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REVIEW ARTICLE

A review on lab-grown meat: Advantages and disadvantages

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ABSTRACT

Meat is an important protein source for humans obtained from slaughtering a living animal. Rearing an animal requires land, water, and other resources, which is challenging to feed the growing population in the world. Therefore, lab-grown meat is one of the optional replacements for farmed animal meat production. Tissue engineering-based cellular agriculture is adopted for production, where bioreactors are used for the cellular harvest. Ample beneficial aspects bring cultured meat to the frontline in the food industry. Cell-based meats are environment friendly in the context of greenhouse gas production, less prone to contamination of infectious pathogens compared with livestock animals. The nutritional content of cultured meat can be regulated, which made it unique. There are disadvantageous aspects too. Cell-based meat is expected to consume higher energy and produce more carbon dioxide than potent methane, impacting the environment. There are ethical questions and religious issues raised by the communities to use Bovine foetal blood as a cultured ingredient. Effects of growth factors are required to observe the long-term effect on humans. Lab-grown meat may be a game-changer for the growing demand for meat. Still, several challenges such as financial, environmental, cultural, and health-related effects need to be considered before large-scale production.

Keywords

Bovine, environment, health, lab-grown meat, muscle tissue

Introduction

Meat is one of the significant sources of protein for humans, consumed since ancient times. Traditional meat production requires land and slaughtering a living animal. As a prediction, in the year 2100, the world's total population will be between 9.6 and 12.3 billion. [1] In the past, total meat production in the developing world increased three times between 1980 and 2002, from 45 to 134 million tons according to the record of the World Bank. [2] Although there are enormous inequalities, the economy is improving worldwide, and the population is gradually becoming more financially solvent. This will create a drastic consequence in the food habit, including a wide variety of choices. So, there will be a gradual switchover from tubers and roots, legumes to wheat and rice, afterward more dependency on animal-based food products and processed foods. [3, 4]

This 'nutritional transition' significantly impacts nature as animal products are costing the land and water. Dietary diversity opens up a more comprehensive range of choice for macro-and micronutrients, which may become a death spiral for natural resources. Therefore, lab-grown meat is one of the optional replacements for farmed animal meat production without changing the dietary content. [5] The concept of cultured meat was born in the 1930s when growing meat in cultured cell systems was started. Winston Churchill even predicted, "Fifty years hence we shall escape the absurdity of growing a whole chicken to eat the breast or wing by growing these parts separately under a suitable medium". [6] Lab-grown or cell-based meat is developed via stem cells obtained from muscle tissue harvested from a live animal. The function of stem cells is unique in that they can form specialized tissues, e.g., muscle tissue and adipose tissue, which are essential for cultured meat. [7, 8]

Animal scientists and other specialists in muscle and cell biology play a vital role in lab-grown meat production. [9] Successful production of lab-grown meat depends on the culture medium and nutrients used for meat cultivation. The ideology behind lab-grown meat is to make a replica of traditional meat in all aspects, such as physical appearance, aroma, texture, nutrients, taste, and most importantly, without any side effects for the consumers. [10]

The production of cultured meat

Cell-based meat production is tissue engineering-based cellular agriculture where four significant primary inputs are required: Cell source, cell culture media, bioreactor, and scaffold. The process starts with harvesting a small piece of tissue through a biopsy process from a living animal sedated by anaesthesia. [10] The tissue is placed on a framework and later developed in bioreactors, followed by utilising the cultured cells. [11] Although the biopsy consists of muscle and fat cells, muscle cells are separated for the process. [12, 13] Harvested muscle cells are dissected and cultured into a suitable artificial environment with an adequate supply of essential nutrients such as inorganic salts, amino acids, vitamins, glucose, growth factors, and carbohydrates. [14, 15] The most suitable medium contains fetal bovine serum produced from the blood of a dead calf. Some other technologies sought to use stem cell replication by stacking them on top and spray cell content onto sheets or other surfaces using an inkjet technique. [16]

One single muscle cell can form many new grown muscle cells that will eventually integrate to form a small strand of muscle tissue known as myotubes. These myotubes associate in a ring growing into small pieces of muscle tissues where these muscle tissues will multiply into many strands that could go up to a trillion in count. These fibers are attached to a sponge-like scaffold that supplies nutrients and stretches the muscle cells to increase their size and protein content. From this process, fewer animals are needed to produce a large amount of meat because of cell multiplication. During the entire process, the cells are constantly monitored and retained in an environment that replicates the normal body temperature, suitable for cellular development. [14, 15]

Benefits of lab-grown meat

Environmental impact

There are enormous positive impacts of cultured meat on consumers and the environment. Cell-based meats are environmentally friendly when compared to livestock meat production. As an estimation, 40% land, 14.5% of greenhouse gas (GHG) emission, 29% agricultural freshwater used for livestock meat production. [17] Conventional livestock farming, e.g., cattle farming, emits three crucial greenhouse gases: Methane, carbon dioxide, and nitrogen. The digestive tract of herbivores, especially ruminants, emit methane gas, a potent gas accountable for a big chunk of global GHG emissions. So, widespread production of cell-based meat may be an opportunity to reduce methane emissions compared to conventional livestock meat production. [18]

