

FAQ

What is Mosa Meat's mission?

Our mission is to revolutionise the way meat is made. Specifically, we're working to commercialise clean meat and bring it to the mass market so that we can feed our growing population in a sustainable, healthy and animal-friendly way.

What is "clean meat"?

Clean meat is the same as conventional meat, but rather than raising and slaughtering a whole animal, we produce the meat directly from animal cells.

Clean meat isn't a plant-based substitute. Rather, it's real meat that under a microscope is indistinguishable from meat tissue that comes from a cow, pig or chicken.

Is it natural?

There is an initial reaction by many people (ourselves included) that "lab-grown" meat is unnatural, and that's completely understandable. But the process of the cells growing is the same natural process, it just happens outside the animal's body (and at scale will not happen in a laboratory, but in bioreactors similar to the bioreactors used to make beer).

Furthermore, it's easy to see that industrial livestock meat production itself is not natural. For example, artificial growth hormones are used to make animals grow faster.

In any case, our view is that "natural" is not what's actually important. There are many things that are naturally occurring but are not good for us (from asbestos and arsenic to snake venom and anthrax). We think what we should be concerned about is [safety](#).

Given growing meat demand and our resource constraints, we really need to find a more efficient way to make meat, and harvesting meat from animal cells is a safe and efficient method.

Is it safe to eat?

Yes, it is. The tissue is the same as meat directly from livestock and will therefore be as safe for human consumption as regular meat – in fact more safe because it is produced in a completely clean environment and without the use of antibiotics.

The safety of the product will be tested by the regulatory authorities and will only be allowed onto the market if the regulators determine it is absolutely safe.

Why do we need clean meat?

For two reasons. Clean meat could solve the coming food crisis, and help combat climate change.

The Food and Agriculture Organisation of the United Nations (FAO) estimates that the demand for meat is going to increase by 70% by 2050, and current production methods are not sustainable. If we want to continue to eat meat, we need a more efficient production method.

Furthermore, livestock contributes significantly to global warming through unchecked releases of methane, a greenhouse gas 20-30 times more potent than carbon dioxide as a heat-trapping gas. It is projected that clean meat will generate 96% lower greenhouse gas emissions, helping us avoid the disastrous consequences of climate change.

Isn't it better to develop plant-based substitutes?

We agree that, if everyone were to adopt a plant-based diet, it would be better as these products are even more sustainable than clean meat.

However, we are concerned that many people will not want to become vegetarian or vegan, especially given plant-based substitutes will never be exactly the same as meat in taste and texture.

Therefore, we think we need to look at every possible avenue of replacing livestock, including clean meat.

How is it made?

The first step is to take some cells from an animal, such as a cow if we're making beef, which is done with a biopsy under anaesthesia.

The cells are fed nutrients and natural growth factors, and allowed to proliferate just as

they would inside an animal.

They proliferate until we get trillions of cells from a small sample. This growth takes place in a bioreactor, which looks similar to the bioreactors that beer is fermented in.

When we want the cells to differentiate into muscle cells, we simply stop feeding them growth factors, and they differentiate naturally.

The cells are then placed in a gel that is 99% water, which helps the cells form the shape of muscle fibres. The muscle fibres contract naturally, causing them to get larger.

When thousands of muscle fibres are layered together we get what we started with – meat.

The meat can then be processed using standard food technologies – for example, by putting the meat through a grinder to make ground beef.

Is it genetically modified?

We do not do any genetic modification. As the cells are simply doing what they would do inside the animal, there is no need to modify them in any way. Furthermore, GM foods are banned in much of Europe, where Mosa Meat is based.

Where did the cells for the first clean hamburger come from?

The cells came from cows raised on organic farms, and the cows were given anaesthesia before the sample was taken. We used two samples, one from a Blanc Blue Belge cow raised at a farm in Belgium and another from a Blond Aquitaine cow.

What are the challenges to developing clean meat as a consumer product?

The biggest remaining scientific challenge is developing a replacement for [fetal bovine serum](#) (the serum most commonly used in tissue engineering). We cannot use this in future, both because it's incompatible with our animal welfare standards, and also because it's inherently unsustainable given clean meat itself will reduce the herd of cows worldwide. So far, we've achieved serum-free [medium](#) that works, but we still need to optimise it.

