Biological Forum – An International Journal **14(4): 363-367(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Cultured Meat – A review

M. Kirthy Reddy[1]*, Rita Narayanan[2], V. Appa Rao[3], C. Valli[4] and G. Sujatha[5]
[1]Ph.D. Scholar, College of Food and Dairy Technology, TANUVAS, Chennai (Tamil Nadu), India.
[2]Department of Food Processing Technology, CFDT, TANUVAS, Chennai (Tamil Nadu), India.
[3]Dean, Faculty of Food Sciences, CFDT, TANUVAS, Chennai (Tamil Nadu), India.
[4]Dean, Faculty of Basic Sciences, MVC, TANUVAS, Chennai (Tamil Nadu), India.
[5]Department of Food Process Engineering, College of Food and Dairy Technology, TANUVAS, Chennai (Tamil Nadu), India.

(Corresponding author: M. Kirthy Reddy)*
(Received 17 August 2022, Accepted 06 October, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: To meet the growing human population's increasing demand for meat consumption, cultured meat can serve as a good alternative for consumers. On a global scale slaughtering of animals is becoming unviable in terms of their welfare, sustainability, and effects on human health. Culturing meat via cellular agriculture or tissue engineering is a promising method for future meat production. Advanced techniques in culturing meat made lab-grown meat as par with conventional meat in terms of organoleptic properties. The advantages of culturing meat are lowering greenhouse gas emissions, being slaughter-free, and antibiotic-free, and reducing carbon footprints. But several challenges still exist such as production at a large scale, regulatory aspects, acceptance by consumers, ethical issues, and optimization of cell culture methodology. This review aims at presenting an overview of the advantages, challenges, and culturing of meat at the lab level.

Keywords: Cultured meat, cell lines, bioreactor, mimicking.

INTRODUCTION

The population is expected to reach 9.8 billion by 2050 globally (UNDES, 2021). This growing population needs a livestock production of 455 million tons for consumption (Gerber *et al*, 2019), which is about 40 percent when compared with 2019. But today, the raring of animals contributes 14.5 percent of anthropogenic greenhouse gas emissions, particularly methane and nitrous oxide gases. These gases contribute to higher global warming and are more potent than carbon dioxide (Bohnes and Laurent 2021). To produce livestock huge land and water are required. All these are leading toward carbon and environmental footprints.

For ages, meat has been a very valuable commodity and an essential source of protein for humans. Proteins from animal foods top the food chain (Chemnitz and Becheva 2014). Apart from protein meat is a rich source of valuable vitamins, minerals, micronutrients, and fats thus forming an integral part of the human diet. India's livestock resources contribute 4.11 percent of the GDP and 25.6% of the Agriculture GDP. Forty percent of meat consumption globally is from animal meat and this demand is expected to double by 2050 (FAO, 2009). The availability of meat in India is only about 15g/person/day whereas, the ICMR recommended 30g/person/day (Islam *et al*., 2016).

In our country most of the animals are growing in very unnatural and unorganized conditions like farms (poultry, cattle, and goats), etc. will result in many diseases like mad cow, Flu, and Scombroid, which have a high chance of transmitting to humans when such meat is consumed. Livestock production is also choking the earth by using 70% of agricultural land, depletion of freshwater reservoirs, loss of biodiversity, erosion of soil and destruction of habitats, etc. Livestock rearing for meat, eggs, and milk is generating about 15% of greenhouse gas emissions globally and is the second-highest source of emissions higher than all combined transport globally (Prabodh *et al*., 2019).

To address queries related to global-scale meat consumption and to meet the meat demand, lab-grown meat could play a crucial role in this era. The present system of livestock cultivation is not sustainable and environmentally friendly. So, to reduce and mitigate these risks the best alternative means of meat production is to be addressed. Cultured meat or lab-grown meat from animal cells is one of the sources to address this issue. Culturing meat at the lab level is less environmental and public health harm, as well as avoids animal slaughter (Post *et al.,* 2020). Also, food neophobia and uncertainties about safety and health seem to be important barriers to the uptake of this technology (Pakseresht *et al.,* 2022).