Impact on health and safety

Cell-based meat production is carried out in a controlled environment, which prevents it from possible contamination during animal slaughtering. Furthermore, the safety of cell-based meat is maintained and protected as it is lab-grown, not produced from the animals raised in a small area which abolishes the risk of an outbreak like influenza. [19, 20] Cell-based meat is claimed to be safer because traditional animal products are a crucial cause of the outbreak, foodborne disease, and food recalls. Gut inhabitant bacteria Salmonella and E.coli can spread into the food supply through fecal contamination resulting in food poisoning. A systematic review by Omar et al. from 1980-2015 in Europe and the United States showed that freshly processed meat products were mostly affected. There were 2279 reported cases of Salmonella outbreaks, of which 1891 were confirmed by laboratory tests. The report showed 94 required hospital admission with a fatality of seven. [21] Cultured meat does not contain any allergic substance compared to other meat products such as plant-based meat. It will also be beneficial

for the increasing demand for the growing world population. Cultured meat will make the meat available for more people on the planet. So, the balance in flora and fauna can be maintained without disrupting the ecosystem.

Nutritional content

The nutrient quality of cultured meat can be regulated by altering the ingredients of the culture medium. There is indeed a possibility of controlling the level of saturated fatty acids and polyunsaturated fatty acids. Omega-3 is an excellent option to replace saturated fats, but the potential risk of higher rancidity needs to be regulated. In recent days, techniques are available to increase the quantity of omega-3 fatty acids in meat. [22] Omega-3 reduces risk factors related to heart disease, such as triglycerides and blood pressure, which may positively impact cell-based meat sales in the future.

Moreover, meat is an important source of minerals, such as iron. So, increasing the cell culture medium with additional iron increase the level of iron in the cultured meat. [23] Iron is present as a part of heme in myoglobin or combination with ferritin. [24] From a nutritional point of view, absorption is better in non-heme form; hence cultured meat loaded with extra myoglobin content is advantageous apart from its texture and taste. [25]

Disadvantage of lab-grown meat

Impact on carbon footprint

Downsides faced during the production and marketing of cell-based meat are expected to increase the carbon dioxide level in the atmosphere. Animal agriculture contributes to the 14% emission of global greenhouse gases. There may be more impact on carbon footprint during the production of cell-based meat. Cell-based meat is expected to produce more carbon dioxide than potent methane, which takes a long time to dissolve. [26] It is still unclear whether cultured meat will be a more climatically sustainable alternative. [27]

Ethical concerns

There are ethical concerns raised with the production of cultured meat. The procedure is in vitro, but the fetal bovine serum is used, which shows the cruelty-free motto misleading contradicts the aim [28], so, may not be a choice for vegans or vegetarians. Bovine fetuses are taken from pregnant cows by slaughtering the animal. Fetuses are made sure to remain alive to maintain the blood quality, drawn out through a cardiac puncture. Whole blood is drained out, which takes an average of five minutes, leading the fetus to death. This process is inhumane as fetuses are in extreme pain and discomfort when the fetus's blood is extracted, raising moral and ethical concerns. [29]

Religious view

Cultured meat raises innumerable religious and philosophical concerns. Religious authorities are still discussing if cell-based meat is Halal (for Muslims, acquiescent with Islamic laws), Kosher (consumable under Jewish dietary laws). According to the Quran and renounced Islamic jurists, cultured meat will be considered halal if the stem cells are harvested from a halal-slaughtered animal, and no other serological sample will be used in the process of culture. [30] So, there is an obvious understanding that the cellular origin of cultured meat from pigs and other harem species is against Islamic law and never be permitted for consumption. [31]

Rabbinical views on the Jewish faith differ. According to some opinions, if the cells are obtained from a sacrificed kosher animal, then cultured meat can be considered as kosher.

Others believe that, without concerning the sources of the cells used to make the cultured flesh come from, they will lose their uniqueness. [32] So, the results are not conclusive towards the prohibition for the cultured meat consumption.

Hinduism primarily focuses on ahimsā, nonviolence, and the importance of veganism, although not highly prominent in Hindu texts. [33] Regarding the approval of cultured meat, the opinions are divided. Some believe that cultured meat avoids harming an animal, whereas others questioned the cultured beef, because cows are considered sacred in the Hindu religion. [34]

Effect on health

Livestock and farm animals produce hormones and growth factors to support growth and development. Hence, the culture medium will also need these hormones sufficiently to sustain cell growth. The hormones might not be able to be produced on an industrial scale. Even if possible, there might be short- and long-term effects that have not been discovered yet. European Union prohibited hormone growth promoters, raising grave concerns for the acceptability of cultured meat. We are also unaware of the repercussions of consuming cultured meat as it is still new to the food industry. There is a difference of opinion in certain authors that the cell culture procedure cannot be conducted flawlessly since unforeseen biological mechanisms can occur. For instance, chances of dysregulation of cell lines (i.e., mimicking cancerous growth pattern) may be higher when cell multiplication is conducted at a commercially viable mass level. Before mass production, intensive research must be conducted to monitor the adverse effects on muscle cells and human metabolism. [19]

