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Is Cultured Meat a Viable Alternative to Conventional Meat?

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ABSTRACT

Rapid urbanization, massive population explosion and an increase in disposable income of middle class have led to a higher demand for meat. Global meat consumption and production have increased and have led to a challenge of sustainably feeding future generations meat products. Livestock agriculture is one of the oldest and most prevalent occupations that cover two-thirds of the agricultural land world over. Livestock rearing is the livelihood of millions of people that not only provides financial security but is also used in various other ways in times of emergencies. Unsustainable farm practices, growing demand for meat and the environmental damage caused by livestock farming have warranted the search for an alternative. In-vitro production of meat is among the latest scientific and technological studies world over. Will cultured meat meet the moral and cultural challenges and be commercialized, remains to be seen. This paper is an attempt to compare and contrast traditional meat and cultured meat.

KEYWORD: Cultured meat, Energy, Environment, Food security, Greenhouse Gases, Land Utilization, India

INTRODUCTION

Meat forms an essential constituent of food all over the world due to its high protein content and energy imparting capacity. Meat, in addition to providing critical nutrients, also signifies status and financial conditions in many developing countries. Livestock production systems help in fulfilling the demand for animal protein, but, meat production is a highly inefficient process taking a toll on the environment. Meat production (red meat) is a significant source of greenhouse gases and other forms of pollution like water pollution and soil erosion. To grow feed for livestock and also allow for grazing lands, there is large scale deforestation (Song et al., 2018) that leads to biodiversity losses (Clark & Tilman, 2017), soil erosion and climate change. Given the massive demand for meat and the harmful effect that livestock production systems have on the environment, scientific and technological research on the production of in-vitro meat has soared. In the 1930s, Winston Churchill had predicted that the world would be consuming lab-grown meat in the 1980s. According to Maastricht University in the Netherlands, a single cow can be the donor of cells for cultured meat that can produce 175 million quarter pounds. At the same time, livestock production systems would require 440,000 cows for the same output, notwithstanding the amount of land, water, feed that would be needed for this

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and also the contribution to greenhouse gases (Ewing-Chow, 2019). Scaling the process from laboratory level to mass production and commercialization is still in its nascent stages, and scientists and technologists are grappling with challenges in trying to make cultured meat as close to livestock meat with regards texture, flavor, nutrient contents, cost and consumer acceptance.

LIVESTOCK SECTOR

Livestock farming is the raising of animals like cattle, goats, sheep or poultry for commercial or personal use. Livestock farming accounts for one-third of the farmlands globally and is a very organized sector that employs the poor and marginalized communities in the developing countries. Livestock products form a crucial component of protein and fat consumption world over. Livestock accounts for 33 per cent of agricultural GDP. It is the fastest-growing sector in the developing countries that, in turn, are witnessing a rapid increase in meat-eaters and rising income (Delgado, 2005). The developed countries have shown stagnation in production and consumption of livestock products while the developing countries are seeing an increase and this divide is spurring the growth of the sector in developing countries and is likely to remain so for a long time. The challenge is to indulge in sustainable agricultural and livestock farming that will not further adversely affect the environment.

Demand for Meat

The increasing population and the growing demand for meat products throughout the world are being met with a lot of scepticism. According to reports issued by UN-affiliated organizations, the world population (mainly contributed by developing countries) is expected to touch around 9.1 billion by 2050. This population growth is expected to be accompanied by widespread urbanization, growing income levels and increasing demand for livestock products along with degradation of the environment, human health, food and water insecurities and poverty (Yates-Doerr, 2012). Globally 2 billion people have meat as their primary source of nutrition, and around 4 billion prefer a plant-based diet (Pimentel & Pimentel, 2003). Technological and scientific advancements have enabled us to utilize various advanced farming techniques, and the use of chemicals and fertilizers has enhanced the land usage patterns globally. Still, then there is always a trade-off involved in this process? Meat production extremely a resources intensive and has impacts on the environment too.

