3111 Major Research Project - CAD A 20/21

The environmental, economic, and social impact of bio-printed meat.

3160 words

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Glossary:

FAO – Food and Agriculture Organization

The environmental, economic, and social impact of bio-printed meat:

Introduction:

The Meat industry is a huge enterprise, rising exponentially due to the great need for food for the constantly growing masses. The problem with this is that farms and butchers cannot keep up with the extremely high demand for meat by the people, causing factory farming to become commonplace, industrializing the farm trade. Causing problems such as this brings up a series of environmental issues, such as 'contributing significantly to global warming through releases of methane, a greenhouse gas 20 to 30 times more potent than carbon dioxide.' (Carlota, 2019), ethical, as any alternative creates 'a tremendous amount of animal slaughter and suffering.' (Vegan.com, 2012) and economic concerns, 'The value of the global meat sector was valued at 945.7 billion U.S. dollars in 2018 and was forecast to increase to 1142.9 billion U.S. dollars by 2023.' (Shahbandeh, 2019) (Figure 1).
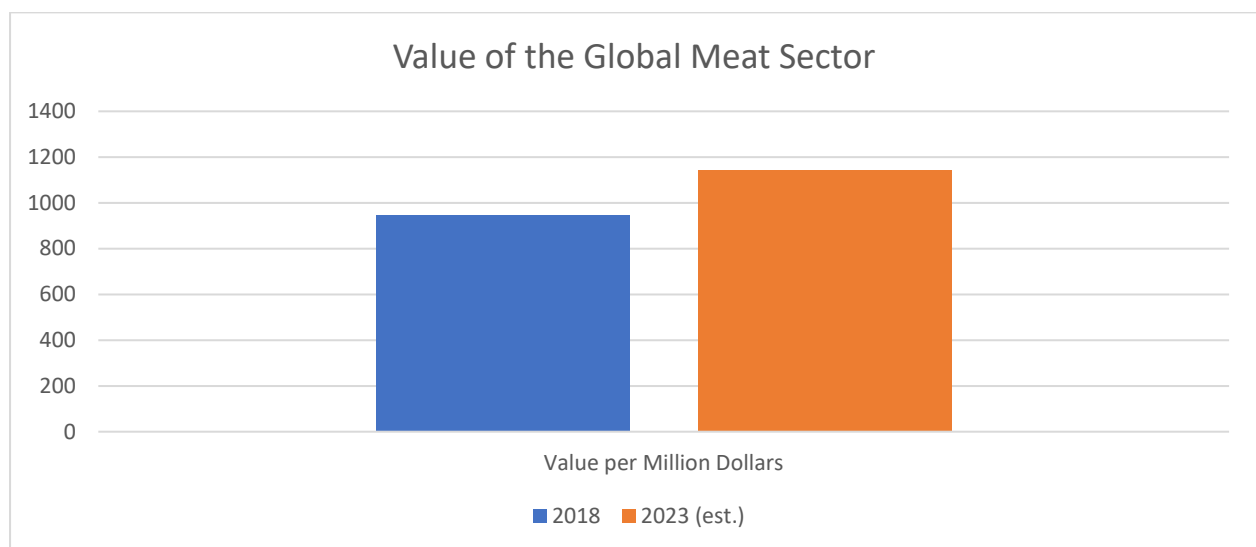

Figure 1: Value of the Global Meat Sector (Shahbandeh, 2019)

Many are campaigning against this by going vegan, vegetarian, reducetarian, or flexitarian. Each of these political campaigns is in protest of the Meat Industry's effect on each of the problems arising due to the growing industry of factory farming.

Bioprinting is a new and innovative way of shaping biomatter into different objects, such as Organs, Muscle tissue, and, when using plant-based fiber, or cell-cultured meat, it can be used to shape, simulate or even create real Meat. By using bioprinting to create meat, there is potential to potentially eliminate the time constraints on rearing animals for food: 'It seems like it would be a lot faster and more efficient than bioprinting a heart.' (Carlota, 2019) Bioprinting could eliminate the need for factory farming, requiring no animals to be harmed and potentially become a much cheaper alternative, while still providing the same product, if the cultured meat is shaped and designed to look and have the same texture as regular meat. Currently, 3D-Printed meat is only being used by KFC, which uses a hybrid mixture of 'roughly 80% plant-based material and 20% cell-based to mimic the taste and texture of Yum! Brands-owned KFC's conventional counterpart' (Southey, 2020). But KFC currently only uses this technology in a single branch in Moscow.

For my dissertation, I will be exploring the possibilities that Bioprinting will open, the extent to which it can be used, and the impact it could have on the world, socially, economically, and environmentally.

I will also be exploring why the Meat Industry is so large and whether the change will be welcomed by all social standpoints, or not.

