IN-VITRO MEAT

APPLICATIONS OF GENETIC ENGINEERING AND BIOTECHNOLOGY

TERM PAPER IN BIOLOGY SUBMITTED BY:
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Preface

At first glance, it seemed impossible for Darlene and Alexia to believe that edible meat is grown in a laboratory and will be released in the food market soon. Alejandro was the one who suggested the topic “In-Vitro Meat”, for he has already informed himself about it long before Mr. Ruggle gave this term paper assignment in Biology class.

This sparked our interest and curiosity because all three of us are meat-lovers, but have friends who are vegetarians. Aside from that, we have background knowledge that meat, although delicious and irresistible, can contain harmful agents like ~~pathogens~~. We then thought to ourselves if it is by any means possible to eliminate or at least immensely lessen these so that meat can ultimately be better for human health. Thus, we are all looking forward to learning more about cultured meat – especially its effect on our body as well as the environment, its taste and most importantly, how far or near we are until it can be served on our plates on a normal day.

not really, rather chemicals, like hormones etc.

The following are a few questions we have in regard to this subject:

1. Does it completely eradicate animal cruelty? - ethics
2. How healthy is it compared to conventional meat? - health
3. How sustainable is in-vitro meat? - sustainability

Introduction

In the current state the world is in, environmental issues have become a significantly prevalent topic. Presently, one of the most important steps to reduce the personal environmental footprint, be it for water or CO2 emissions, is to stop eating meat. Yet, for many people, to completely stop eating meat sounds unimaginable. In our society, vegetarianism and veganism are relatively rare, which brings up the question of why meat is so hard to let go and why we continue in being carnivores despite knowing its negative effects to our environment. There are many answers to this question, but generally, there are two major factors to consider; evolution and marketing.

According to the science journalist Marta Zaraska, meat was an easy source of protein and iron for our hominine ancestors, which was available in relatively big quantities. We like the smell of meat because humans evolved to eat meat. Therefore, the taste buds on our tongue, and the smell receptors on our nose ended up becoming very sensitive to meat, especially when it was cooked (Zaraska, 2016). When asking why we like meat, many people will probably talk about the flavor or the nutritional value. However, some studies also conduct that there is a subconscious motivation to eat meat, which is that meat is perceived as a status symbol as it is closely tied to masculinity, power and wealth (Y. Chan & Zlatevska, 2019), a narrative which is enforced through marketing.

put the reference next to the first citation

Besides the environmental issues involving the production and consumption of meat, there are also some health concerns involving the consumption of meat. Processed meat was declared by the World Health Organization as being a carcinogen which increases the risk of both colon and rectum (colorectal) cancer by up to 18 percent (S. M. Chan, et al., 2011). A vast amount of studies have also found that eating meats, such as red meat, chicken, and pork can promote cancer in many forms. Vegetarians

were about 40 percent less likely to develop cancer, as opposed to meat consumers (Bouvard, et al., 2015). According to Dr. Stanley Hazen of the Cleveland Clinic, meat can also increase the risk of heart disease and diabetes since they all contain cholesterol and saturated fats which can increase the amount of a chemical called TMAO, shown to increase the risk of heart disease (L Hazen, et al., 2019).

Lab-grown meat, also known as in-vitro meat is becoming more of a viable option for environmentally friendly and ethical meat consumption over time. It can integrate both muscle and fat tissue and looks like a thin piece of steak. However, according to Didier Toubia, co-founder and CEO of Aleph Farms, the mass of cells in lab-grown meat does not resemble the complex tissue that is meat, which gets its specific 3-dimensional structure from its various types of cells interacting together (Toubia, 2019). If lab-grown meat gets adopted, it could reduce much of the unethical treatment of animals raised for our meat-consumption and also considerably reduce environmental costs, since the resources would only be needed to create and sustain cultured cells, not an entire organism from its birth.

G. Owen Schaefer from Scientific American explains in an article that lab-grown meat is created by extracting a small amount of muscle tissue out of the respective animal, stem cells can then be collected out of this tissue. These stem cells can then be multiplied dramatically and differentiated into primitive fibers that bulk together to form muscle tissue. One tissue extraction can translate to about 8000 – 10000 kilos of lab-grown meat (Schaefer, 2018). The first successful production of lab-grown meat cost more than 300’000 US-Dollars in production, compared to the average wholesale cost of beef for 1 kilo in the USA being around 10 US-Dollars[1]. Since then the average cost to produce lab-grown meat has fallen to about 80 US-Dollars per kilograms of meat according to an ABC News interview with Dutch Professor Mark Post, it is believed to drop even further to an astounding price of 5 US-Dollars per kilogram of meat. Yaakov Nahmias, founder and chief scientist of Future Meat Technologies explains that this can be achieved by recycling the medium used for growing the cells, similar to the way an animal’s liver and kidney can clean and recycle blood. By using this process, one can also avoid the use of serums produced from animal blood, which are also very expensive. Besides, the bioreactors used to grow the cells could be built as smaller units, which can be used by farms, replacing animal agriculture with a cellular agricultural market (Nahmias, 2018).