Livestock Production Systems and Land Utilization

Animal-based food like meat is very resource intensive as compared to a plant-based diet. Since most of the animal-based food depends on agricultural land and plants for feeding the livestock, land use is a prominent feature in livestock production systems. Feed conversion ratios (amount of feed or plant crops needed to produce one unit of meat) are used to discuss efficiencies of livestock farming. The crux is to understand the number of nutrients lost by utilizing crops and land for meat versus directly eating a plant diet and thereby to know whether this is a viable or sustainable proposition for the environment and food security issues of the world. The key to reducing degradative impacts of livestock on land is to alter the supply side by making changes in the livestock production systems that could enable the availability of more food crop for human consumption (Bouwman et al., 2013; Weindl et al., 2015) or the demand side by lowering the consumption of meat and other livestock commodities that depend on agricultural land.

In an attempt to intensify livestock production to meet the demands of animal protein, land use gets skewed in terms of redirecting higher quality and nutrient-rich feed to animals instead of residues, food waste and grazed biomass thus causing a scarcity of nutrient-rich feed for human consumption. Most of the Amazon forests have got wholly destroyed and degraded due to

unsustainable cattle ranching and soybeans plantations thereby causing conversion of biodiversity-rich forests into pastures (Barona, Ramankutty, Coomes, & Hyman, 2010). A study showed that the number of forest fires in Northwestern Amazonia that occurred in 2004 and 2007 correlated with deforestation, illegal cattle ranching and various other anthropogenic drivers (Armenteras & Rentana, 2012). Grasslands are not only the main sources of feed for livestock (Lund, 2007) but also habitat for a variety of species (Krausman et al., 2009).

Livestock and Water Utilization

A research study reports livestock system utilizes around 31% of the total water requirements for agriculture and it is also projected that if demand for animal products is to be met with, the water utilization will double (Herrero, Thornton, Gerber, & Reid, 2009). Water is still not a priced resource in most parts of the world, and livestock is one of the biggest consumers of freshwater (Diogo, Buerkert, & Schlect, 2010). Drinking water accounts only for 2% of the total water requirements of livestock; the rest of the water is used for feed production for the livestock (Peden, Taddesse,& Haileslassie, 2009). With the intense scarcity of water that various countries are facing the world over and the inefficient usage of water for livestock systems, it is essential that countries look for better ways of production or consume less of animal protein.

Environmental Impacts of Livestock Production

Livestock grazing has a large number of the environmental effects like helping as agents of seed dispersal, reducing incidences of forest fire due to unavailability of grass biomass, displacement of natural animals thereby destroying the delicate ecosystem of the region and causing wastewater containing soil residues and organic animal wastes to run off into neighbouring water bodies. Cattle after grazing, get into the process of ruminating. Cellulose rich grass being more difficult to digest undergoes fermentation and digestion in the cattle stomach and releases methane as a byproduct of this enteric process (Chhabra, Manjunath, Panigrahy, & Parihar, 2009). Fertilizers added to the pastures contribute to nitrous oxide in the atmosphere. The primary sources of agricultural emission of methane are ruminants, crop cultivation, processing of livestock manure and biomass burning (Naqvi & Sejian, 2011). Methane is 28 times potent than carbon dioxide in warming the environment. Still, it remains in atmosphere only for 12 years (Archer & Brovkin, 2008), and nitrous oxide is 300 times as powerful as carbon dioxide as a greenhouse gas but remains in the atmosphere for 110 years. There is also the other side of the coin, that attributes carbon sequestering to cattle grazing, thereby avoiding the release of carbon from the soil into the atmosphere.

Cattle manure can also be used instead of synthetic fertilizers, thereby reducing nitrous oxide released into the atmosphere. Researchers who studied ground-nesting birds, like the ground species, found that habitats of such birds were much disturbed by the grazing habits of livestock (Boyd, Beck, & Tanaka, 2014). Impacts of livestock on wildlife species cannot be deemed as good or bad by themselves. Still, their effects are highly dependent on other factors like soil, precipitation, the plant diversity of the region and the specific organism that is affected by the livestock (Krausman et al., 2009). River water gets polluted with wastewater discharge from urban cities and intensive livestock farms, especially the Ganges in India (Wen, Schoeps, & Van De Giesen, 2017; Maybeck, 2003). It is a well-known fact that the livestock raised in many parts of the world is in environmentally sensitive zones like North America's plains, Amazon Savannahs, and the Great Barrier Reef watershed of Australia. Cattle ranching is responsible for greenhouse gases emissions due to their enteric fermentation processes as well as due to the fertilizers added to the soil. Livestock production has a substantial environmental footprint. Deforestation, land degradation, soil erosion, water pollution, biodiversity loss and similar damages are associated with cattle ranching. Beef production is also very resource-intensive requiring massive amounts of water and grain as compared to pork or chicken. Cattle ranching

can lead to severe water and food insecurities in regions that face water shortage or frequent drought-like symptoms.