Thesis Statement, Aims & Objectives:

Bio-printed meat could potentially be a more ethical, economic, and environmentally friendly alternative than factory farming living animals.

Aim:

To find if bio-printed meat is a more ethical, economic, and sustainable way to produce meat than other alternatives and if there would be opposition to it.

Objectives:
- Investigate what Is required to bio-print a meat alternative.
- Explore whether bioprinting is a cheaper alternative than farming animals for producing the world population's 'need' for 'meat' in their diet.
- Identify why there is such a need by people to eat meat.
- Discover whether bio-printed meat would be an acceptable alternative for meat-eaters.
- Investigate the impact on the environment if farming meat was replaced by bio-printing meat.

Structure of the Dissertation:
- Introduction: Where society stands now, the current consensus of the general populace's thoughts on 3D printed meat, the divide on consumer's thoughts on if they would eat it or not. Educated hypothesis on what kind of impact bio-printed meat could have on the environment and the economy.
- Literature Review: Analyzing current academic sources and using this to show my understanding of the current situation for bioprinting, from an ethical, environmentally friendly, and economic standpoint, to better assess where the future of bioprinting lies and how useful it will be for the meat industry.
- Methodology: Planning what questions I will ask during my interviews of avid vegans, vegetarians, and meat-eaters, to see if bio-printed meat will change their diet and to see if they have any problems with the process of the creation of this meat. I will detail where and who I will be questioning and interviewing and why I have chosen the target audience to answer all my questions.
- Result and Analysis: Analyzing the results from my primary research to paint a clear picture of the opinions of the general public and using this to deduce a future for bioprinting. I will also have found if bio-printing is a sound alternative for the meat industry economically and if it is better for the environment, by finding out what the method of creating bio-printed meat currently entails and if it is any better than current methods of factory farming. I will also research whether it can be produced quickly enough, in enough quantity, to replace factory farming.
- Conclusion: Closing points, a summary of what I have learned from my research. Explaining what the future of bio-printing will be like and how it will affect the world if it becomes the new, proper alternative to factory farming and if it has the potential to do so.

Time Management:

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Thinking of Ideas	■											
Research		■	■									
Planned future research		■		■								
Writing Drafts				■	■	■					■	
Proofreading						■				■	■	
Review and Hand-in											■	

I had planned to have the majority of my research completed by week 4, so that I could focus on just writing out my work, using the relevant sources I had found previously, as to not break the flow of my writing. As I was writing, I found that some points I was making were not justified explicitly, as such I was able to do small parts of research as and when required. I was able to keep to this plan, save for a few statements made, but any unsupported points I was able to remove and replace with new research found on the topic while investigating that previous point.

Literature Review:

Introduction:

The focus of this literature review is to understand how viable bio-printing can be used to enhance the reputation and usage of cultured meat, and plant-based meat alternatives, especially if being used in conjunction with one another. For example, KFC's idea of using plant-based materials to feed and develop the cultured meat into the correct shape and texture to mimic the meat itself (Southey, 2020).

Many recent journals[1] have focused on understanding and focusing on bioprinting and cultured meat separately, as they are both very new and promising technological advancements. Bioprinting is mainly being used for its medical benefits: 'As of today, most products derived from mammalian cell cultures are in the high-value, low-volume territory, e.g., therapeutics and pharmaceuticals' (Zhang, et al., 2020) while cultured meat has been in development for the last two decades. This means that there is considerable research and academic writing concerning cultured meat, although it is still relatively new, there are a growing number of academic journals on the topic, such as (Bryant & Barnett, 2018;Ewing-Chow, 2019;Mancini & Antonioli, 2019;Verbruggen, et al., 2018);Wilks, et al., 2021) among others, that will be explored in-depth throughout my literature review. Bioprinting for medical uses, such as creating new organs and muscle tissue, is gaining significant traction in the academic world because of its high usage and interesting, fresh discoveries. However, the bioprinting of meat, shaping cultured meat into an interesting and edible shape and texture, has not been widely researched, leaving a gap in the research for bio-printing technology being used to mimic meat.