Description of the Engineering Process

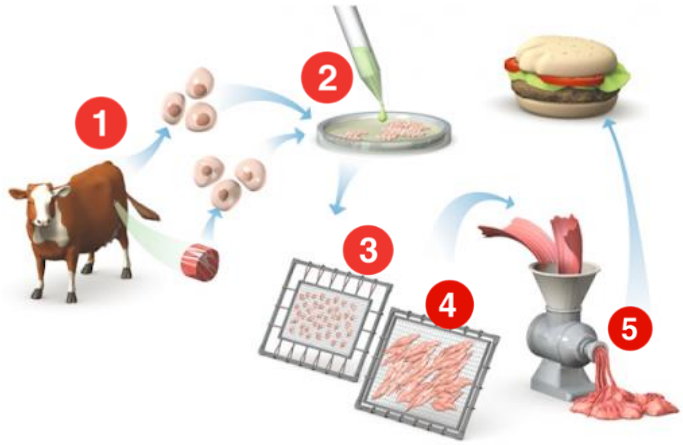
The production of cultured meat is made possible by using tissue engineering techniques, where the initial step is collecting cells that have a rapid rate of proliferation from the muscle of an animal; usually a cow (see Picture 1, #1 below) (GCF Global, n.d.). The ideal cells are the stem cells of muscles called *myosatellite cells*. Within the animal, these stem cells generate new muscle tissue once the muscle is injured. This is exactly the essential characteristic utilized in making cultured meat. The process is done with a small biopsy under anesthesia. (Mosa Meat, 2020)

After that, the cells are to be raised in an environment that resembles the animal body as close as possible (Eater, 2015). Oxygen, amino acids, carbohydrates, and naturally occurring growth factors must, therefore, be present in the serum-free medium surrounding the cells (see Picture 1, #2 below).

Then, the cells proliferate in a bioreactor until trillions are developed (see Picture 1, #3 below). Eventually, the feeding of growth factors is put to stop, since the goal is for the cells to differentiate into muscle cells on their own. The muscle cells then ultimately merge to form *myotubes* (a primitive muscle fiber that is no longer than 0.3mm long) which are later positioned in a gel that is 99% water to aid the cells in forming the shape of muscle fibers.

Afterward, the muscle cells contract naturally and cause them to bulk and grow into a small strand of muscle tissue (see Picture 1, #4 below). A total of 800 million strands of muscle tissue can be produced from one sample from a cow. This is enough to make 80,000 quarter pounders (Every Cell A Universe - Youtube, 2018).

Once all the strands are layered together, the cultured meat can be processed using standard food technologies like putting them through a meat grinder to make ground beef (see Picture 1, #5 below) and soon enough, the meat is ready for seasoning, cooking, and consumption. Many food technology companies follow the same basic principle, but the exact process may vary.



Picture 1 Simplified visual aid of the production of cultured meat
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Interview

Finding a person to interview in Basel was a challenge to us since there were almost no people to be found working with in-vitro meat. That is when we decided to search beyond Basel and Switzerland, which eventually brought us to the company “Mosa Meat” in the Netherlands. We sent a mail to the company asking for an online interview and luckily, we got an answer from the operation coordinator Beckie Calder-Flynn, who was happily interested to answer our questions. Below is a copy of our interview:

1. Even though cultured meat is not yet officially out on the market, have you included it in your diet as well as your family’s? How do you encourage them and how do they react to you?
No, we have not yet gone through the regulatory process for approval for our meat and so we are not yet able to eat it.

2. Do you think that it is favorable if researchers and scientists invest more time into the development and production of plant-based meat instead of in-vitro meat?
Absolutely! We believe we need cultured meat for two major reasons. Cultured meat could solve the coming food crisis and help combat climate change. The Food and Agriculture Organization 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 cultured meat will generate 96% lower greenhouse gas emissions, helping us avoid the disastrous consequences of climate change.
Because both these reasons are critical to our planet, and our own, future, cultured meat is an important place to invest time and effort.

