NSF/ASME Design Essay Competition 2018

Undergraduate Category

Viva In Vitro

Replacing farmed meat with lab grown meat on supermarket shelves everywhere

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Abstract

In this paper, the potential of a global manufacturing corporation utilizing lab grown meat to replace the farmed meat industry is proposed. Commercializing lab grown meat offers "healthy" competition to large meat production companies by offering something they can't: a product that is cruelty free, non-threatening towards the environment, and does not contain antibiotics nor cause food borne illnesses. By partnering with small start-up companies, major innovative research laboratories, and local farmers, in vitro meat will become the food of the future provided by a global and high tech corporation. The process of manufacturing lab grown meat involves the simple extraction of muscle and fatty tissue that is grown on a 3D bio-structure in a bath of nutrients. Significant research is needed in optimizing the flavor and appearance of lab grown meat as well as driving the cost down to an affordable rate. This high tech solution to an age old problem has several applications in other industries such as humanitarian efforts, space travel, saturation diving, and military usage. In general, lab grown meat has the ability to replace farmed meat across supermarket shelves worldwide.

Introduction

Recent breakthroughs in technology have enabled us to manufacture self-driving cars and send them to space, but can we fabricate the one thing we can't live without: food? Agriculture has heavily influenced the course of human history and will continue to do so well into the future, especially as the population continues to rise. Where some picture the future as hovercrafts and iridescent metal buildings, others see an impending global food crisis. With a growing population comes an even larger desire for high quality food like meat and dairy; however, we are encountering a climate system that is harming harvests worldwide, specifically for grain crops which food animals are fed [1]. As humanity reaches this critical impasse, we bring you a new method of food production: in vitro meat.

In vitro meat production is the jack-of-all-trades solution to this ongoing problem. By the year 2035 this corporation will bring beef patties and chicken tenderloins to restaurants and grocery store shelves that did not come from an animal, but from a culture dish. We have brought both old and new technology together to completely take over the current food industry sustainably as a "source of societal hope" [2]. Current practices of meat production harm the environment, food animals, and human health. By growing meat in a lab setting we will reduce environmental harm, eliminate animal abuse, and increase health benefits typically found in meat.

How it Works

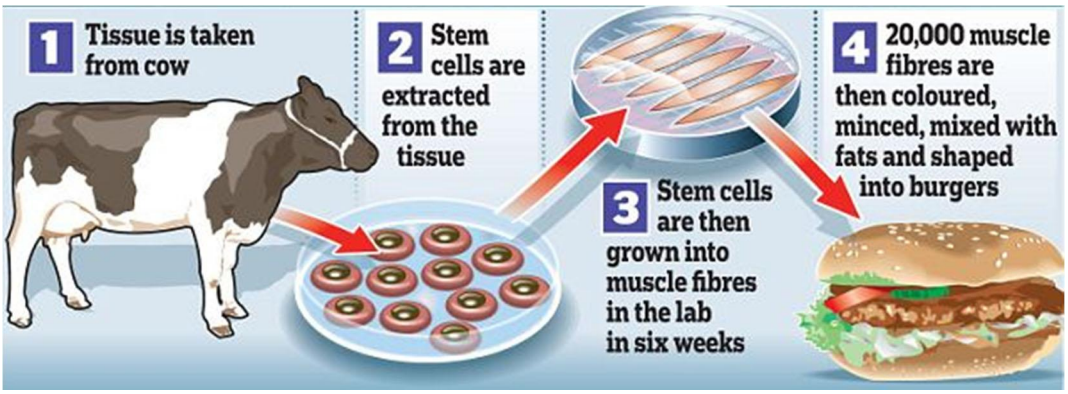

Figure 1: Process of Lab Grown Meat [3]

First, a small tissue sample is extracted painlessly from the donor animal and specific muscle or fat stem cells are extracted. These cells are then placed into a nutrient medium to allow them to multiply and grow. A three dimensional support structure can also be added to the concoction to provide a template for the muscles to grow around and resemble different types of muscles such as a steak or tenderloin [4]. The support structure is typically made of natural biomaterials that are non-toxic. In large scale applications, such as replacing the meat production industry, bioreactors are utilized to produce a greater volume of cells with more control over nutrients and metabolites [4].

