

# The Potential of Cell and Plant-Based Meat Alternatives to Improve Global Health Outcomes

Leigh Foran<sup>1</sup> and Jesse Bauks<sup>#</sup>

<sup>1</sup>Staples High School

<sup>#</sup>Advisor

## ABSTRACT

In recent years, public and global health officials have come to the consensus that fostering sustainable eating habits is a crucial step towards preserving healthcare outcomes worldwide. This publication aims to explore the advent of new cell-based meat (CBM) and plant-based meat (PBM) alternatives, and their capacity to improve the health and wellbeing of global populations. These products present consumers with replacements for animal-based meat (ABM), a staple aspect of diets worldwide. CBM and PBM can be applied toward the production of animal products, allowing global communities to utilize more sustainable farming techniques. They can reduce the health impacts of climate change and also provide healthier alternatives to ABM. However, potent obstacles when it comes to the production, development and marketing of these products may impede upon their capacity to truly benefit the health of people and the planet. But if CBM and PBM can overcome these challenges, these feats of bioengineering may provide the world's growing population a healthier and more sustainable diet.

## Introduction

To observe one of the most promising technological advancements with the capability to vastly improve healthcare outcomes globally, communities must look to the place they least expect: a farm. On some pastures, thousands of cows are being raised for human consumption, but will never face slaughter. Instead, every couple of months a veterinarian will come and remove a peppercorn-size sample of flesh, full of muscle and fat cells, and send them back to their tranquil lives. These cows are able to avoid slaughter thanks to an emerging industry that is pioneering a solution to some of the world's greatest problems.

## Differentiating Cell and Plant-Based Meats

More than 70 startups are engaged in fierce competition to create some of the first lab-grown alternatives to animal-based meat (ABM), such as beef, chicken, pork, tuna and shrimp (Flint et al., 2023). This type of meat, called cell-based meat (CBM), begins as a few cells taken from a flesh sample. When grown in a bioreactor the cells can become a meaty, juicy hamburger sitting on a plate. However, these surrogates are not the only options—plant-based meat (PBM) is another meat substitute, made from the organic compound heme. Heme is found in plants and the blood of animals, which gives it a meat-like quality (Butz, 2021). Companies such as Impossible Foods and Beyond Meat, the latter of which had the most successful initial public offering of 2019, have already found the support of millions of consumers (Min, 2019). And these buyers have good cause.

## Potential Benefits of CBM and PBM

The production and processing of livestock contributes to 14.5% of the world's annual greenhouse-gas emissions (Baker, 2021), contributing to climate change and air pollution. Climate change impacts health outcomes in a myriad of ways, exacerbating social determinants of health such as access to clean air, safe drinking water, sufficient food and secure shelter (WHO, 2021). Furthermore, studies have consistently shown that switching to meat alternatives could improve human health. This nascent technology has a bright future, and investors have already thrown billions at these companies.

## Challenges Ahead

However, creating products that could shift global eating habits from ABM to alternative meat sources, achieving better health outcomes for vulnerable populations around the world, requires extremely large-scale production. Though a single gram of tissue could theoretically be used to produce 4.4 billion pounds of meat (Baker, 2021), limits to currently existing technology prevent this from becoming a reality. The meat alternative industry has the potential to foster a world with sustainable eating habits, vastly improving global health, if it can surpass the obstacles of creating a marketable, cost-effective product at a large scale.

## Environmental Sustainability and Global Health Impacts

Plant-based and lab-grown replacements could drastically limit the impact industrial farming has on the environment. Numerous professionals have affirmed this, such as Dr. Aaron E. Carroll, professor at the Indiana University School of Medicine. He reports that cows produce methane, causing 10 percent of anthropogenic greenhouse gas emissions even when feed production, processing and transportation aren't counted (Carroll, 2019). The processing and production of meat products, especially beef, can have caustic impacts on the environment. It facilitates the degradation of the Earth, and with global demand only rising ABM has the potential to seriously harm the environment. To prioritize the health of the world, consumers can shift away from traditionally harvested sources of meat towards promising alternatives.

## CBM and PBM: Promising Solutions

According to a team of researchers from the Department of Biomedical Engineering at Tufts University, the first relevant assessment published in 2011 estimated that CBM would involve 45% less energy consumption, 96% less greenhouse gas emissions, 99% less land use, and a 96% reduction in water use compared to ABM (Rubio, et al., 2020). The meat alternative industry has the potential to solve some of the world's greatest problems, including climate change. This issue, which plagues leaders and institutions around the world, could be solved by making a switch to meat alternatives.