The food industry has been responsible for the largest environmental impacts of humans on natural systems: 'presently, the largest shares of human land and freshwater use, biomass appropriation, and the alteration of the global nitrogen and phosphorus cycles, and a significant contribution to energy use and greenhouse gas emissions.' (Kastner, et al., 2012) Many sources, such as the Food and Agriculture Organization (FAO) of the United Nation, have calculated that 14.5% of the global carbon footprint comes from the production of meat and livestock farming (Carbon Stock Editor, 2019). This number is an important one, but only shows the Carbon Dioxide output created by the meat industry. continuation more comprehensive picture can be shown with the following statistics: 'the predominant greenhouse gases emitted from agriculture are methane (CH4) and nitrous oxide (N2O), which respectively possess 21 and 310 times the global warming potential of carbon dioxide (CO2) (IPCC, 2006). Nationally, agriculture is the dominant source of both methane (59%) and nitrous oxide (84%) emissions (Department of Climate Change, 2006).' (Biswas, et al., 2010) Putting these figures together, it is clearer to see 'livestock farming accounting for close to 18% of all greenhouse emissions' (Ewing-Chow, 2019) as well as 'monopolizing 70% of all arable land and 46% of all crop-production for feed' (Ewing-Chow, 2019). These combined figures show that the effect of farming and modern agriculture is hugely detrimental to the environment. That is why it is important to find an environmentally friendly alternative, especially with the estimation that 'demand for meat is going to increase by more than two-thirds in the next 40 years and current production methods are not sustainable.' (FAO, 2011). Furthermore, farming uses a considerable amount of space, academics Li,

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[1] (Murphy & Atala, 2014), (Mattick, et al., 2015)

Filimonau, Wang, and Cheng (2020) have completed a study to determine how much cultivatable land is used by farms for food production:

> 'It finds that tourist food consumption per meal has increased by 8% within the period of 2013–15 which translates into over 50% increase in arable land requirements (ALR). The study further pinpoints that 84% of the ALR increase is attributed to the animal-based food consumption of tourist. Lastly, the study shows that, in 2015, nearly 62% of the arable land area of the Lhasa region was required to meet the growing tourist demand for food.' (Li, et al., 2020)

A 2013 study into agriculture yields finds that only 55% of [usable product] from global crops are allocated to human consumption, 36% is used as feed for livestock and the remaining 9% is used for other uses, such as biofuel. (Cassidy, et al., 2013) It goes without saying that by lowering the amount of livestock, fewer crops will be used for animal feed, and that space can be used to produce more edible food for the growing population. However, as previously stated, 'The value of the global meat sector was valued at 945.7 billion U.S. dollars in 2018 and was forecast to increase to 1142.9 billion U.S. dollars by 2023.' (Shahbandeh, 2019) (please see Figure 1), while the 'investment firm UBS projects growth of plant-based protein and meat alternatives to increase from $4.6 billion in 2018 to $85 billion in 2030. The Swiss company said that estimate could be a conservative one if innovation and consumer awareness drive more consumption.' (Siegner, 2019). This shows there is a market for meat-alternatives, and potentially a market for 'clean meat', or 'Cultured Meat'. This is discussed later, theorized by Tomiyama, et al. (2020) as well as Mourtisen and Styrbæk (2017), that taste is a key factor and that bioprinting can fix this problem, potentially along with the shape and look of the meat.

Cultured Meat, and by extension bio-printed meat, can be much more beneficial to the environment, this is supported by multiple studies showing the sustainability of Cultured Meat compared to alternatives. They provide an indicator of approximately 78%-96% lower greenhouse gas emissions, 99% lower land use, and 82%-96% less water use. (Tuomisto & Mattos, 2011;Mattick, et al., 2015). Many providers of cultured meat praise the ethical and sustainable way in which it is created: 'We argue, among other things, that genetic engineering firms understood their work to be humanitarian and environmentally friendly and so were unprepared for popular backlash' (Mohorčich & Reese, 2019). Additionally, from an economic perspective, 'research has shown a rise in UK consumers incorporating more vegetarian and vegan choices into their diets (Caldwell, 2015). Informa Agribusiness Intelligence estimates that by 2021 UK sales of meat analogues will grow by 25% and milk alternatives by 43%; such growth will take the total UK sales of milk alternatives from £149 million (US$208 million) to £299 million (US$400 million)' (FoodBevMedia, 2017 cited in Stephens, et al., 2018) This shows that due to popular demand, with people's views changing about what is ethical changes in diet are taking place:, 'younger people also may be more open to ethical and environmental messages regarding their food choices, as they are less likely to be skeptical about anthropogenic climate change' (McBey, et al., 2019). This changes the dynamic of where money may be made. Moreover, cultured meat does not use as much space as a farm: 'Commercially available production-scale bioreactors for cell cultures are typically 1–2 m3 in working volume, although larger vessels up to 10–20 m3 can be custom built' (Oosterhuis, 2018 cited in Zhang, et al., 2020) However, the problem with large-scale bioprinting of meat, is that it is not yet known about the optimal conditions to maximize the amount of product received from one bioreactor, therefore it is difficult to know

whether it is the most cost-effective process to replace the current meat industry (Verbruggen, et al., 2018).

