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Agriculture is an incredibly large sector of the food industry, which entails the raising, feeding, watering, and housing of livestock, eventually resulting in food on the supermarket shelves. This is convenient for consumers, as it is easy to take a trip to the store and pick up whatever is needed for a meal. The industry behind what is on the shelves, though, is a bit more of an arduous process, and one that is not mentioned as much in mainstream conversation. The specific livestock referenced throughout this paper will be beef, as it is one of the highest contributors towards environmental impacts and is a relatively common household food item. Beef production contributes to greenhouse gas emissions, uses large amounts of freshwater and grain resources, and requires antibiotic use to ensure the livestock remain relatively healthy. The current emerging issues involving climate change warrant action, as changes to the environment affect weather patterns and sea levels. These changes to the environment directly impact people all over the world, as witnessed through worsening natural disasters and temperature changes which negatively affect crops and other fragile ecosystems. A solution to this problem can be seen in technology which produces lab-grown beef. If lab-grown beef became a mainstream source for beef consumption, many of the issues caused by cattle livestock would be completely alleviated as there would no longer be such a large demand for the livestock.

Among the most affected resources involved in the production of beef are water and grain. Water is used in many aspects of beef production, from watering the crop that feeds the livestock to hydrating the cattle. Since beef production is practiced at such a large scale, the water used towards the livestock involved is massive as well. Similarly, grain is needed to feed cattle in large amounts, also requiring water to sustain. Mekonnen & Hoekstra (2012), who conducted a study comparing the water footprints of different animal productions in different countries, noted, "When we consider the total water footprint per animal category, we find that beef cattle have the largest contribution (33%) to the global water footprint of farm animal production" (p. 409). They also noted, "The average water footprint per calorie for beef is 20 times larger than for cereals and starchy roots" (p. 401). These figures give an idea of the copious water usage involved in beef production. Steinfeld et al, who wrote on environmental issues caused by livestock, mentioned, "The livestock sector not only contributes to the use and pollution of freshwater resources but also impacts directly the water replenishment process" (p. 162). Additionally, they noted, "The water used by the sector exceeds 8 percent of

the global human water use. The major part of this is water used for feed production, representing 7 percent of the global water use" (p. 162). Water is used in large quantities towards beef production, much of that towards feed such as grain, while also becoming contaminated in the process, possibly rendering it unusable or working its way into other sources.

One of the most harmful ways beef production affects the environment is through the emission of greenhouse gasses. Through the reallocation of natural lands towards pastures and crops for feeding, beef production contributes significantly to greenhouse gas emissions. This disrupts the natural gas cycles and raises temperatures, which then affects ecosystems around the world. Steinfeld et al mentioned carbon emissions: "Livestock also affect the carbon balance of land used for pasture or feedcrops, and thus indirectly contribute to releasing large amounts of carbon into the atmosphere" (p. 83). Also noting, "Overall, livestock activities contribute to an estimated 18 percent to total anthropogenic greenhouse gas emissions from the five major sectors for greenhouse gas reporting: energy, industry, waste, land use change and forestry and agriculture" (p. 112). As noted in these statistics, livestock contribute to greenhouse gas emissions, not just directly throughout the life cycle but also indirectly through feed crop usage. Carlsson-Kanyama & González (2009), who reviewed climate change effects by different food systems noted:

> When the efficiency of converting feed into food is low, emissions per unit of food are high. Birds and pigs convert feed more efficiently than cattle and sheep. As a result, methane emissions from enteric fermentation counted per unit of beef can be the largest single contribution to total GHG emissions. (p. 1705)

These reports indicate that not only does livestock contribute significantly to greenhouse gas emissions, but beef production contributes the most in many cases.

An argument can be made that since livestock contributes merely 18% to greenhouse gas emissions, there are more urgent contributors to address to mitigate this issue. However, Hedenus, Wirsenius & Johansson (2014) researched agriculture produced greenhouse gas emissions and compiled projections based on current findings to compare them with the current temperature targets for mitigating climate change. They found:

> Only by also assuming reduced meat and dairy consumption do we find agricultural emission levels that do not take more than half of the total emissions space in 2070. We therefore conclude that dietary changes are crucial for meeting the 2 °C target with high probability. (p. 89)

As the global population continues to increase, the demand for meat does as well; the issues caused by the beef industry will only continue to increase as time goes on unless alternative methods are implemented.

Another unintended consequence of beef production is the mass use of antibiotics and the unknown effects towards society and possibly other animals. In order to keep livestock healthy, functioning, and growing properly, agriculture workers need to give them antibiotics. This is not only beneficial for the animal, but it also ensures the food is safe to eat as well. The problem arises when antibiotics are being given at such an unprecedented rate to accommodate the growing number of livestock that the effects are still widely unknown. Landers, Cohen, Wittum, & Larson (2012), who reviewed literature on antibiotic use in livestock and its possible contribution to antibiotic resistance, noted:

> Antibiotic use in animals can have direct and indirect effects on human health: direct effects are those that can be causally linked to contact with antibiotic-resistant bacteria from food animals, and indirect effects are those that result from contact with resistant organisms that have been spread to various components of the ecosystem (e.g., water and soil) as a result of antibiotic use in food animals. (p. 11)

Similarly, Durso & Cook (2014) focused on reviewing antibiotic resistance data and noted, "Many of the applied details of how, and at what rate bacteria and genes move from animals to humans through agricultural systems (soil, water, wildlife, insects, dust, food,) remain to be determined" (p. 37). Though livestock are administered antibiotics at such high rates, the effects of this practice are not known. It can be argued that this is not necessarily a bad thing; the absence of research does not indicate negative effects. However, the research that does exist indicates antibiotic-resistant bacteria as a result of antibiotic use in livestock can affect human health, but the rate and process are just unknown at this time.