Economically, the biggest challenge is scaling up production and bringing the price down to a competitive level. We are working to achieve this within 3-4 years.

What does it taste like?

Like meat! As clean meat is molecularly the same as livestock meat, it tastes the same.

How has the meat industry reacted to clean meat?

The meat industry recognises that conventional farming is unsustainable, and meat companies are looking to diversify the range of proteins that they produce. Mosa Meat and other clean meat companies have received investments from some of the world's largest meat companies. We aim to work with meat companies to bring clean meat to the market as widely and as soon as possible.

Meat substitutes haven't taken off. Why do you think clean meat will?

In fact, plant-based meat substitutes are seeing strong growth fuelled by the rise in vegan, vegetarian and flexitarian diets.

We think that clean meat will also take off in a huge way because it will be the same as meat in taste and texture, but healthier, more sustainable, kinder to animals and eventually cheaper.

Does clean meat involve cruelty to animals?

Improving animal welfare is one of the main reasons we started Mosa Meat, and our meat does not involve cruelty to animals.

We do have to take a cell sample from a donor animal using a biopsy, but this is done under anaesthesia by a veterinarian and does not cause damage to the animal. Furthermore, one cell sample can create up to 20,000 tonnes of meat, so we don't have to take biopsies very often (and we do not need many cows – we would only need 150 cows to satisfy the world's meat demand).

Importantly, drastically reducing the number of farm animals in human care will allow humane treatment and comfortable living conditions for those few animals.

Will consumers accept clean meat?

A number of surveys have been conducted in various European countries and in the US with a range of results (indicating as few as 20% or as many as 90% of consumers will try clean meat). Even 20% of the public is an enormous market of first adopters. We are confident that when the product is of high quality and is competitively priced the benefits will appeal widely to consumers.

How much did the first burger cost?

The first burger cost €250,000 to produce. It was funded by Sergey Brin, the co-founder of Google, who shares our concerns about the environmental and animal welfare impacts of conventional meat production. The burger was this expensive in 2013 because back then it was novel science, and we were producing at a very small scale.

What is the current price?

When the production is brought to industrial scale (but still using the current state of efficiency) the cost of producing a hamburger will be around €9. The cost of a hamburger in the supermarket is around €1, and we project that with further efficiency improvements we will be able to bring the price down to this level in the next 5-7 years.

When will it be available to buy?

We are aiming for market introduction in 3-4 years. Like other new technologies, it will be relatively expensive in the beginning, and available at venues such as gourmet restaurants. But within 2-3 years we project it will drop in price so that there will be products on supermarket shelves that are competitive with livestock meat products.

What changes can we expect when clean meat is a mass-market food?

As clean meat production is more efficient than livestock production, we can expect that once clean meat is being produced at large scale it will eventually become more affordable than meat is today.

We should see a large drop in foodborne illnesses and deaths, and a slowdown in patients arriving at hospitals with antibiotic-resistant diseases.

There will be a reduction in greenhouse gas emissions, and no need for further deforestation – in fact, we could choose to restore forests to their wild state, which in turn would increase the planet's carbon sinks and further help mitigate climate change.

We expect there will be no more industrial farms, to the benefit of many millions of farm animals.

Can you make different meats using cell culturing techniques?

Yes, we can make clean 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. So we could make the meats we commonly eat, such as beef,

chicken and pork.

Could you make a steak?

Currently our focus is on producing ground meat products, which account for 50% of the total meat market.

Producing a larger and more complex 3D tissue structure (such as a steak) presents a larger scientific challenge.

We aren't close to being able to do this yet, but we are actively working on it (as are many scientists in medical fields) and we believe we will be able to do it in the future.

What evidence is there that clean meat will be better for the environment?

One of the most pressing problems facing our environment – and perhaps our species – is climate change.

Livestock contributes 15% of global greenhouse gas emissions. Furthermore, livestock production releases methane, a greenhouse gas that is 20-30 times more potent than carbon dioxide as a heat-trapping gas.

Meat demand is set to increase by 70% by 2050, and this will significantly increase greenhouse gas emissions if we continue to produce meat using livestock.

A life cycle analysis published in *Environmental Science and Technology*¹ confirms large reductions in the use of energy in the production of clean meat compared to obtaining meat through livestock, and a reduction in greenhouse gas emissions of up to 96%.