Livestock and Livelihood

Livestock is of high importance to smallholders all over the world. It plays a vital role for the rural people who are either engaged in agricultural work or depend on these animals for essential nutrition (Holste & Otte, 2007). The importance of livestock animals can be attributed to reasons like outputs like meat, milk, eggs, hide, and skin (Riethmuller, 2003), strong religious values and beliefs(Parkes, 1987), status symbol and food supply for the owner (Bettencourt, Tilman, Narciso, Carvalho, & Henriques, 2015), financial security to the farmer, usage as collaterals in times of emergencies (Thornton, 2010). Given the environmental damage, scarcity of land and the resource-intensive nature of livestock farming, is there a solution to the increasing demand for meat?

CULTURED MEAT

In vitro culturing of meat is being studied extensively as an alternative to traditional meat in response to the increasing demand for animal protein. The concept of cultured meat is still under the research and development phase (Allan, Bank & Ellis, 2019). While the article is being written, there is no commercially available cultured meat product available. Though it seems to be an innovative solution, there are significant challenges in terms of energy utilization, environmental impact, taste and consumer acceptability and its innate ability to mimic livestock meat in appearance, texture and nutrient content (Post, 2012; Verbeke et al., 2010). Post (2012) reports technologies like stem cell isolation and identification, ex vivo cell culture and tissue engineering, to generate skeletal muscle and tissues like muscle, fat and fibrous tissue.

Production Challenges of Cultured Meat

Cultured meat involves the production of animal muscle cells trough tissue culture under controlled environment in a bioreactor in a factory or laboratory (Lynch & Pierrehumbert, 2019). Traditional meat being natural in origin develops in the animal body under-regulated and controlled conditions with the various body organs playing multiple roles. The animal skin is a temperature regulator; the digestive system helps digestion and assimilation of the nutrients from the feed crop, the circulatory system helps in distributing oxygen necessary for various metabolic processes as well as energy and the immune system helps fight against disease-producing organisms. There are an appropriate balance and homeostasis in the entire physiological process. In the production of synthetic meat, the same conditions need to be maintained by supplying energy from outside, and this mostly comes from industrial energy sources. Cultured meat involves utilizing viable and capable cells (with potential to form muscle) in a bioreactor to multiply under highly controlled conditions. A bioreactor is used to maintain temperature conditions and other nutrients and oxygen are pumped into the bioreactor from external sources. A bioreactor that is full scaled for production of cultured meat is to be designed (Datar &Betti, 2010), though there is still testing going on in this line (Skardal, Zhang, & Prestwich, 2010).

Growth Media

The nutrient media in which the cells are cultured is obtained from the fetal calf serum or horse serum in addition to growth media (Bian & Bursac, 2009; Chiron et al., 2012), along with antibiotics to prevent infection (Stephens et al., 2018), thus enabling cultured meat to be less prone to infections as growth conditions are very controlled (Post, 2012). Cultured meat can help provide specific health outcomes by the way it is produced and the ingredients added on during the process. Various nutrients like amino acids, fat, proteins, polyunsaturated fatty acids and additional tastemakers can make the cultured meat more nutritious and sumptuous than

traditional meat. Also, cultured meat can be engineered to be resistant to animal-borne diseases like swine flu, avian flu or mad cow disease. Cultured meat can be made free from pesticides, fungicides, antibiotics, hormones and heavy metals that become an invariable part of the large-scale traditional livestock production system (Hultin, 2017).

Energy Requirements

As on date, the muscle tissue that is few microns thick have been produced successfully in lab levels but to build on a large scale highly perfused scaffolds would be required (Stephens et al., 2018). Energy is needed for all these processes as well to keep the bioreactor under sterilized conditions. Thus, synthetic meat would mean a greater reliance on industrial energy (Mattick, 2018). Tuomisto and de Mattos (2011) used hypothetical models. They found that cultured meat as compared to traditional meat involves approximately 78–96% less greenhouse gas emissions, 99% less land use, 82–96% less water use, and 7–45% less energy use. Synthetic meat is mainly associated with carbon dioxide emissions. Thus although synthetic meat appears to be environmentally friendlier than conventional meat, the cumulative impact of Carbon dioxide cannot be neglected ((Lynch & Pierrehumbert, 2019). Thus, cultured meat is expected to have a more significant effect on global warming, in the long run, due to high energy requirements, but as a trade-off, it requires lesser land, water and feed requirements.