The real-world impacts of CBM and PBM have been applied in a global context by professionals at higher institutions. In a study by nutrition scientist Christopher Gardner, PhD, professor of medicine at Stanford University, he and his co-authors modeled the impact of individuals consuming 25 percent less protein, and also shifting 25 percent of the remaining protein from ABM to PBM. They concluded that this dietary shift would lead to 40 percent lower carbon dioxide emissions from food production-related sources, commensurate with about eight percent of the greenhouse gas emissions reductions pledged by the United States under the Paris Climate Agreement (Armitage, 2019). This research exemplifies the potential impact that PBM could have on preserving the environment. Reducing ABM and replacing it with alternatives is a promising solution to the numerous environmental problems existing today. By simply making a switch in eating habits, the global population could easily mitigate threatening climate issues. Revolutionary products like PBM or CBM give consumers the ability to benefit the world with a simple dietary switch.

## Large-Scale Changes

The vast extent to which meat alternatives could make an impact serves as the foundation for their potential to replace traditional sources of meat. Mark Post, vascular cardiologist and CEO of CBM company Mosa Meat, described how lab grown alternatives could substantially reduce the meat industry's impacts on the environment. He said, "eventually, we would need only some 30,000 to 40,000 cows worldwide, instead of the 300 million we slaughter every year," (Baker, 2021). This statistic highlights the rigid dichotomy between meat from slaughtered animals and lab grown alternatives. CBM could be so revolutionary as to refine the farming industry to be more eco-friendly. Only a fraction of the cows used by humans would be necessary, making farming more sustainable and convenient. Minimizing the number of animals needed to sustain a growing population would reduce methane emissions and reverse the propensity of the food industry to be a threat to the world. Alternatives such as lab-grown beef could sustainably support a global population.

## Environment and Global Health Impacts

By averting environmental destruction and climate change, meat alternatives may also improve human health worldwide. Between 2030 and 2050, global warming is expected to cause approximately 250,000 additional deaths each year from malnutrition, malaria, diarrhea and heat stress (Bowler et al., 2010). Besides direct environmental ramifications including storms, floods, and fires, climate change will also contribute to hospitals shutting down, people losing their homes, and a rise in mental health problems (Watts et al., 2018). By mitigating the effects of environmental destruction, switching to alternatives such as CBM and PBM will in turn play a crucial role in preserving global health.

## Direct Health Impacts

Both PBM and CBM have health benefits that are unmatched by ABM. Dr. Frank Hu, chair of the Department of Nutrition at Harvard Medical School, emphasizes that red and processed meats do in fact increase health risks. He reported, "the evidence is consistent across different studies" that certain ABM is correlated with an increased risk of heart disease, cancer, diabetes, and premature death (Harvard Health Publishing, 2020). Though the topic has been controversial within the past few decades, professionals directly associate ABM with negative health impacts. The effects of consuming red meat are anything but short lived, causing long-term illnesses that may seriously affect wellbeing. Red meat has been classified as a probable human carcinogen and facilitator of the development of several diseases such as cardiovascular disease, obesity, and type 2 diabetes mellitus (Rizzo et al., 2023). This validates the consequences of ABM and its burden on global health, underlining the importance of a shift in protein sources.

## Health Advantages of PBM

Parallel to the harmful impacts of ABM, a recent clinical trial administered by the Stanford School of Medicine demonstrates the benefits of PBM. It revealed that participants who substituted PBM for ABM over an eight week period exhibited lower risk for cardiovascular disease, which could benefit consumers who desire a decrease in blood pressure, body mass index, and cholesterol (Rubio et al., 2020). Additionally, based on the United Kingdom's Nutrient Profiling Model, 40% of conventional meat products were classified as 'less healthy' compared to just 14% of plant-based alternatives (Bryant, 2022).

The ability of food producers to add ingredients such as edible fungi, microalgae or spirulina to plant-based foods can boost their nutritional properties by increasing amino acids, vitamins B and E and antioxidants

(Bryant, 2022). Further innovations in processing and ingredients are likely to lead to greater nutritional improvements in the future. This reinforces the crucial role that PBM can play for the global population, allowing it to become a more widely consumed source of protein. PBM may be a promising part of the solution to the problems raised by ABM, highlighting its potential to truly change the eating habits of the world.

