to raise and kill living animals for it. For sure, it will change our ethical perspective on animal welfare related to food consumption.

25. Will the consumer accept cultured meat?

A number of surveys has been performed in various European countries and in the USA and they indicate that a large minority, ranging from 20 to 50% of consumers is willing to try cultured meat. As an early adopter base that is more than enough. We are quite confident that when the product is of high quality and not too expensive that the benefits will appeal to the consumer.

26. It is not much better to develop plant protein based substitutes like Impossible Food and Beyond Meat is doing?

Given the nature and magnitude of the problem, we will need to look at every possible avenue that can replace livestock meat production and consumption. Plant-based substitutes are likely more sustainable than cultured meat, however, in contrast to cultured meat, you cannot make an exact copy of livestock meat with plant proteins. Eventually, the preference for either of these products will be determined by the consumer.
Plant-based meat substitutes could completely substitute meat consumption as humans do not really need animal proteins, when we balance plant proteins in such a way that we obtain all essential aminoacids

27. Will cultured meat be acceptable to vegetarians or vegans?

Cultured meat is not intended for the vegetarian or vegan market, in fact, we would consider it unwanted if vegetarians and vegans start to eat meat as a result of our endeavors. That would be the opposite trend of what we are trying to achieve. We obviously cannot prevent vegetarians who are craving for meat but do not allow themselves to eat because of animal welfare concerns, to start eating cultured meat.

28. How do you physically scale up production?

Cell culture, in particular of mammalian cells that need grow while being attached to a surface, is typically done in Petri dishes or culture flasks. These have an unfavorable surface to volume ratio and cannot easily be scale up and that is why we investigating ways to culture the myoblasts on microcarriers that are suspended in a small or large vessel (i.e. bioreactor) containing medium, that is usually well mixed by automated stirring. Since one starts with a small amount of cells, the culture begins in a flask and moves up from there to a small bioreactor and then to a larger bioreactor to end up in a 25,000 liter bioreactor that is big enough to produce a year's supply of meat for 10,000 people.

29. Do the cells need to be exercised?

We typically do not exercise the cells as they are contracting and developing tension spontaneously. We have electrically stimulated in the past and it creates slightly better muscle fibers, but the energy requirements make the process very inefficient and not scalable. Although we are happy with the result of spontaneous contraction, we are still working on other ways to stimulate the muscle fibers that require less energy and resources.

30. Can you increase the myoglobin content to add color, taste and nutritional value?

Myoglobin is a protein made by muscle cells and provides oxygen transport within the cell. Very similar to hemoglobin in blood, myoglobin in muscle is red and provides the red color to meat (contrary to popular belief the red color of meat does not come from blood as there is very little blood left in meat). Myoglobin is also the source of heme-iron in meat and likely adds to its taste. As was already known from other species, by culturing myoblasts and myofibers at a reduced oxygen concentration, myoglobin is produced by the muscle cells and the fibers turn pink

31. Are you producing fat tissue as well to complement taste and texture?

Yes, we are currently culturing fat tissue from fat tissue derived stem cells. The stem cells can also be taken as a sample from a cow and cultured to obtain large numbers. Differentiation of primitive fat cells into mature fat cells can be done by newly developed methods that are compatible with food production. Growing fat tissue takes a couple of weeks longer than growing muscle tissue.

32. How do you make a patty from the individual muscle fibers?

Making a patty from muscle fibers is done by regular food technologies. Briefly, the fibers are mixed with a bit of salt that disrupts the cells and releases the predominant muscle proteins actin and myosin. The “dough” will become sticky. To facilitate that process, some egg white powder is added and to retain the meat juices, bread crumbs are added. For the hamburger that was presented in London, we also added a binder based on algae.

33. How do you optimize texture, taste and color?

Texture of the patty was already pretty good according to the tasters at the London presentation. For color see Q28. Juiciness will be further improved by adding fat in the new version of the hamburger. By recreating exactly the same tissue as livestock meat, we assume that the taste will be similar if not identical. We also realize that most processed meat products such as hamburger are artificially flavored, so that option is always available.

34. Is there any video or photo material available that is free for use?

Yes, please follow the link to a dropbox folder containing the requested material:
https://www.dropbox.com/sh/l2pzkg0233myzss/AACZcPHRxUiyzrFxyo2j6bUQa?dl=0

35. How did the idea of culturing meat from stem cells come about?

The idea is actually quite old. In 1932, Winston Churchill already alludes to growing pieces of animal under a suitable medium to produce meat. In the Netherlands, a retired entrepreneur, Willem van Eelen, pursued the idea and motivated scientists from the Universities of Utrecht, Amsterdam and Eindhoven and representatives from a meat processing industry (Stegeman, represented by Peter Verstrate, the CEO of MosaMeat B.V.) to develop a program and obtain funding from the Dutch government. The so-called InVitroMeat project was granted in 2004 and the project continued until 2009. Mark Post joined that project in 2007 and continued to work on it even after expiration of the grant. The idea to create a proof of concept was born out of the investigators of InVitroMeat.

