An overview of *In-vitro* meat production and its limitations

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Abstract

Meat is one of the highly demanded article and its demand is increasing steadily day by day. The demand of meat of continuously growing human population cannot be fulfilled by conventional methods of meat production which are having various disadvantages. The *In-vitro* meat has been developed by the researchers using tissue engineering/ stem cell technology in laboratory without using an actual animal. Stem cells can grow in culture media and new muscle fibres are developed which can be used to prepare various meat products. Cells, scaffolds, bioreactors, culture medium, growth factors and fields are required to grow *in-vitro* meat in laboratory. No significant differences in sensory qualities were reported between products prepared from lab-grown meat and products prepared using conventional meat. The *in-vitro* meat is grown in sterile environment hence it is better for human body. It is better for the environment also as overall environmental impacts of *in-vitro* meat production are comparatively lower. While production of *in-vitro* meat, emission of greenhouse gasses are less than conventional methods. *In-vitro* meat can be produced with less energy, land and water. *In-vitro* meat is also considered as vegan meat and there are other advantages like fat content can be controlled, healthy meat, diseases can be controlled, chemically safe, reduce waste production etc. Therefore one can say that the *in-vitro* meat can be worked as an alternative to conventional meat.

Keywords: *In-vitro* meat, lab-grown meat, cultured meat

1. Introduction

Meat is an indispensable part of the human diet which provides easily available good quality proteins, minerals and all the B-complex vitamins. The excellent digestibility and well balanced composition of essential amino acids make the meat a highly demanded article of human nutrition (Kim, 2005) [9].

In 2017 global meat consumption was 318 million tons which may increase up to 366 million tons in 2027 (OECD-FAO Agricultural Outlook 2018-2027). Global human population in 2017 was 7.53 billion (World Bank, 2019) [14] and it is projected to reach about 10 billion in 2050 (World Population Prospects, 2019) [15]. Demand of meat and seafood is increasing steadily in all over the world especially in China and India and it will be doubled by 2050, reaching 544 million tons.

Therefore it will be very difficult to meet the demands of continuously increasing human population with conventional meat production methods. Meat is produced by conventional methods which has various drawbacks like food borne illnesses, nutrition related diseases, use of farm animals, inefficient use of resources, environmental pollution (Bhat and Bhat, 2011) [3]. According to the UN, global industrial meat agriculture creates more greenhouse gas emissions than all transportation combined (Matthews, 2006) [10].

*In-vitro* meat is also called as lab-grown meat, victimless meat, synthetic meat, cultured meat, test-tube meat, hydroponic meat, clean meat, etc. Its produced using tissue engineering/ stem cell technology by culture of skeletal muscle in laboratory without using an actual animal. Technologists evolved some plant based protein powders also to replace the meat entirely but lab-grown meat is the only product that results in real meat (animal based) without any harm to the animals.

2. History of *In-vitro* meat

As per documented records Alexis Carrel was successful in keeping a piece of chicken heart
muscle alive and beating in a petri dish (Carrel, 1912) [3]. The idea of in-vitro meat was predicted long back by Winston Churchill in the 1920’s (Churchill, 1932) [4]. In 1999 theoretical idea of in-vitro meat was patented by Van Eelen's (In-vitro meat godfather) and muscle tissue of common gold fish was cultured in 2002 (Benjaminson et al., 2002) [2]. This idea got boost in 1995 as NASA wanted improved food for astronauts in space and in the same year technique got approval from FDA. In 2004 tissue engineered meat for humans was patented by Jon Vein. Recently NRC on meat, Hyderabad is working on a research project to developed processes for production of cultured meat in collaboration with CCMB, Hyderabad.

3. Production of In-vitro meat

In-vitro meat is grown in laboratory by utilising the stem cells recovered from tissue of live animals. These stem cells grow in culture media and new muscle fibres are developed which are used to prepare various meat products.

Cells, scaffolds, bioreactors, culture medium, growth factors and fields are required to grow in-vitro meat in laboratory (Arshad et al., 2017) [11]. Most practical cell source for in-vitro meat production are embryonic myoblasts (also called as satellite cells/my satellite cells/muscle stem cells). Satellite cells with high proliferative potential have been isolated from skeletal muscles of chicken, pigs, lambs and cattle. Satellite cells are precursors to skeletal muscle cells (Kadi et al., 2005) [8]. These are located between the basement membrane of the sarcosome of muscle fibres (Zammit et al., 2006) [16] and can lie in grooves either parallel or transversely to the longitudinal axis of the fibre.

Satellite cells are attachment dependant, so it requires a scaffold. Scaffolds must be edible and derived from non-animal sources (e.g. Cytodex-3, micro carrier beads). Cytoskeletal proteins serve as scaffold for alignment of myofilaments during myofibril and sarcromere formation (e.g. Titin, Nebulin, C-protein, Desmin, M-protein, Filamin, Z-protein and Vinculin) which are active in live animal only. The scaffolds have to be derived from non-animal sources to grow the in-vitro meat.

In-vitro meat requires large bioreactors that maintain low shear and uniform perfusion (Pathak et al., 2008) [12]. Nutrients and oxygen need to be delivered close to each growing cell. In animals this job is handled by blood vessels. Bioreactors emulate this function in an efficient manner. The usual approach is to create a sponge-like matrix in which the cells can grow and perfuse it with the growth medium.

Cultured meat production systems also provide an appropriate array of growth factors. Growth factors are synthesized and released by muscle cells themselves.