3. Normal meat contains carcinogens. Can in-vitro meat then be made healthier during the production?
We are currently focused on producing meat that is identical to the livestock product (albeit produced in a cleaner, safer environment). Our meat is produced without hormones, antibiotics, and antifungal drugs. Carcinogens often come from the way we preserve meat (such as in nitrates used in curing deli meats) and this is not something we are going to do. We also believe that, if there is a public demand for it, it will probably be possible to make cultured meat healthier than livestock meat in the future, without using any genetic modification. The most obvious improvement would be to reduce the amount of fat tissue that we add. Besides, we are probably able to induce the fat cells to make more poly-unsaturated fatty acids (also known as o-3 fatty acids) simply by adjusting their feed (just as cows that graze on grass have lower saturated fatty acid content 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 the future.

4. Since the price is a huge issue, what strategies have Mosa Meat thought to date to make in-vitro meat affordable for everyone?
Once the production is scaled up, we project the cost of producing a hamburger that will be around €9. The cost of a hamburger in the supermarket is around €1, and we expect that with further efficiency improvements we will be able to bring the price down to this level over the next decade. Ultimately, cultured meat should be cheaper than conventional meat given its production is more efficient.

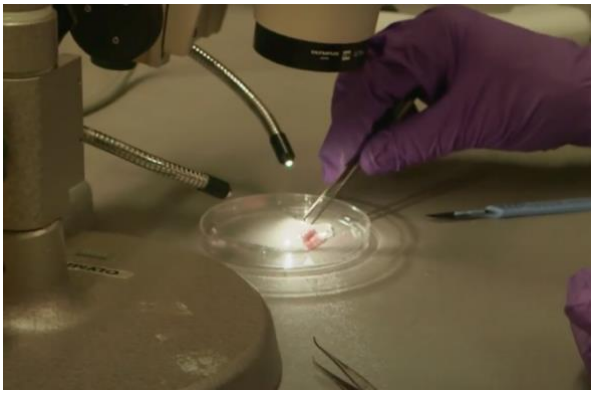
5. Animal cruelty is one of the biggest factors why people choose to be vegetarians. Hence, do you think they would consume in-vitro meat?
Yes, this is one of the biggest reasons we created Mosa Meat so that we could create meat without animal suffering. For vegetarians, it perhaps depends on how one defines "vegetarian" and "vegan". If it is taken simply to mean not eating meat (or meat and dairy) then the answer is "no" – cultured 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 cultured 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.

6. If in-vitro meat is significantly present in one's diet, are there any potential health risks at the moment, and if so, what is your approach to diminish them?
None that we are aware of, as cultured meat is cellularly identical to traditional meat.

7. We have read from your FAQ page that the first products will hopefully be on the market by 2021. How are things looking now?
We are still aiming for this date, but this does depend on how long it takes to go through the regulatory process.

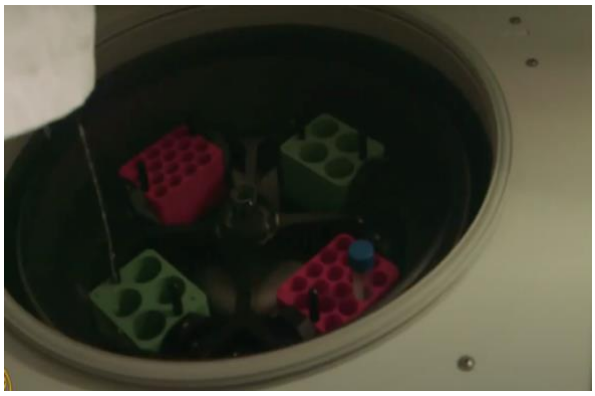
8. Are samples of cultured meat available for consumption?
Unfortunately, no, as we have not gone through the regulatory approval process yet.