36. Why did you present the first hamburger in a worldwide stage event?

There were two reasons for seeking public exposure with the hamburger. The first one was to change the discussion on cultured meat from skepticism about its feasibility to the acknowledgement that it is feasible and that we should start focusing on how to make it a commercial reality. The second reason was to wake up the public and make them aware of an existing and growing sustainability and food security issue with livestock meat production in the wake of a global increase in demand.

37. What are the environmental benefits of cultured meat?

Livestock meat and beef in particular, is a very costly product from a resource and environmental point of view. Worldwide, seventy percent of arable land is used for livestock. One kg of beef requires 15,000 liter of fresh water to produce. It is estimated that meat production is responsible for 15-20% of all greenhouse gas production. Several preliminary life cycle analyses of cultured meat have been performed. They are preliminary because not all details of cultured meat production have been established and many await scaling up of the production. It is generally acknowledged that cultured meat will lead to a substantial saving in land and water usage, up to 90%. For land, that will mean that deforestation will no longer be profitable. Estimates differ widely on energy savings, ranging from 60% saving to no saving at all. Even if the latter is true, energy expenditure will still not be associated with methane exhaust. Methane is a very powerful greenhouse gas that is emitted by ruminants such as cows and sheep and arises from manure of other livestock.

38. Do you need to add blood vessels and nerves to the muscle tissue?

The muscle fibers that are created through self-assembly of muscle cells are small (∅ = 1mm) and do not need a blood vessel structure to get oxygen and nutrients distributed. Oxygen and nutrients can just diffuse through the tissue along those short distances (< 0.5 mm). Once full thickness muscle (see Q6) will be produced we will need a channel and perfusion system and perhaps blood vessels. We currently do not think that blood vessels add to structure and taste, but we are still investigating that. Nerves do not seem to be required to initiate and sustain spontaneous contraction and tension development by cultured muscle cells. Culture

of different cells together is possible and has been exercised before, but it requires a much more elaborate optimization to align the conditions for each of the cell types. If not necessary for texture, taste and quality of the meat, we will refrain from those meat components.

39. How does the meat industry react to cultured meat?

    No major reactions were expressed towards us yet. We do have some interest from industry associated with meat production, even with respect to future investments

40. What is the goal of MosaMeat B.V.?

    MosaMeat B.V. intends to commercialize cultured minced beef, starting with further improving the product, scaling up production and gaining regulatory approval.

41. Will there be any ethical concerns with cultured meat?

    We see mostly ethical benefits, but this technology might disrupt a current industry with many employed people, intense usage of land and many animals. That obviously will require a transition.

42. Do you still use fetal bovine serum in the medium?

    We are working hard to get rid of the serum. There are a number of pressing reasons to eliminate serum. The most important is that the use of serum is inherently unsustainable as supply will be limited by reducing the herd of cows worldwide as a result of the cultured meat technology. In addition, obtaining serum from unborn calves is incompatible with our animal welfare standards and is a disease risk.

43. Will cultured beef age the same way as livestock beef and how will that affect packaging and storage?

    Ageing, packaging and storage of beef depends on auto-digestion and microbial contamination. Cultured beef is sterile, not contaminated, so that is less of a concern than in livestock beef. Auto-digestion is the decay/tenderization of meat by enzymes that are present in the tissue. They will be present in cultured meat, similarly to livestock meat.

44. Could you culture meat at home?

    The technology is relatively easy and one could design equipment to even further simplify it, so that meat can be cultured at home. We do not see that as a viable business option though, since it requires space, 8 weeks to grow and more nurturing than vegetable gardens or baking your own bread. We think that a community-based local production system would be more optimal. One could have community farms in the middle of a city with a couple of animals that are tended by and cared for by locals,

together with kids. Once in a while you get some stem cells from the animals and in a shed adjacent to the farm meat for the community is grown.

Glossary

medium: fluid with all the nutrients that support growth and maturation of cells and tissues

myoblast: A daughter cell derived from the myosatellite stem cell. The myoblast can proliferate very effectively and serves as the precursor of the primitive myotube, which itself will mature into a muscle cell, the basic building block of a muscle

myosatellite cell: This is the stem cell of muscles. It resided in close proximity with the muscle cell/fiber and functions as the stem cell, i.e. it can self-renew almost infinitely and at the same time give rise to fast proliferating myoblasts that will regenerate the damaged muscle fiber.

myofiber: Set of matured muscle cells that align and form a macroscopically visible muscle tissue.

myotube: primitive muscle fiber that consists of dozens of merged myoblasts. As a first step of differentiation, myoblasts start to merge and form a multinucleated elongated structure, the myotube, which can subsequently mature into a muscle cell.

microcarriers: microcarriers are small spheres, typically > 100 µm in diameter and made of some sort of plastic

bioreactor: a bioreactor is a device that allows cells or tissues to grow under body-like conditions. In its simplest form it is a container in which medium and cells are kept at body temperature where stirring continuously mixes the fluid so that the cells, oxygen and nutrients remain evenly distributed

essential aminoacids: aminoacids are the building block of proteins. We have 22 different aminoacids that build all of our proteins. Most aminoacids can be produced in our body but 8 aminoacids need to be acquire through food and these are called essential aminoacids. Meat contains all 8, but one can easily get sufficient supply of the essential aminoacids through a vegetarian or vegan diet.