Wastage Reduction

Another reason to move away from conventional meat to artificial meat is to avoid wastage of other body parts like hooves, horns, eyes and other body parts that would necessarily be thrown away after the meat is obtained. Creating meat artificially would mean making only that part which is consumable. Also, artificially created meat would offer freedom from the slaughter of animals and a viable solution for the food insecurity problems across the globe (Ahmed, 2019)

Future Human Health

Substantial amounts of antibiotics are administered to livestock animals not only as a remedy for illnesses but also as a precautionary measure to protect them from possible diseases or to enhance growth. This indiscriminate use of antibiotics is leading to antibiotic resistance among the animals that have severe consequences for humanity. The FDA has withdrawn various antibiotics due to resistance of certain strains of microorganisms to the drug in humans, for example, withdrawal of Enrofloxacin due to Fluoroquinolone resistance developed in strains of *Campylobacter* in humans (Clifford et al., 2018, Schmidt, 2002).

Customer expectations

Cultured meat seems to offer certain benefits over traditional meat on the resource, environmental and health grounds but customer perceptions, apprehensions and opinion on acceptance of cultured meat is still questionable. The first lab-grown hamburger using the fetal bovine serum, which cost €250 000 to produce by Professor Post in his laboratory of Maastricht was eaten in front of a focused audience of 200 journalists and academicians on 05 August 2013 (Laestadius, & Caldwell, 2015). Tasters opined the lack of fat which was very important for the flavor of the meat. In a qualitative research study conducted by Laestadius and Caldwell (2015), there were differing opinions with regards impact on animals, views of cultured meat as a dystopian vision, whether cultured meat was necessary at all, safety and security issues of cultured meat and also ethical issues in the usage of fetal bovine serum. An online survey suggested that two-thirds of 673 participants in the US reported that they would try cultured meat, but only one third would eat it regularly (Wilks& Phillips, 2017). Focus group studies in Finland reported a markedly lower level of support for cultured meat (Vinnari & Tapio, 2009) while those in the Netherlands felt that if they were provided with more information, they

would possibly be more favourably disposed towards the idea of cultured meat (Van der Weele & Driessen, 2013).

CULTURED MEAT: IS IT THE FUTURE?

Cultured meat that involves the technology of cellular agriculture is more promising as far as the use of land for food production for human, maintaining the biodiversity of the region and prevention of soil erosion, is concerned. The growth media is obtained from fetal bovine serum, and this is the primary component for cultured meat. So, cultured meat cannot be free from animal slaughter. Livestock when administered with antibiotics and hormones, use physiological processes to flush out the residues with the help of the liver and kidneys, but in cultured meat when antibiotics are added removal of residues require an artificial mechanism. The cultured cells need a scaffold to enable the growing cells to bind on, and this matrix is usually bovine collagen, which would remain a part of the final product, and this could alter the texture, taste and consumer acceptance. In a bioreactor, there are rapid multiple divisions of the cells under controlled conditions, and hence trials need to be conducted to ensure no carcinogenicity or genetic instability sets in. The cells were growing in a bioreactor exhibit a yellowish hue rather than a red hue that may affect consumer acceptance. Also, to produce cultured meat, producers need to have separate cell lines of production like fat, nerves and muscle, that itself could be an expensive undaunting task (Pascual, 2019).

Cultured meat may also provide a solution to human health issues due to infections from traditional meat and problems of environmental sustainability. Energy utilization and emissions seem to pose a problem right now, and cultured meat producers need to think of innovative ways of resolving the issue. Renewable energy sources pose their challenges. Solar energy is expensive compared to fossil fuels. It would require back up energy sources during the nights and in places that are cloudy and prone to frequent seasonal or unseasonal rains while nuclear energy produces radioactive wastes (Mattick, 2018). Also, it needs to be determined whether people would prefer synthetic meat to traditional meat and whether people's apprehensions about the safety of cultured meat are assuaged, and they are convinced enough to opt for cultured meat over conventional meat.

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