Product cost and customer behaviour

Cell-based meat production requires massive amounts of energy where constant electricity is required. So, the higher production cost is a challenging factor to compete with the current price tag of animal meat. Thus, cultured meat is out of reach of the middle and low-income people, despite their interest. Livestock products such as beef, pork, and sheep use 27410 MJ, 16300MJ, and 23100MJ energy, whereas cultured meat uses 32710 MJ of energy despite the lowest land requirement. [35, 36] Certain companies tried to bring cultured meat into markets, but the cost has always been an issue. Companies have now raised funds to lower production

costs and blend them with plant-based meat substitutes, making them commercially available. [37]

Even though advocates of cell-based meat proclaim that these are still real meat, producing the meat is different from the traditional, causing rejections from some consumers. Average consumers prefer real meat as they expect it to be safer and more nutritious to consume. Food neophobia, also known as the fear of new or unfamiliar food, is prevalent in some Asian countries is a cause of aversion for the alternative meat foods. [38]

Food neophobia is a barrier caused by harmful associations of fresh or non-traditional foods. Consumers appear to be conservative in their food purchases, making this something common. Many meat substitutes have been produced and continue to appear in the market. [39] Moreover, the taste of cell-based meat will be a bit different when compared with traditional meat. This is because blood vessels, nerves, intramuscular fats and connective tissue plays a significant role for the taste. Burgers made from veggie meat fail to compete on texture and taste with the livestock preparation. [19]

Future of lab-grown meat

The shift to cultured meat has a strong potential, and it can significantly influence the present meat industry. So, farmers and companies which produce conventional meat products would face a financial challenge. Although lab-grown meat is a better alternative when seen theoretically, it might not be as simple as it sounds to end animal cruelty. Forming cell-based meat is challenging even though scientists have all technologies for developing skeletal muscle and adipose tissue, which have been created and tested before. [10] From a vegan's perspective, this is still far from good as we need to use the animal product to produce cultured meat. [40] Despite these hurdles, as the world population increases, the appetite for meat is set to grow. Therefore, our future food system must ensure affordable healthy food for humans while preserving natural resources and biodiversity. [37] Hence, cultured meat would be a sustainable solution in this context.

Competitor: Plant-based meat

Plant-based meat originates from plants and is processed to look, feel, and taste like conventional meat from animals. Plant-based meat is healthier than regular meat because of its lower calories. The components of plant-based meat include coconut oil, vegetable protein extract, and beet juice. Plant-based meats are widely sold in the market, such as nuggets and patties. Plant-based meat has a tremendous impact on the environment and the health of consumers on the whole. By replacing all conventional meat with vegetarian alternatives, massive emissions of carbon dioxide can be saved. When animal product consumption decreases, water shortage can be prevented since most freshwater is used for livestock production. Generally, plant-based meat is healthy if eaten in a decent amount since it is a balanced diet. According to a certified dietician, plant-based meat appears to have a lower amount of total and saturated fat, a high amount of fiber, and the corresponding amount of proteins. [37] Meanwhile, fiber consumption can minimize the likelihood of developing breast, colon, and other digestive-related cancers. Based on specific health examinations, researchers have found that people who consume plant-based meat have lowered their possibility for cardiovascular morbidity compared to people who ate animal-based meat in a given time frame. [41]

There are disadvantages of plant-based meat, as it contains a high amount of sodium used for fabrication, is more delicious, and shelf-stable. Sodium increases cardiac mortality by increasing blood pressure and may cause a stroke. Plant-based meats are highly processed food, thus impacting health by increasing the risk of weight gain due to the high amount of calories in processed food. Plant-based meat consumers require vitamin B12 supplements as it is insufficient when compared to animal meat. [42] Still, plant-based meat may compete with animal meat as a better option for vegetarians. [43]

Conclusion

Lab-grown meat may result in lesser animals being used and reduced environmental costs associated with livestock raising. Cultured meat seems to be advantageous to feed the growing population, but at the same time, there are disadvantages, cultural and financial challenges that need to overcome. Large-scale research, clinical trials need to be done to obtain more data to support cultured meat as a climatically sustainable alternative. Based on currently available information, it will be too early to comment on the viability, environmental impact, carbon footprint, and necessary rethink for unrestrained culture meat production and consumption.

Abbreviations

Greenhouse gas (GHG)

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Authors' contribution

a. Study planning: BR

b. Data collection/review of literature: BR, AH, YD

c. Manuscript writing: BR, AH, YD, NM, AB

d. Manuscript revision: BR, AH, YD, NM, AB

e. Final approval: BR, AH, YD, NM, AB

f. Agreement to be accountable for all aspects of the work: BR, AH, YD, NM, AB

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