Therefore, switching to clean meat could have a significant impact on total greenhouse gas emissions, and on mitigating climate change.

Beyond climate change, there is also evidence that clean meat will benefit the environment by reducing the amount of land and water used in production.

Conventional meat production uses huge quantities of land and water. This negatively impacts the environment in numerous ways. For example, large parts of the Amazon rainforest have already been cleared to make way for cattle. At current rates of deforestation, rainforests may have vanished entirely in 100 years, causing drastic loss of biodiversity.

¹ Environmental Impacts of Cultured Meat Production, Hanna L. Tuomisto and M. Joost Teixeira de Mattos, *Environmental Science & Technology*, 2011 45 (14), 6117-6123
DOI: 10.1021/es200130u.

On the other hand, according to the life cycle analysis, clean meat production will require 99% less land (and up to 96% less water), making it possible to return cleared forests to their wild state.

What have you been working on since the first hamburger launch in 2013?

We have focused on four main areas:

- 1) We improved our meat's protein content, most notably changing culture conditions to allow the cells to produce more myoglobin, which gives meat its red colour.
- 2) We added fat tissue, which is important for taste and texture.
- 3) We developed a culture [medium](#) that is free of [fetal bovine serum](#) (FBS). This is highly important from a cost perspective given serum comprises 80% of the production cost.
- 4) We designed a bio-production process that can be scaled to industrial volume.

What's next for Mosa Meat?

Looking forward, we are focused on actually scaling production (including the construction of a pilot factory) and on improving efficiencies to bring the price down to a competitive level. We are also working on obtaining regulatory approval. We are aiming to have our first products on the market by 2021.

Is clean meat real tissue or just a heap of cells?

It is real meat tissue that, under the microscope, is indistinguishable from muscle fibres taken from a steak. The cells actually form the tissue structure themselves through self-organisation. They first merge into large, primitive muscle fibres (called "[myotubes](#)"), and then they spontaneously align and start to contract, thus forming a firm muscle fibre.

Do you use antibiotics or antifungal drugs?

No, because our production process is completely sterile, we do not need to use any antibiotics or antifungal drugs. In contrast, in order to keep farm animals healthy in non-sterile, crowded feedlots, livestock are routinely treated with antibiotics and antifungal drugs.

How long does it take to make a hamburger?

It takes about 10 weeks to make a hamburger. But this doesn't mean we can't produce at industrial scale in the future. Because cell growth is exponential, it takes 10 weeks to produce one hamburger, but only about 12 weeks to produce 100,000 hamburgers. In comparison, it takes 18 months to raise a cow for slaughter, from which you'd only get about 2,000 burgers.

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

Meat consumption varies widely from continent to continent, and from country to country within continents.

Globally, over 300 million tonnes of meat is produced for consumption each year (at a value of nearly one trillion US dollars).

The FAO estimates that meat consumption will be 70% higher than the current level by 2050. In line with this, the WHO projects meat demand will double in the next 40 years.

This soaring demand is driven by global population growth, as well as a growing middle class in the developing world.

Will there be food shortages in the future?

If the world switched to a plant-based diet, we would not face any food shortages in future. However, unless we start to produce meat more efficiently using clean meat technology, there will likely be a shortage of meat as soaring demand outstrips supply.

This could mean that meat becomes a high-priced delicacy enjoyed only by the wealthiest few. By transitioning to clean meat we can avoid this outcome. In fact, because the production process is inherently more efficient, we expect clean meat to ultimately be cheaper than livestock meat is today.

Why are you focusing on beef?

Given the scientific and economic challenges involved, we decided to focus on one type of meat initially.

We chose beef because cattle are the least efficient links in food production. They convert only 15% of edible food crop into meat we can eat (pigs are twice as efficient and chickens are four times as efficient).

This means that cows use the most resources, and have the greatest impact on the environment. They also generate the most greenhouse gas emissions.

In future, we will be working on other species. While millions of cows are slaughtered each year, even more chickens and pigs are killed. From an animal welfare perspective in particular, it is therefore very important to change the way we produce chicken and pork.

What volume of beef can you produce from a cell sample?

That depends on the level of scaling of production in future. Theoretically, from one sample of less than one gram of muscle we can produce 10,000 kilograms of beef, reaching a multiplication factor of 10 million. If this is translated into a reduction of cows, we would need only 150 cows to meet the entire world's meat demand (the planet now hosts roughly 1.5 billion cows).