Pictures from Mosa Meat Company



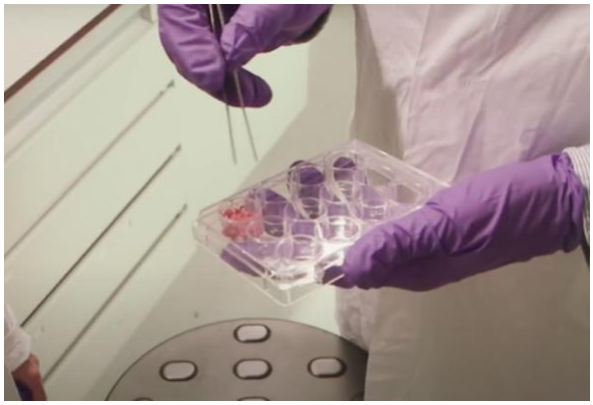
Picture 2 a small piece of muscle taken with needle biopsy from a cow

Picture 3 Mark Post in his laboratory dissecting every single muscle fiber

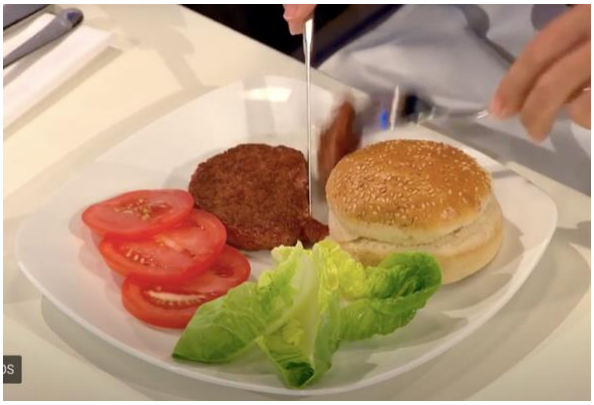


Picture 4 the tissue placed inside a blender to break it down further

Picture 5 cells placed in an icubator after fed with a special culturing solution



Picture 6 end result with the individual fibers



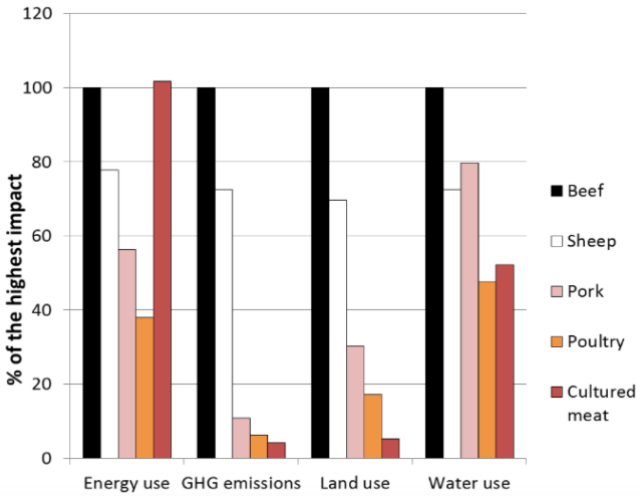
Picture 7 the first lab-grown meat burger created by Mark Post

Discussion

Advantages

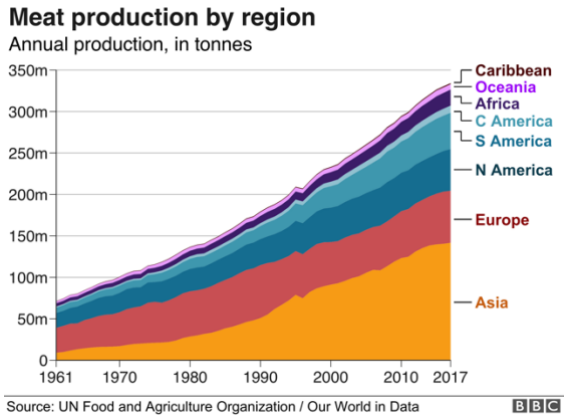
Sustainability

One of the major problems that we face nowadays is climate change caused by global warming. It is reported that the livestock subsidizes about 15% of global greenhouse gas emissions, as they are capable of releasing methane. Methane is known to be a greenhouse gas that has 20 to 30 times more intoxication than carbon dioxide, as it acts as a heat-trapping gas (Mosa Meat, 2020). With the trajectory of cultured meat, it is predicted that it will exceedingly help in the reduction of global warming up to 96% because the amount of greenhouse gas produced by the in-vitro meat is about 96% smaller (The Week, 2018). Thus, a huge impact will be noticeable to the green gas emission and within spouted climate change by swapping to clean meat. Furthermore, another remarkable benefit would be reducing the quantity of water and land used in production (Better Meets Reality, 2019). As known, conventional meat needs a huge amount of land and water and this causes deforestation to feed the cattle. If trees are cut in this rate in the future, it will have a great impact on the biodiversity (Mosa Meat, 2020).