### Health Advantages of CBM

Furthermore, the capacity of CBM to solve health-related predicaments broadens the potential scope of these ABM alternatives. Researchers from Tufts University describe that the risk for transmission of zoonotic and foodborne illnesses are virtually nonexistent with CBM, as cell proliferation and production of CBM requires sterile conditions (Ong et al., 2021). This substantiates the fact that CBM could eliminate some of the major risks associated with food processing as a whole: if it were able to replace ABM, CBM could eradicate significant safety concerns. Considering the extent of the caution that goes into producing CBM, a myriad of concerns arise regarding the safety of producing ABM. For this reason, health and safety is one aspect of CBM and PBM that may boost their consumer appeal. PBM and CBM can not only reduce health concerns, they can also address epidemiological issues that plague the food industry.

### Looking Ahead: Market Viability

The capacity of PBM and CBM to benefit the global population is dependent on their marketing performance and consumer appeal. One of the most significant challenges comes from large producers of ABM: the U.S. Cattlemen's Association has petitioned the U.S. Department of Agriculture to limit the use of the terms beef and meat exclusively to "products derived from the flesh of a [bovine] animal, harvested in the traditional manner" (Butz, 2021). Though a name does not necessarily define a product, it does in the eyes of the consumers. It's unlikely that the average American consumer would want to buy and eat a product labeled "lab-grown cell-protein isolates" (Ong et al., 2021). Therefore, one of the most potent challenges that CBM and PBM alternatives may face in the future is the ability to successfully advertise to their consumers.

### Association with GMOs

Marketing these products is also limited by other factors. For instance, Michael Dent, senior technology analyst at market-research company IDTechExHe, discusses how being associated with genetically modified organisms (GMOs) could seriously taint the image of CBM. This has been a concern for the producers of these meat alternatives. Dent calls GMOs a "pariah" and says "it could go the same way with cultured meat. If they get it wrong now, in 20 years, people will still be saying, 'Cultured meats, uh-uh, freak meats, we aren't touching it'" (Baker, 2021). The crucial importance of marketing in the commercial success of meat alternatives cannot be overlooked. Though they have numerous potential benefits for the Earth and global health, the public will not embrace CBM and PBM unless producers market them properly. For this to happen they must eliminate their association with GMOs completely.

### Marketing and Support

Though these alternatives may face challenges, there is still strong public backing. For instance, large investors such as Bill Gates, Richard Branson, and Warren Buffett have already thrown nearly \$1 billion at cultivated-meat companies over the past six years (Baker, 2021). The trust that these public figures put into the emerging

industry could further help with its consumer appeal. The fact that large investors are putting their funds into businesses creating CBM and PBM supports their potential to succeed. The actions of these investors highlight their trust in the success of these companies. Some of the world's most financially successful have faith in meat alternatives.

### Consumer Product Appeal

High consumer acceptance rates for PBM products were recorded in China (95.6%), India (94.5%) and the United States (74.7%) (Rubio et al., 2020). These promising margins of consumer appeal could prove to be a key factor in defining the industry's success. If it can find customers to purchase its products, this may increase its capacity to revolutionize global eating habits. More people may make the switch from slaughtered meat to more sustainably cultivated options, if they are open to the product in the first place. (Hassoun et al., 2022). This could lead to a switch from conventionally harvested meat to more sustainable options. The meat alternative industry has the potential to become massive, but it must continue to successfully navigate the many marketing challenges it faces to harness consumer acceptance.

### Profitability and Cost-Effectiveness

Though some may claim that the outlook of meat alternatives seems secure (Bryant, 2022), there are still many obstacles that the industry must overcome before it can become a staple of global diets. Some of these challenges include the issue that CBM as a product is neither profitable nor fit to survive in a capitalist economy. At the moment, the cost to produce cultivated beef hovers around \$50 a pound, and CBM company Eat Just's portion of three chicken nuggets costs about \$17, or ten times as much as the equivalent at McDonald's (Baker, 2021). This reveals one of the key hurdles that the meat alternative industry must surpass. Without the ability to make a profit and compete with more affordable options, these companies will not survive. To avoid financial turmoil, CBM and PBM companies must find a way to create a product that is cost-effective enough to survive in a global market. However, the economic challenges for these companies are not the solitary problem.