In more recent methods, fat cells are mixed with the muscle cells in order to provide a more realistic flavor because “fattier meat is generally tastier” [4]. This corporation will be focused on regulating a perfect ratio of fat and muscle tissue to reduce health risks associated with consuming fatty tissue. Jon Vein suggested exposing the muscle tissue to electric current to simulate exercise to make it more synonymous to the real muscle tissue found on a living animal. In order to make our lab grown meat healthier, nutrients may be directly added to the growth medium through the genes that are responsible for the biosynthesis of Vitamin A, B, or D [4].

Background

We will not make in vitro meat production popular for being a new technology, we will make it popular for being an important technology. With the ability to save the environment, food animals, and meat eaters alike, it's a surprise this fairly old technology hasn’t been globalized on a large scale before us. In 1982, Winston Churchill wrote in his novel *Fifty Years Hence* “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...parks and gardens will cover our pastures and ploughed fields” [5]. Churchill understood the wastefulness of meat production and the detrimental effects is has on the environment, taking up almost a quarter of the worlds land for pasture alone [6]. What started out as a mere suggestion will allow us to blossom into a groundbreaking high tech corporation.

In 2001, Jon Vein patented a method for producing consumable tissue engineered meat. This method involved culturing muscle stem cells and allowing them to mature into specific types. When the cells become muscle tissue, a structure support is added to allow the cells to grow in three dimensions. This support structure can be made into any shape or size to represent a steak, chicken breast, tenderloin, etc. Another support system involves porous membranes diffusing nutrients from one side of the cell to another. This structure must be able to provide nutrients to the growing cells. In order to produce a greater volume of cells in a more controlled environment, a bioreactor is used [4]. To optimize taste, fat cells are added to the muscle cells; however, it is important to get the ratio right to avoid risks of heart disease.

The clean meat venture has so much potential that even PETA (People for the Ethical Treatment of Animals) participated in the movement, offering the first company to produce a market ready lab grown specimen by 2012 one million dollars [7]. Time magazine included cultured meat production to be one of the 50 breakthrough ideas of 2009 [8]. This has been a breakthrough idea for a while now and it's time someone acted on it.

A true breakthrough occurred in 2013 when Dutch scientist Mark Post debuted the world's first "clean burger" funded by Google cofounder Sergy Brin [9]. This historical patty is actual animal tissue, "without the living conscious animal" [5], created from extracted cells and grown in a culture dish to form strands of muscle tissue. While this one of a kind burger cost researchers $330,000, Post insights that lab grown meat will soon be less expensive than farmed beef and be more appealing than plant-based meat substitutes [9]. Taste testers agreed the "clean burger" has similar taste and appearance to that of a farmed burger.

Figure 2: Lab Grown Burger [10]

Challenges

- Gaining a positive public opinion
- Shutting down large meat production plants and slaughterhouses

- Perfecting the flavor
- Funding

It is important for this corporation to be transparent with the media in allowing them to understand the process, its benefits, and the harmlessness of it [11]. There is a negative stigma around genetic modification and it is imperative to keep this form of cellular agriculture separate. Individuals who may not understand or agree with science may be skeptical of this new form of meat and it is up to us to gain their trust and approval.

The hardest part about this transition from farmed meat to clean meat will be the competition: the farmed meat industry. “People who are environmentally aware are keen on this, animal rights activists are keen on this, health advocates are keen on this. The only people who aren't keen are in a business that this will affect,” [11]. An exception to this is Tyson Foods who recently invested in Future Meat Technologies, a startup focusing on a new process to reduce the cost of clean meat [6]. This process involves a medium made of sugars, salts, and amino acids that are recycled and cleaned rather than replaced. Unfortunately, not all large food production corporations are concerned about their negative impact on society, which is what will make our empire stand out above all others.