One solution to the growing problem of the beef industry on the environment is the use of lab-grown beef to mitigate these effects. Penn (2018), who reviewed the process and possible positive effects of using lab-grown beef, briefly explained how it works: "Cultured meat is the process of taking a single cell of muscle tissue from a cow and replicating it in a controlled setting to create layers of muscle that can be ground together to produce ground beef" (p. 105). Galusky (2014), who detailed the positives and negatives of a future with lab-grown meat, explained, "In vitro meat technologies are contemporary techniques aimed at producing meat protein in isolation, without the rest of the animal body, in a sterile setting" (p. 935). Even if used as a partial solution, instead of eliminating the entire

cattle industry, this could be viable towards negating the effects the cattle industry has on the environment. An argument could be made towards the expense of such a venture: lab-grown beef is bound to be expensive. Galusky wrote:

> Price—current protein production is very expensive. For example, in 2013, in London, an in vitro meat burger was taste-tested in an effort to demonstrate proof of concept and edibility. That single burger, funded by Google's Sergey Brin, was purported to cost US $325,000. (p. 937)

Though, every new technology is always extremely expensive at its inception. This should not deter the development and hope that someday, as is the case with all new technology, it will become affordable over time. Byrd (2016), who wrote an article detailing the process of making lab-grown meat, added some context to the aforementioned $325,000 burger, which was produced by Mark Post, founder of the clean meat company Mosa Meats:

> To put the developments of the past few years into perspective, Mark Post's first burger cost $330,000 to produce, and within a few years, Memphis Meats was producing meat for less than one-fiftieth of that price tag. By 2020, Post plans to sell Mosa Meats' burgers for about $10 a patty, and within about five years after that, for about the cost of the least expensive meat on the market.

The current hefty price tag on lab-grown meat is projected to lower to a price which will make it accessible to the mainstream consumer within the foreseeable future.

The positives of lab-grown beef over agriculture include less of a demand for livestock, which in turn lessen all the above described issues involving the livestock industry. Less grain would be needed, along with less water, less antibiotics, and less greenhouse gasses emitted by livestock and their feed. In this solution, individuals who are hesitant to give up beef to help the environment do not have to; they have a realistic alternative. Another positive component involved in lab-grown beef is that it can be grown to be healthier and can be manipulated to the liking of the consumer. Galusky (2014) confirmed this idea:

> These solutions, so offered, rely on the idea that the process of growing meat without the animal can reach peak efficiency and efficacy in large part because the entire process is controlled. Nothing is present that isn't desired to be present, and humans can dictate the terms of the protein" (p. 936)

Penn wrote,

> If cultured meat were substituted for ground meat, consumers could save 26.8 pounds of feed, which could be repurposed to feed the growing population or create ethanol. This would also free up Additionally [*sic*], 167.6 gallons of water for use in other sectors. (p. 106)

The resources being used for agriculture could go towards other current needs in the world. The massive amounts of water being used on grain and to sustain the livestock could instead be redirected to other causes in need of that water. The process of clearing land for grain and grazing fields would no longer be necessary to meet the demands of the beef industry. Meanwhile, those that enjoy meat would still be satisfied in this scenario, as they could get exactly the type of meat they want without sacrificing resources and impacts on the environment. In this solution, the pressure is taken off the individual consumer: if lab-grown meat becomes widely available and offered at affordable prices, they simply buy it from the supermarket as they would regular beef.

One alternative to lab-grown beef might simply be for society to embrace vegetarianism. It is easy to see the appeal. The benefits would likely be the same or better, yet we have the means to do become vegetarian right now, as opposed to having to wait until the lab-grown beef technology is developed to the point where it can be mass-produced at analogous or lower prices than its conventional counterpart. Similarly, there are already products in the market catering to vegetarians, which are meant to emulate the taste and texture of beef with plant-based materials. Yet, this alternative requires individual effort, while glossing over the fact that being vegetarian seems to be a tough endeavor for most people. One only needs to look at the size of the beef industry and the global impact it has, as outlined in paragraphs above, to understand that vegetarianism does not seem to pose an attractive offer. It logically follows that this impact would not exist without a similarly gigantic demand, as the studies would suggest given the minute proportion (2%) of people who follow a strict vegetarian diet (Herzog, 2014). Even a number of people who try vegetarianism make the switch back to eating meat (84%), though most people never try it to begin with (Herzog, 2014). Thus, perhaps a second alternative that might be suggested could be the establishments of social norms around cutting back on meat consumption without entirely giving it up. Many places practice activities such as having "Meatless Mondays" which would theoretically cut down on beef production. Though unless drastic measures such as legislation were to be utilized, it is doubtful many people would participate given the lack of interest in giving up meat. Yes, it may constitute a gentler compromise, but not only does it offer an incomplete solution to the beef industry's issues, delaying the impact until the population size catches up, but it does not offer people an alternative if they simply didn't want to change their lifestyle. Lab-grown beef is ideal because it does not require anything from the individual.

The beef industry is damaging to the environment and humans in many ways. The water used in the industry is excessive and often creates pollutants in water sources. The grain usage is also excessive, feeding into the issues with water as it requires large amounts of water to sustain. The beef industry also contributes much more significantly than any other agriculture sectors to greenhouse gas emissions. Antibiotics are used to maintain livestock at alarming rates, with little research indicating the implications of effects on human lives regarding antibiotic resistance. The best solution to mitigate the issues involved in beef production is to support lab-grown beef where applicable. When lab-grown beef becomes more affordable, it can lessen many of the environmental issues the world faces as a result of agriculture.

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