Various fields can be used like mechanical, electromagnetic, gravitational, fluid flow. The field affect differentiation and proliferation of myoblasts (Powell et al., 2002) [13]. The products prepared from lab-grown meat were compared with the products prepared using conventional meat and found no substantial difference in sensory attributes. In 2013 Netherlands’ M/s Mosa Meat tasted Burger and in 2016 meatball tasting was done by M/s American Memphis Meats and both companies reported that products were nearly or as good as the original.

Major players of in-vitro meat industry are M/s Memphis Meats, California (developing lab-grown pork, beef, chicken and even duck), M/s Mosa Meat, Netherland (created the world’s first tissue cultured hamburger without slaughtering an animal in 2013). Other startups are M/s Super Meat, Israel, M/s Future Meat Technologies, Israel, M/s Meat the Future, Israel (working lab-grown meats), M/s Just, inc., M/s San Francisco (working on clean meat) and M/s Finless Foods, Brooklyn (working on lab-grown seafood) Table 1.

| Constraints | Solutions |
|-------------|-----------|
| 1. Consumer resistance | Need to run a few vigorous marketing campaigns to convince the consumers |
| 2. Moral objections to the stem cells source: e.g. Cow/pig stem cells | Researchers has developed in-vitro meat from stem cells of other species also |
| 3. Regulatory concerns | Researchers and multinational companies trying hard to get approval from regulatory authorities |
| 4. Cost of the product | Start-ups are working to overcome the constraint. The price has fallen remarkably in past 4-5 years. |
| 5. Cannibalism | Implementation of strict rules and regulations |
| 6. Taste and Texture: can be different/ Unnaturalness | As per preliminary trials, workers reported in-vitro meat: nearly or as good as the original |
| 7. Limited to ground meat | Research is going on |
| 8. Possible unknown health consequences | Research is going on |

Compared to traditional meat, it is better for human body as it is grown in a sterile environment and hence micro-organisms found in traditional meats can be avoided. It is better for the environment as overall environmental impacts of in-vitro meat production are comparatively lower (Hanna and Mattos, 2011) [7]. It involves approximately 7–45% lower energy use, 78–96% lower greenhouse gas emissions, 99% lower land use and 82–96% lower water use.

Cultured meat production systems also provide control over meat composition and quality by modifying flavor, fatty acid composition, fat content, and especially, the ratio of saturated to unsaturated fatty acids (Bhat and Fayaz, 2011) [4]. In-vitro meat is considered as vegan meat and other benefits are helpful for reforestation and wildlife, quick production, more ethical in animal welfare point of view, no social taboos, healthy meat, diseases can be controlled, reduce incidences of meat borne infections, reduce waste production, etc.

4. Conclusion

Production and supply of in-vitro meat is not commercialized yet anywhere in the world and the research work on in-vitro meat has just started in some of the institutions in India. Recently a research project to develop process for production of cultured meat (In-vitro meat) was started at National Research Centre on meat, Hyderabad, India. The constraints like consumer resistance, moral objections to the stem cells source, regulatory and guidelines concern, cannibalism and possible unknown health consequences has to be overcome, otherwise the developed in-vitro meat may also face the challenges as faced by the Genetically Modified Foods.
5. References

1. Arshad MS, Javed M, Sohaib M, Saeed F, Imran A, Amjad Z. Tissue engineering approaches to develop cultured meat from cells: A mini review. Cogent Food & Agriculture. 2017; 3(1):1-11.

2. Benjaminson MA, Gilchriest JA, Lorenz M. In vitro edible muscle protein production system (MPPS): Stage 1, fish. Acta Astronaut. 2002; 51:879-889.

3. Bhat ZF, Bhat H. Animal free meat bio fabrication. American Journal of Food Technology. 2011; 6(6):441-459.

4. Bhat ZF, Fayaz H. Prospectus of cultured meat-advancing meat alternatives. Journal of Food Science & Technology. 2011; 48(2):125-140.

5. Carrel A. On the permanent life of tissues outside of the organism. Journal of Experimental Medicine. 1912; 15:516-28.

6. Churchill W. Fifty years hence: in thoughts and adventures. Thornton Butterworth, London, 1932, 24-27.

7. Hanna LT, Mattos MJTD. Environmental impacts of cultured meat production. Environmental Science & Technology. 2011; 45(14):6117-6123.

8. Kadi F, Charifi N, Denis C, Lexell J, Andersen JL, Schjerling P et al. The behaviour of satellite cells in response to exercise: what have we learned from human studies?. Pflugers Arch. 2005; 451(2):319-27.

9. Kim YS. Meat Production. Meat Science and applications (1st Indian Reprint), Mercel Dekker, Inc. New York, Basel, 2005, 563-579.

10. Matthews C. Livestock a major threat to environment. Available from, 2006. http://www.fao.org/newsroom/en/news/2006/1000448/index.html

11. OECD-FAO. OECD-FAO agricultural outlook 2018-2027. Available from, 2018. http://www.agri-outlook.org/commodities/Agricultural-Outlook-2018-Meat.pdf

12. Pathak V, Bukhari SAA, Bhat ZF, Sharma N. Prospectus of in vitro meat. Indian Food Industry, 2008, 33-35.

13. Powell CA, Smiley BL, Mills J, Vandenburgh HH. Mechanical stimulation improves tissue-engineered human skeletal muscle. American Journal Physiology Cell Physiology. 2002; 283:1557-1565.

14. World Bank. Available from, 2019. https://data.worldbank.org/indicator/SP.POP.TOTL

15. World Population Prospects 2019. World population prospects-population division-united nations. Available from https://population.un.org/wpp/.

16. Zammit PS, Partridge TA, Yablokova-Reuveni Z. The skeletal muscle satellite cell: the stem cell that came in from the cold. Journal of Histochemistry and Cytochemistry. 2006; 54(11):1177-91.