Can you make clean meat healthier than the livestock product?

We are currently focused on producing meat that is identical to the livestock product (albeit produced in a cleaner, safer environment).

However we believe that, if there is public demand for it, it probably will be possible to make clean meat healthier than livestock meat in future, without using any genetic modification.

The most obvious improvement would be to reduce the amount of fat tissue that we add. In addition, we are probably able to induce the fat cells to make more poly-unsaturated fatty acids simply by adjusting their feed (just as cows that graze on grass have lower poly-unsaturated fatty acids in their meat than cows from feedlots).

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 colorectal cancer. The component in red meat that causes colorectal cancer has not been unequivocally identified yet, so unfortunately we cannot specifically focus on reducing the risk for colorectal cancer yet. However, with further scientific discovery this may become possible in future.

Will clean meat be acceptable to vegetarians or vegans?

This perhaps depends on how one defines "vegetarian" and "vegan".

If it is taken simply to mean not eating meat (or meat and dairy) then the answer is "no" – clean meat is meat.

However, many people who are vegetarian or vegan do not object to meat in and of itself, but rather the ethical problems associated with its production.

As clean meat does not require the inhumane treatment or slaughter of any animals, nor does it have the same environmental impacts as livestock meat, it may be acceptable to many vegetarians and vegans.

Our real goal, however, is to provide sustainable and animal-friendly meat for the majority who currently eat meat, as this will have the greatest effect in reducing greenhouse gas emissions, environmental damage and animal suffering.

How do you physically scale up production?

Cell culture, in particular of mammalian cells that need to grow while being attached to a surface, is typically done in Petri dishes or culture flasks.

These have an unfavourable surface-to-volume ratio and cannot easily be scaled up.

Therefore, at scale we culture cells on [microcarriers](#) that are suspended in a large vessel (i.e. a [bioreactor](#)). The bioreactor contains [medium](#) which is 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. The largest bioreactors are 25,000 litres in volume and large enough to produce a year's supply of meat for 10,000 people.

Do you still use fetal bovine serum (FBS) in the medium?

No, we have developed serum-free [medium](#), which we are now optimising.

It was important to eliminate FBS from the production process. For one, it is inherently unsustainable given that clean meat will reduce the herd of cows worldwide, and FBS is derived from the foetuses of slaughtered cows. In addition, obtaining FBS from unborn calves is incompatible with our animal welfare beliefs.

Does clean meat contain myoglobin?

Yes, clean meat contains myoglobin as livestock meat does.

Myoglobin is a protein made by muscle cells and provides oxygen transport within the cell. Very similar to haemoglobin in blood, myoglobin in muscle is red and provides the red colour to meat (contrary to popular belief, the red colour of meat does not come from

blood as there is very little blood left in meat). Myoglobin is also the source of haem iron in meat and likely adds to its taste.

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 the purity of the 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 extracted by a magnet.

Does clean meat contain fat cells?

Yes, just like livestock meat, clean meat contains fat.

How do you make a hamburger patty from the individual muscle fibres?

We make patties from the muscle fibres using standard food technologies. Once the muscle fibres are ready, they are pushed through a meat grinder to create the familiar “strands” we see in minced meat. This can then be shaped by a machine into a patty.

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

As the muscle fibres created through self-assembly of muscle cells are very small, we do not need a blood vessel structure to distribute oxygen and nutrients to produce minced meat.

However, in order to produce a 3D structure (such as a steak) we will need a “perfusion system” to distribute oxygen and nutrients, and this is something we are currently researching.

Will clean meat age the same way as livestock meat?

Ageing of meat depends on “auto-digestion” and microbial contamination.

Auto-digestion is the decay/tenderisation of meat by enzymes that are present in the tissue. They will be present in clean meat, similarly to livestock meat.

However, as clean meat is produced in a sterile environment, there will not be microbial contamination as there is with livestock meat.

Therefore, it is likely that clean meat will last for longer. This could mean that there will be less food wastage (as the meat will not go “off” as quickly).

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

The idea is actually quite old. In 1931, Winston Churchill authored an article where he imagined the world “Fifty Years Hence”. He wrote: *“We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium”*.

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 company (Stegeman, represented by Peter Verstrate, our CEO) to develop a program and obtain funding from the Dutch government.