While the first clean burger tasted similar to a real burger, there was still plenty of room for improvement. It will take the perfect combination of fatty tissue, muscle tissue, and flavorings to produce a product with a taste identical to farmed meat. With a team of scientists and flavor chemists, we will achieve the perfect flavor for all of our products at an affordable price. Another challenge is finding the funding to allow this important process and resource to become available worldwide. As of now, it costs around $1,000 to produce one pound of clean meat [12].

Advantages

There is nothing natural or sustainable about meat slaughtering and processing plants. These facilities are incredibly wasteful and harmful to man and animal alike. By changing the way we produce our main food source, we will also change the course of human history. To be a leading global industry, you must first acknowledge your impact on the consumer and the environment. The twenty-first century holds a renewed sense of awareness in its residents, understanding the importance of healthy habits and sustainable living has never been more prevalent. The modern consumer is attracted to transparency [13] and what is called conscious consumption; where the consumer actively seeks out ways to make positive decisions as well as solutions to the negative impact of blind consumerism. A common theme is product origin, making the meat production industry a target for scrutiny as billions of animals are slaughtered each year. According to a survey conducted in 2016, of the 726 individuals questioned, 80% became vegan due to ethical concerns for animals, 15% converted to veganism for personal health benefits, and 12% converted for environmental reasons [14]. Majority of the individuals

questioned were between the ages of 18 and 49, making them the perfect target audience for a new food group of the future: clean meat.

Clean meat, also known as lab grown meat or in vitro meat, will completely take over and replace farmed meat in the food industry by the year 2035. Bringing meat and poultry to the lab for widespread manufacturing will have tremendous benefits to society including a decrease in greenhouse gas emissions, food borne illnesses, starvation, and animal suffering.

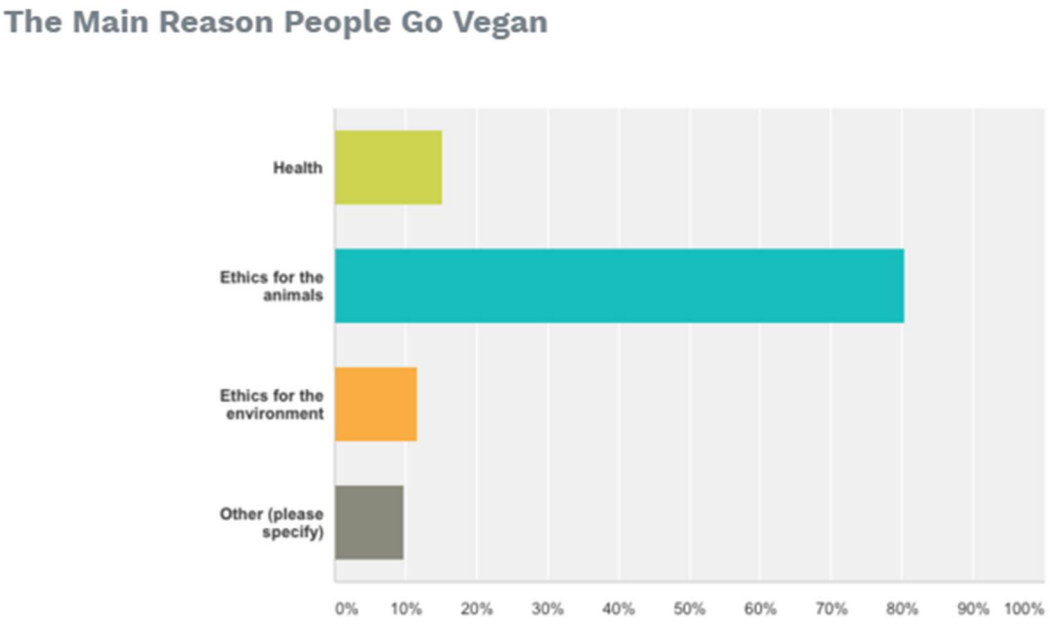

Figure 3: Reason People Go Vegan [14]

Environmental Advantages:

The agriculture industry alone accounts for 30% of the world's greenhouse gas emissions and 70% of the water footprint [15]. It takes thousands of gallons of water just to produce one pound of beef, allowing the average American meat eater to contribute one and a half tons more CO_2 to the environment than a vegetarian [12]. These numbers will continue to rise as food production is projected to increase 70% by the year 2050 [15].