So why are so many people still eating meat? Academics have explored this in the past, examples include E Scott, G Kallis, and C Zografos (2019), who found '[environmentally conscious interviewees] reasoned that they eat meat because either technological, or political changes are more important than what they personally do, because of doubts about the impact of personal action in a complex world, or simply because they lack the determination to stop eating meat.' (Scott, et al., 2019) Having an environmentally friendly way of eating meat seems ideal. However, the main problem with replacing farming is the initial 'disgust' and neophobia that comes with the change, due to 'perceptions of naturalness [being] crucial to the acceptance of food technologies (Roman, et al., 2017). The results of one qualitative study suggested that cultured meat evoked feelings of tampering with nature' (Marcu, et al., 2015 cited in Siegrist & Hartmann, 2020), At first glance, this appears to be the main reasons against cultured, or 'clean', meat. As previously stated, Cultured Meat is a modern way of producing meat using In-vitro methods, which means the meat is grown without the need of a live animal: 'Cultured Beef is created by painlessly harvesting muscle cells from a living cow. Scientists then feed and nurture the cells, so they multiply to create muscle tissue, which is the main component of the meat we eat. It is biologically the same as the meat tissue that comes from a cow' (Cultured Beef, 2013). The biggest issue with cultured meat, which is currently the only modern alternative to farming or hunting for meat, is the concern for the taste and texture of the product. 'A number of potential barriers to engagement were identified and coded into 9 categories: The proportion of respondents citing these reasons were: taste/appeal of the product 79%' (Wilks & Phillips, 2017) But does cultured meat taste any different? This is where the texture of the meat becomes a potential problem, as 'texture actually becomes the most important concept' (Mourtisen & Styrbæk, 2017). Modern methods only allow for 'using beads as a substrate to grow cells as building blocks of cultured meat; this can support blended products, such as burgers and hot dogs' (Tomiyama, et al., 2020). However, Bioprinting can now be used to shape and texture the meat, 'to achieve cultured meat that mimics the texture of different cuts of meat, muscle fibers can be produced on edible scaffolds generated using techniques from tissue engineering and regenerative medicine; some of these approaches are already used in plant-based meat' (Tomiyama, et al., 2020) to give the meat structure, providing the texture of conventional meat, thus eliminating some of the negative perception, which will help to increase customer engagement.

Further studies into the distaste of cultured meat found:

> 'We found little evidence that naturalness perceptions flowed from a process of analytic reasoning; rather, ratings of unnaturalness appear to be grounded in affective mechanisms such as disgust and fear. This suggests that acceptance strategies that target analytic processing (e.g. information) may have limited success, which has indeed been the case with the strategies tested to date.' (Wilks, et al., 2021)

This shows that to tackle the misconceptions of cultured meat, the scientists must address the neophobia of the meat, making it look and seem natural, by going to extensive precautions to show that it looks tasty, and is tasty, in the same way, that conventional meat is. For this, they can use bioprinting, as suggested and referenced earlier (Tomiyama, et al., 2020).

'In terms of negative attitudes and intentions toward cultured meat, the most powerful predictors were food neophobia, political conservatism, and distrust of food scientists. When it comes to absolute opposition to cultured meat - defined by the unconditional belief that it should never be allowed under any circumstances - the strongest predictors were food and hygiene disgust sensitivity subscales, food neophobia, and conspiratorial ideation. A number of presumed mechanisms held no relationships to cultured meat attitudes, including social dominance orientation, speciesism, and naturalness bias.' (Wilks, et al., 2019)

It seems logical, that the only problem unsolvable by bioprinting, is the distrust of scientists and the politics behind it. As most cultured meat laboratories are open about how they create it (Mosa Meat, 2019;Cultured Beef, 2015), we know that this is not a major concern. However, this seems so alien and advanced, that mostly only the young and adventurous, those well-educated and already familiar with cultured meat, will take to the idea, which is a vast minority. This can be deduced by a study undertaken in Italy: 'The profile for a potential consumer of cultured meat was young, highly educated, somewhat familiar with cultured meat, a meat consumer and willing to reduce meat consumption.' (Mancini & Antonioli, 2019) and that 'as commercialization of this technology appears increasingly feasible, there is growing interest in the research on consumer acceptance of cultured meat.' (Bryant & Barnett, 2018).

Summary:

The meat industry is constantly growing, due to an increasing population, but many people are opting for vegetarian and vegan options to try to slow climate change, for ethical concerns, and to shift the economy over to a more sustainable and ethical lifestyle. Cultured Meat is a huge step forward, being able to create meat without the need of harming, or even killing animals to get the same product. The concerns with cultured meat can be solved with education and bioprinting. Bioprinting will allow cultured meat to taste and feel the same as conventional meat, allowing the new normal to become bio-printed meat, creating a more sustainable and happy future.

With this information, the objective of my primary research will be to assess the viability of changing public opinions, based on what I have discovered with my research, as well as finding definitive answers for my question, pertaining to whether bioprinting is a cheaper and less spacious way to produce meat.

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