The so-called “InVitroMeat Project” was started in 2004 and the project continued until 2009. Our Chief Scientific Officer 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 – what came to be the world’s first clean hamburger - came from Mark Post and Peter Verstrate, at that time both working on the InVitroMeat Project.

Why did you present the first hamburger at a global press conference?

There were two reasons for seeking public exposure.

Firstly, we wanted to change the discussion on clean meat from scepticism about its feasibility to the acknowledgement that it is indeed feasible and that we should start focusing on how to make it a commercial reality.

The second reason was to help make the public more aware of the existing and growing sustainability and food security problems with livestock meat production. With meat demand expected to soar in coming decades, we thought it was important to do something to help catalyse action toward developing solutions such as clean meat. Indeed, the press announcement inspired a completely new clean meat industry with start-ups appearing in the US, Europe and Israel.

Will there be any ethical concerns with clean meat?

We think there are mostly ethical benefits in switching from conventional meat to clean meat. It will be much kinder to animals, will help protect natural environments that many people and animals value, and is expected to be better for human health.

There is of course the concern that this technology would likely disrupt existing industries, and this will require a gradual transition and consideration of the people whose livelihoods depend on those industries. Fortunately, those working in livestock industries may be the best positioned to take advantage of new market opportunities from clean meat. For example, farmers already running feedlots may have an advantage in transitioning to producing feed for cells, which will be a massive new market.

Could you make clean meat at home?

The technology is relatively easy and one could design equipment to further simplify it. So theoretically it would be possible to have meat production in your own home, just as some people have vegetable gardens.

However, it probably isn't a very realistic scenario. Producing meat on a tiny scale would take about 10 weeks, so it would perhaps only appeal to the most patient of chefs!

On a slightly bigger scale, however, we can imagine communities sharing a local production system. We could have community farms in the middle of the city with a couple of animals that are cared for by the locals together. Every now and then, they would take some stem cells from the animals (using a biopsy under anaesthesia) which would be used to farm meat for the community in a small building nearby.

This could be very advantageous for communities that don't have ready access to meat. We can even imagine having self-supporting "meat factories" carried around in vans that could deliver meat to areas that are completely cut off, such as refugee camps and disaster zones.

Will clean meat put farmers out of a job?

Clean meat will change the way that meat production is organised, and most likely make some farming functions obsolete. This won't happen instantly, so there will be some time to transition. Fortunately, those working in livestock industries may be well positioned to take advantage of new market opportunities from clean meat. For example, farmers already running feedlots may have an advantage in transitioning to producing feed for cells, which will be a massive new market.

Can clean meat give you cancer?

No. The cells in clean meat are not cancer cells. Cancer cells are undifferentiated cells that divide uncontrollably, whereas clean meat comprises cells that are differentiated into muscle cells.

Furthermore, by the time you eat them, the cells in clean meat are dead (just as livestock meat cells are dead when you eat them). Therefore there is no possibility that they can

continue dividing after consumption.

What is Mosa Meat's position on working with meat companies?

The established meat companies have been instrumental in providing food for us for a long period of time and they, together with us, recognise that livestock will not be the only future of meat protein. That's why they're investing in clean meat.

We believe the fastest and most effective way to bring clean meat to the mass market will be by collaborating with traditional meat companies, which already have large-scale processing and distribution channels in place. Therefore, we're keen to work with established meat companies.

Is clean meat just Silicon Valley hype that will never be a reality?

We don't think so. There is a real problem here that we need to find a solution to if we want to continue eating meat, and the science is genuinely advancing.

Up until three years ago, we were the only ones working on clean meat. Now, there is a completely new industry, and the major meat companies worldwide are putting their financial backing behind clean meat.

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

Yes, we would be delighted for you to use any of the photos or videos available for download in our [press kit](#).

Glossary

bioreactor: 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

fetal bovine serum: The most commonly used serum for culturing cells. It comes from the blood of cow foetuses removed from female cows at slaughterhouses

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

microcarrier: A small sphere, typically $> 100 \mu\text{m}$ in diameter and made of some sort of plastic

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

myofibre: A set of matured muscle cells that align and form a macroscopically visible muscle tissue

myosatellite cell: The stem cell of muscles. It resides in close proximity to the muscle cell/fibre 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 fibre

myotube: A primitive muscle fibre 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