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

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Abstract
Meat is a 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. Itis 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) [5]. The idea of *in-vitro* meat was predicted long back by Winston Churchill in the 1920's (Churchill, 1932) [6]. In 1999 theoretical idea of *in-vitro* meat was patented by Van Eelens (*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) [1]. 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 sarcolemma 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 sarcomere 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 sear 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.
Culture medium contains the necessary nutritional components and be presented in a free form available to the myoblasts. In addition to this it is necessary to 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.

Table 1: Constraints of *in-vitro* meat production and their solutions

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.

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