### Industrial and Manufacturing Concerns

Technical challenges stop the meat alternative industry from becoming as large as it could be. One company, GOOD Meat, is currently using 1,200 and 5,000 liter bioreactors, which are machines that can produce a few hundred pounds of CBM at a time. But to go large scale would require 100,000 liter bioreactors, which currently do not exist (Butz, 2021). Though the meat alternative industry could potentially become very large, current technological barriers stand in its way. Without certain machinery, these companies cannot reach their full capacities. Thus, there are still clear challenges that stand in the way of meat alternatives. Additionally, most CBM companies are not currently in a place to compete with the widely accessible meat options that presently exist (Hassoun et al., 2022).

Although CBM company Mosa Meat is currently aiming for 80,000 hamburgers per 1 gram biopsy of tissue, a singular hamburger can cost around \$330,000 (Baker, 2021). If the meat alternative industry is going to survive, it needs to be able to produce a product that consumers will be able to buy. Though the company is still new, they must take large leaps before the price of a hamburger can drop to a cost-effective amount (Hubalek et al., 2022). Thus, this is clearly a limiting factor in the development of these products. The alternative meat industry may have many promising aspects, but there are challenges it must overcome to be as successful as it can be.

## Conclusion

If the meat alternative industry can surpass technological, economic, and marketing obstacles to mass produce a product while still managing to make a profit, it could alter the eating habits of the world. This is supported by the high consumer acceptance rates and mitigating impacts CBM and PBM can have on climate change and health concerns. Both CBM and PBM alternatives have clear benefits to the environment, and could reduce energy consumption and greenhouse gas emissions. Furthermore, these substitutes could also have positive health benefits, such as minimized risk for cardiovascular disorders. Though meat alternatives could greatly benefit people and the world, there are still serious obstacles they must surpass. Marketing challenges, such as the names these products may sport, could seriously determine how consumers respond. Besides this, there are significant difficulties of creating a cost-effective product at such a large scale. If meat alternatives are to achieve hegemony in the food industry, they must first best the obstacles in their way. They could be a solution to climate change. A remedy for health disorders plaguing millions. This product could be a revolutionary cure for numerous global health concerns—but only if consumers put their faith behind it.

## Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

## References

- Armitage, H. (2019, February 6). Q&A: Meat, health and the environment. Stanford University. Retrieved November 29, 2021, from <https://earth.stanford.edu/news/qa-meat-health-and-environment#gs.he64hs>
- Baker, A. (2021, November 2). The cow that could feed the planet. TIME Magazine. Retrieved November 29, 2021, from <https://time.com/6109450/sustainable-lab-grown-mosa-meat/>
- Bowler, D., Buyung-Ali, L., Knight, T., & Pullin, A. (2010, August 4). A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health. Retrieved March 12, 2023, from <https://doi.org/10.1186/1471-2458-10-456>
- Bryant, C. J. (2022, December). Plant-based animal product alternatives are healthier and more environmentally sustainable than animal products. Elsevier Science Direct. Retrieved March 13, 2023, from <https://doi.org/10.1016/j.fufo.2022.100174>
- Bryngelsson, S., Moshtaghian, H., Bianchi, M., & Hallström, E. (2022, May 12). Nutritional assessment of plant-based meat analogues on the Swedish market. International Journal of Food Sciences and Nutrition. Retrieved March 13, 2023, from <https://doi.org/10.1080/09637486.2022.2078286>
- Buckley, M. (2023, January 9). Connecting Climate Change and Health. Harvard Medical School. Retrieved March 12, 2023, from <https://hms.harvard.edu/news/connecting-climate-change-health>
- Butz, L. (2021, June 25). "Meatless meat" and the increasing popularity of plant-based meat alternatives. Hunter College New York City Food Policy Center. Retrieved November 29, 2021, from <https://www.nycfoodpolicy.org/meatless-meat-and-the-increasing-popularity-of-plant-based-meat-alternatives/>

Carroll, A. E. (2019, October 1). The real problem with beef. *The New York Times*. Retrieved November 29, 2021, from <http://nytimes.com/2019/10/01/upshot/beef-health-climate-impact.html>

Climate change and health. (2021, October 30). World Health Organization. Retrieved March 12, 2023, from <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>