Slaughtering animals takes up resources, so does feeding them. Cattle ranching is to blame for most of the deforestation in the Amazon basin, depleting it at a rate of 500 square feet for every pound of beef [12] [4]. As the human population grows, so does the population of food animals such as cows, chickens, and pigs. “We’re running out of land, we’re running out of water resources, and if you want to continue feeding a growing population…then we need to fundamentally change the way we produce meat,” [6].

By creating the meat we want to eat, no energy or bodily structures are put to waste as would be in traditional meat production. Farmers can own and care for fewer animal cell donors, allowing the industry as a whole to take up less land utilize fewer resources.

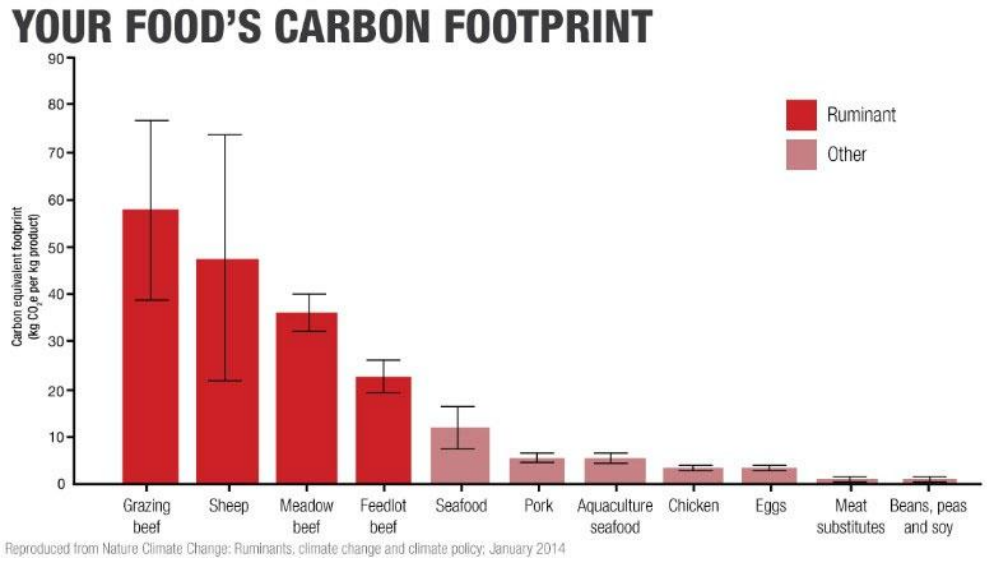

Figure 4: Carbon Footprint of Food Animals [16]

Moral Advantages:

Billions of land animals are slaughtered each year at the hands of the meat production industry. Hens are kept in tiny 8x10 inch cages, pigs are only given a 2x6 inch footprint, and of all retained meat, over 25% of it goes to waste [17]. Animals are suffering, the environment is suffering, and it is time for a change. The few animals needed for cell donations can live painlessly and die of old age in "truly humane conditions" [12]. Farmers can be educated on how to collect and grow cells in house to maintain the same number of occupations even after slaughterhouses are shut down. Cruelty is reduced dramatically with our method of meat production.

Table 1: Annual Death Toll of Food Animals

Animal	*Killed Annually*
Chicken	9 billion
Turkey	300 million
Cow	30 million
Pig	110 million
Duck	30 million
Sheep	2 million

Health Advantages:

There are many health risks involved with current meat production methods. Every year, 76 million people are affected by fouled food; 5000 of those cases ended with fatality [12]. Salmonella is a major concern in poultry and shockingly enough, 45% of chickens are allowed to test positive for the disease [4]. Also allowed in animal feed is brains, spinal cords, restaurant waste, and poultry litter [12].