Picture 8 evaluation of environmental impacts of cultured meat with European livestock

According to the Food and Agriculture Organization of the United Nations (FAO), the demand for meat is estimated to increase globally by 70% by 2050 (Mosa Meat, 2020). It was taken into consideration that the present production method would not fulfill the uprising request and a more efficient one is looked for. Thus, clean meat was seen as a solution for the coming food crisis since once cell sample could already be able to produce 10,000 kg of in-vitro meat. This means that only 150 cows are needed for cultured meat producers to satisfy the entire world, once the production is moved to an industrial volume (Mosa Meat, 2020).



Animal cruelty

Surely enough, not every meat-eater is happy about the fact that we have to hunt and kill animals for us to live, however, there is no other choice until now but to continue this lifestyle unless going vegan. Cultured meat offers a great solution to this problem as it only needs a muscle tissue from a cow, for instance, to create meat. The process

of overfeeding the cow to gain weight faster, followed by the slaughter process are completely taken out in this procedure (Mosa Meat, 2020).

Health benefits

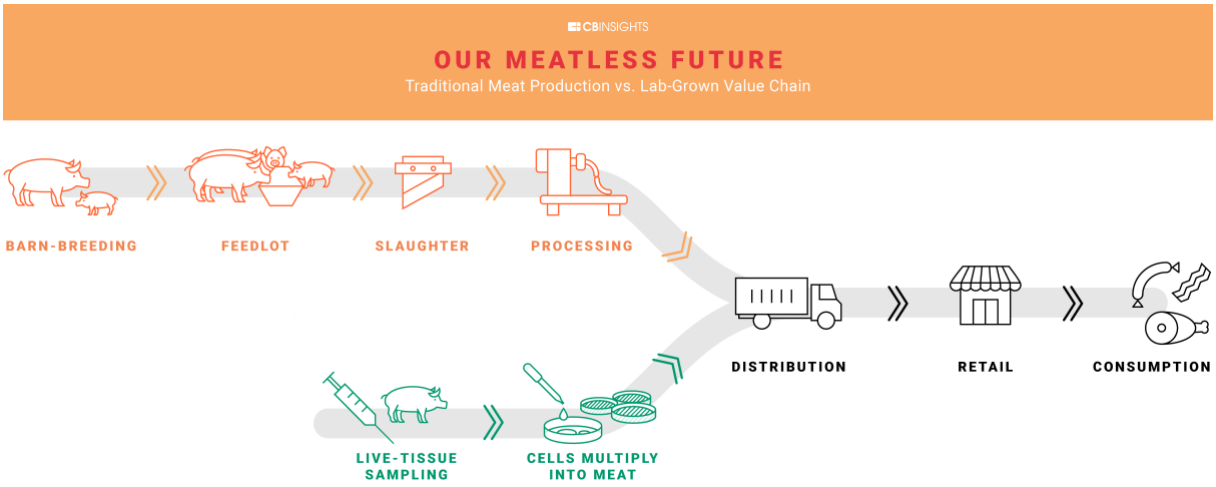
Compared to conventional meat, there are several health benefits for having a cultured meat diet. Firstly, drugs like antibiotics or antifungal are not used in the lab-grown meat as their production process is completely sterile. Yet on the other hand, farm animals are regularly given these drugs to keep them healthy in the non-sterile and crowded feedlots. Secondly, since the meat is antiseptic, the risk for bacterial contamination is also very low (Mosa Meat, 2020) (World Animal Protection, 2018). Thirdly, the health risk caused by the additional hormones given to the cattle to grow larger and to produce more milk is less in clean meat. This is because they use zero growth hormones (World Animal Protection, 2018).

Job provider

As mentioned before, the demand for meat is growing year after year, and once the companies that work under the cultured meat get their permission from the regulatory authorities to proceed, the demand for the cultured meat could increase tremendously. This could create new business sectors generating more job opportunities in these areas (Better Meets Reality, 2019).

Faster production

According to Mosa Meat, at the moment “it takes 10 weeks to produce one quarter-pound hamburger but only 12 weeks to produce 100,000 hamburgers. In comparison, it takes about 18 months to raise a cow for slaughter, from which you would get less than 1500 quarter pounders.” Once the production can move into industrial volume, the manufacture of clean meat would be way quicker than the conventional meat and also the present rate. Moving to an industrial level not only speeds up the production rate but also brings down the price to a competitive level and therefore will become more affordable than the conventional meat at present (Mosa Meat, 2020).



Picture 9 simplified comparison of the productions of traditional meat and cultured meat

Disadvantages

Unemployment

According to an article posted by Bruno Jacobsen in 2017, the livestock sector employs about 1.7 billion people in the world. If we do decide to consume cultured meat primarily, the negative effects for plenty of workers and their livelihood, from factories to farm, would surely be immense.