Fleming, A. (2022, June 9). What is lab-grown meat? How it's made, environmental impact and more. *BBC Science Focus*. Retrieved March 12, 2023, from <https://www.sciencefocus.com/science/what-is-lab-grown-meat-a-scientist-explains-the-taste-production-and-safety-of-artificial-foods/>

Flint, M., Bowles, S., Lynn, A., & Paxman, J. R. (2023, January 6). Novel plant-based meat alternatives: future opportunities and health considerations. *Proceedings of the Nutrition Society*. Retrieved March 13, 2023, from <https://doi.org/10.1017/S0029665123000034>

Hassoun, A., Boukid, F., Pasqualone, A., Bryant, C. J., García, G., Parra-López, C., Jagtap, S., Trollman, H., Crobotova, J., & Barba, F. J. (2022). Emerging trends in the agri-food sector: Digitalisation and shift to plant-based diets. *Current Research in Food Science*, Volume 5. Retrieved March 13, 2023, from <https://doi.org/10.1016/j.crfs.2022.11.010>

Hubalek, S., Post, M. J., & Moutsatsou, P. (2022, October). Towards resource-efficient and cost-efficient cultured meat. *Current Opinion in Food Science*. Retrieved March 14, 2023, from <https://doi.org/10.1016/j.cofs.2022.100885>

Key facts and findings. (n.d.). Food and Agriculture Organization of the United Nations. Retrieved February 9, 2022, from <https://www.fao.org/news/story/en/item/197623/icode/#:~:text=Total%20emissions%20from%20global%20livestock,of%20all%20anthropogenic%20GHG%20emissions.&text=On%20a%20commodity%2Dbasis%2C%20beef,the%20sector's%20overall%20GHG%20outputs>

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020, February 20). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*. Retrieved March 12, 2023, from <https://doi.org/10.3389%2Ffpubh.2020.00014>

Min, S. (2019, May 16). Eat dirt, uber! Beyond meat is most successful IPO of 2019 so far. *CBS News*. Retrieved December 21, 2021, from <https://www.cbsnews.com/news/beyond-meat-ipo-most-successful-initial-public-offering-of-2019-so-far/>

Ong, K. J., Johnston, J., Datar, I., Sewalt, V., Holmes, D., & Shatkin, J. A. (2021, October 10). Food safety considerations and research priorities for the cultured meat and seafood industry. *Institute of Food Technologists*. Retrieved March 12, 2023, from <https://doi.org/10.1111/1541-4337.12853>

Remoundou, K., & Koundouri, P. (2009, July 31). Environmental Effects on Public Health: An Economic Perspective. *National Center for Biotechnology Information*. Retrieved March 12, 2023, from <https://doi.org/10.3390%2Fijerph6082160>

Rizzo, G., Testa, R., Cubero Dudinskaya, E., Mandolesi, S., Solfanelli, F., Zanolì, R., Schifani, G., & Migliore, G. (2023, June). Understanding the consumption of plant-based meat alternatives and the role of health-related aspects. A study of the Italian market. *International Journal of Gastronomy and Food Science*. Retrieved March 13, 2023, from <https://doi.org/10.1016/j.ijgfs.2023.100690>

Rubio, N. R., Xiang, N., & Kaplan, D. L. (2020, December 8). Plant-based and cell-based approaches to meat production. US National Library of Medicine. Retrieved November 29, 2021, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7722853/>

Shanmugam, K., Bryngelsson, S., Östergren, K., & Hallström, E. (2023, March). Climate Impact of Plant-based Meat Analogues: A Review of Life Cycle Assessments. *Official Journal of the European Federation of Chemical Engineering*. Retrieved March 13, 2023, from <https://doi.org/10.1016/j.spc.2023.01.014>

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., & Berry, H. (2018, November 28). The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. *The Lancet*. Retrieved March 12, 2023, from [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(18\)32594-7/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)32594-7/fulltext)

What's the beef with red meat? (2020, February 1). Harvard Health Publishing. Retrieved December 17, 2021, from <https://www.health.harvard.edu/staying-healthy/whats-the-beef-with-red-meat>

Why Is Global Environmental Health Important? (2016). University of Minnesota. Retrieved March 12, 2023, from <https://www.takingcharge.csh.umn.edu/why-global-environmental-health-important>