Food animals are pumped full of antibiotics and growth hormones to keep up with America's large appetite for meat. Antibiotics allow livestock to grow larger in shorter amount of time and eat less. While farmers argue it is necessary to keep the animals healthy, it may be doing the opposite to their human counterparts [18]. As germs become antibiotic-resistant in animals they increase the risk of deadly infections towards humans.

Bringing clean meat production to industry eliminates the usage of antibiotics and other genetic modifiers completely. The size and weight of the animal does not matter when you are only taking a few cells. When dealing with the product on a cellular level, salmonella and other diseases are at much lower risk, if any at all [6]. Scientists and engineers will have the ability to customize the final product, adjusting the fat and muscle components that contribute to it. In order to make the lab grown meat healthier, life threatening omega 6 fatty acids can be replaced with more beneficial omega 3 fatty acids [6].

Global Advantages:

It is estimated that there will be 9 billion humans on the planet by the year 2050, meaning the demand for animal protein will grow as much as 80% [12]. In order to meet this high demand, more land and resources will need to be compromised and there simply isn't enough to go around. While thousands of pounds of water and other resources are wasted in the food industry, over 800 million people are malnourished and dying throughout the world [4].

By manufacturing meat in a lab, it can be mass produced in large quantities at an affordable price for all. Instead of raising thousands of chickens or pigs, producers just need to collect cells and place them in a cultivator.

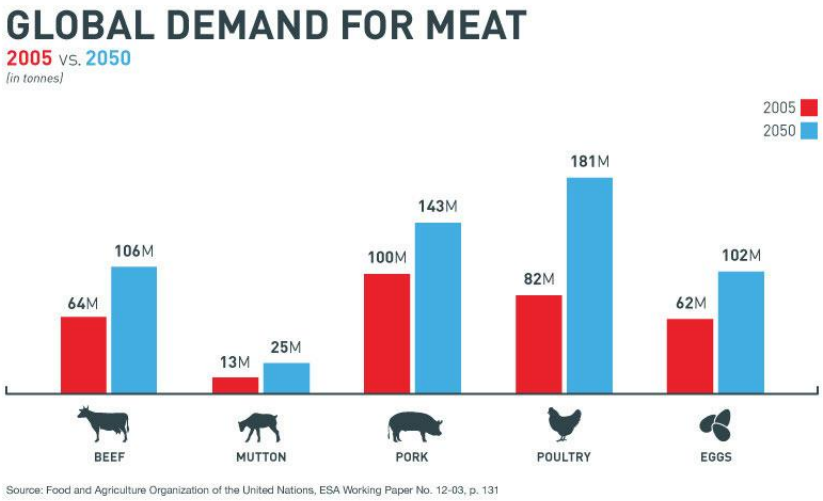

Figure 5: Demand for Meat Increase from 2005 to 2050 [19]

Commercial Opportunities

By the year 2035 in vitro meat will have the capability to replace farmed meat on supermarket shelves worldwide. Local farmers have the opportunity to transform slaughterhouses into peaceful pastures for cell donor animals and provide their samples to larger corporations. Lab grown meat is extremely attractive to the average consumer when considering its increased health benefits, redeemed moral values, positive impact on the environment, and reduced cost. Depending on where the cells are sourced from, lab grown meat may be consumed by vegetarians/vegans and can even be considered kosher for those following strict dietary regulations. With the ability to customize the appearance and flavor of the meat at a cellular level, new and rich flavors can be developed based on consumer preferences.