Further Harm to the Environment and Animals

The amount of heat and electricity necessary to create in-vitro meat on a huge scale is not completely benign but rather gigantic, as mentioned in studies at American Universities. Furthermore, finding the appropriate type of muscle tissue from the livestock still demands invasive methods that do not promise the elimination of suffering, especially since it would need to be done on a way larger scale than as of today.

Trust

The labeling of lab-grown meat was an issue brought about during a discussion between the Food and Drug Administration (FDA) and other organizations. How will every consumer know what they are buying upon purchasing different lab-grown meat products? Aside from that, convincing people to eat meat grown in a lab is undoubtedly going to need a significant amount of time, as people often perceive that in-vitro meat is unnatural.

Price

Presently, in-vitro meat is still not affordable for everyone because of its high production costs. These expenses are proven to be more expensive compared to the amount of meat it can produce.

Taste

To many buyers, the manufacturing of in-vitro meat already seems not enticing, and to be able to convince the mass to turn to it, it has to look and taste like real meat. It is described that the first lab-grown meat patties made were tasteless. Understandable, but food technology companies will surely need to allot time until they perfect the taste of their product.

Accomplishments

The company Mosa Meat has been working on mainly 4 factors since the first launch of the lab cultivated hamburger in 2013.

The first factor is that they were able to produce the meat in red color just like the livestock meat, which means that they were able to improve the protein content in it. This was possible by allowing the cells to produce more myoglobin to provide oxygen carriage within the cells just like the ones in the conventional meat. Aside from that, they were able to add fat tissues into the meat to maintain the taste and moist texture within the meat. Then, they were able to find a solution to the biggest challenge which was to find a substance that could replace the fetal bovine serum (FBS). Through the development of the serum-free medium, they were also able to reduce the production cost, as the serum had embraced 80% of the cost. Lastly, they were able to plan a bio-production process that could help them mount in the rate of production (industrial volume) in the future when they finally have the permission from the regulatory authorities (Mosa Meat, 2020). **Alternatives, like plant-grown meat?**

Future Research Steps

Although the first lab-grown meat burger was already produced in 2013 by Mark Post in the Netherlands, the meat itself needs more time to get to the markets as a selling product. Mosa Meat aims to bring the finished products to our dining tables by 2021 (Mosa Meat, 2020). To accomplish this goal, they have to make sure that they produce “The best” lab-cultured meat. Now that they had found feasible solutions to the problem of animal slaughtering, global warming, food crisis, etc. through the cultivation of meat, their focus has gradually changed to steps in making the meat healthier as well as the improvement of the rate of production.

As mentioned before in the interview, their current focus is to obtain the lab cultivated meat as a replica of the conventional meat. This includes the addition of fat tissues that can lead to a rise in cholesterol levels. So, the alteration that they can do in the future is to reduce the quantity of fat tissue applied. Inducing the fat cells to make more o-3 fatty acids by letting cows graze on grass rather than from feedlots would also help in maintaining the cholesterol level steady and decreasing the threat of cardiovascular diseases. The other problem that they are trying to solve in the future is to pinpoint the element in red meat that causes colorectal cancer with the help of more advanced scientific inventions. Despite the fact Mosa meat was able to develop the serum-free medium for tissue engineering, they still need to enhance it in the future. Just like now, their main objective is to make the cultured meat healthier than the livestock meat without using any genetic modification also in the future.

Another goal is to bring down the price of lab-cultivated meat. According to Beckie, once the meat is out to the public the price of a hamburger would be 9 €, which is relatively expensive. Thus, their goal is to bring this price down in the future by improving its efficiency. The price could also be dropped by increasing the rate of production. The production rate could be augmented once they get the regulatory approval and then change the location into an industry, where they can produce in a large scale in less time.

Summary

In-vitro meat is meat grown artificially, also known as lab-grown meat. It shares many attributes with real meat, such as smell, taste, and appearance, it does however not have the same complex 3D structure that real meat has and is presently still costly. Yet, in-vitro meat significantly reduces the unethical treatment to animals raised for our meat consumption as well as considerably lessens the environmental damage and cost during production. In-vitro meat is created by extracting a small amount of muscle tissue out of the respective animal, from which stem cells can be collected. The collected stem cells can then be multiplied in a growth medium that promotes tissue growth and later differentiated into primitive fibers that bulk together to form muscle tissues.

The sequence of statements is different from the paper (e.g., the description of technique is at the end here.

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