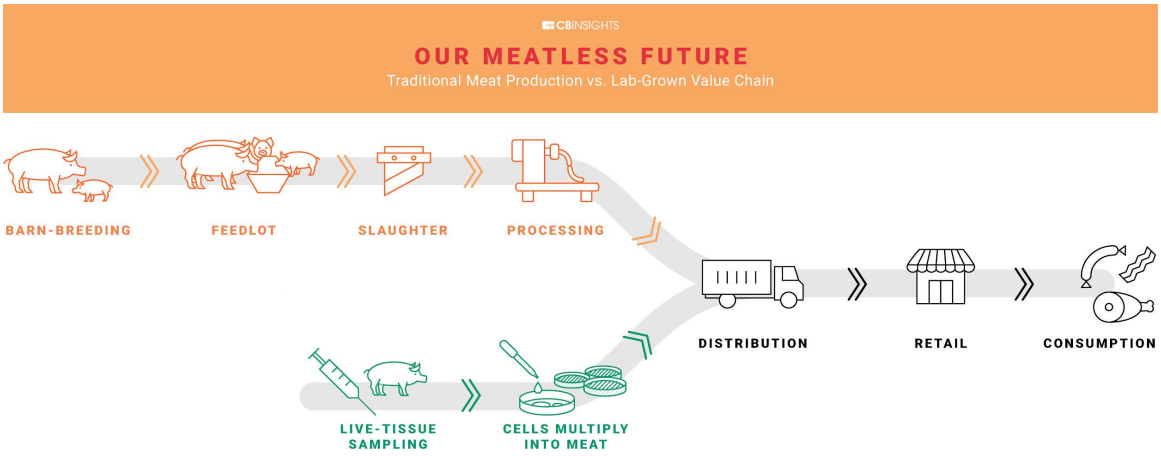

Figure 6: Process Differentiation of Farmed Meat vs. Lab Grown Meat [20]

Technology to Develop

With further development and applications in fields outside of agriculture, production of clean meat has even larger benefits. To replace farmed meat, lab grown meat must first taste the same, if not better. The perfect ratio of muscle tissue to fatty tissue must be found to acquire the accurate taste and cellular representation of farmed meat. Further developing the technology, a vascular system could be developed inside the maturing tissue to distribute nutrients evenly throughout the developing product. As these processes become more widespread and optimized, the cost will continue to drop, allowing availability to more consumers worldwide. Once lab grown meat tastes the same as farmed meat and is less expensive than farmed meat, there will be no reason to resist the transition.

Because lab grown meat eliminates bacteria and diseases typically associated with farmed meat like E. Coli and salmonella, further applications can be utilized in space travel, saturation diving, and the military where illness can quickly turn deadly.

While making the transition to lab grown meat will benefit the environment and moral beliefs, it has other beneficial applications. The concept of cellular manipulation can be combined with bioprinting to develop a process for "growing" human tissue or organs. While this technology is developing rapidly, it is yet to hit large scale manufacturing. There are currently 115,000 people in the United States on the waiting list for a life-saving organ transplant [21]. The capability to readily manufacture an organ from a few donor cells will alleviate the wait list and save thousands of lives.

Company Profile

Small startup companies and research labs are appearing all over the world with the same goal: offer the consumer a cruelty free meat alternative that is cost efficient and comes from a sustainable process. However, two things are lacking: money and the public eye. Combining the resources of these smaller parties with our large global corporation will provide lab grown meat with the popularity and funding it deserves.

Table 2: Partnerships

Industrial Partnerships	Research Partnerships
Tyson Foods	Penn State Engineering: Bioprinting lab
Local Farmers*	The Good Food Institute
Future Meat Technologies	University of Minnesota
Memphis Meats	Karlsruhe Institute of Technology

Tyson Foods share our drive and passion for developing the technology to mass produce meat in a lab setting rather than on a farm [22]. A partnership with this multi-billion dollar company would allow all further research to advance. Tyson Foods has already invested in Future Meats Technology and Memphis Meats, organizations we would be glad to work with as well [6].

Partnerships with research labs will benefit us immensely with their ability to continuously discover new and refined methods in this up and coming industry. University research labs also give students the opportunity to gain experience with this technology and hopefully inspire them to pursue a career on the same path.

Conclusion

In conclusion, converting to lab grown meat will revolutionize the meat production industry. As a high tech global manufacturing company at the forefront of this movement, it is important to learn from old methods and understand the wants and needs of the consumer. Farmed meat production is harmful to the environment and the consumer and should not be tolerated any longer. Production of lab grown meat is an idea of the past, a reality of the present, and the shining beacon of the future.

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