Cultured meat: The term "cultured meat" will be used here as it seems to be the most widely used and accepted term, but alternative terms also include "synthetic meat", "in vitro meat", "lab-grown meat", "stimulated meat" and sometimes "artificial meat". The two main stem cells considered the most suitable for culturing meat are embryonic stem cells and satellite cells (Datar *et al.,* 2018).

The advantages of Cultured Meat.

1. Can customize and alter the composition of the final product in a controlled environment, concerning customers' tastes, and texture, and can alter nutritive quality also (Post, 2012).
2. This can address the problem of antibiotic contamination in the supply chain and can deliver zoonotic diseases free safer products to the consumer (EC, 2010).
3. At any stage of culturing meat at the lab level does not involve the suffering of the animals and slaughtering. This concept would attract people from many sections like vegetarians and animal welfare sections (Hopkins and Dacey 2008).
4. Cells from various animals can be cultured to produce lab-grown meat so, consumers have a wide variety of options. This also has the possibility of incorporating even the meat from the cells of exotic animals into the food menu (Zaraska, 2013).
5. The traditional genetic pool can be retained
6. More profits can be seen if the production is on a large scale
7. Food wastage can be lowered
8. Lesser environmental impact and lowers the use of resources (Stephens *et al.,* 2018).
9. A cell line or a tissue sample from single livestock will give raise to meet the numberless meat supply (Rorheim *et al.,* 2016).
10. Low emissions of GH gases.
11. Fewer carbon footprints
12. Less land and water usage

Steps in Culturing Meat. Culturing of meat is still in the nascent stage, despite enormous and numerous research, there are huge challenges in front of the scientists and technicians such as source, serum-free culture media, the acceptance rate of consumers, and production at an industrial scale (Haagsman *et al.,* 2009). The success of growing meat in the lab mainly relies on two 1) Simulating or mimicking this meat as close to conventional meat in terms of organoleptic properties 2) Cultured meat should have a price that is affordable by the consumer (Sharma *et al.,* 2015).

The important technique of in-vitro meat production was to isolate and proliferate tissues in a medium that is acceptable and then harvest them (Benjaminson *et al.,* 2002). The meat is produced in the lab by culturing stem cells from the adult muscle of an animal in a matrix made from collagen which is obtained from a live or dead animal. The next step is providing the source of energy required for their growth (proliferation and differentiation) into striped skeletal muscle tissue (Bhat *et al.,* 2015). Some of the advancements in *in vitro* are engineering in meat and tissue engineering have been evolved in the process of cell selection, placing them on the scaffolds, proliferating them in the bioreactors, and making use of the cultivated cells to form muscle tissues in form of masses (Bhat *et al.,* 2017).

Choice of cell lines. Meat muscles mainly consist of skeletal muscles which are in turn composed of many other types of cells in them. These muscle fibers develop from the development stage and get differentiated into embryonic myoblast or satellite cells (Langelaan *et al.,* 2010). Commonly used cell sources for growing meat in the lab are myosatellite cells, embryonic stem cells, myosatellite cells, and adult stem cells (Mesenchymal, induced pluripotent, totipotent, pluripotent, and multipotent stem cells). As muscle cells do not contain fat it can be beneficial if myofibrils are co-cultured along with fat cells which are called adipocytes which can enhance the sensorial and organoleptic properties of the cultivated meat by increasing intramuscular fat-ingrown meat with add to the palatability and tenderness in the meat (Hocquette *et al.,* 2010).

Among several types of cells used to produce cultured meat, the most promising and prominent ones are myosatellite cells, which act as the primary stem cells for producing muscle. Tissue engineering is also called the agriculture system at the cellular level, aiming at culturing meat synthetically outside the body of an animal. Using the chemical, mechanical and biological cues present in the cultured media the above said technology entails differentiating stem cells into muscle cells (Langelaan *et al.,* 2010).

Culturing: The source/initiating material for cellular agriculture using tissue engineering can be either from original tissue by using the biopsy samples harvesting tissue samples by biopsies from a small herd of animals and culturing them (Jung *et al.,* 2012) or obtained via induction (genetic engineering or chemical) or spontaneous mutations (Thermofisher *et al.,* 2017). The process of developing lab-grown meat involves a gathering of cells that are apt with the potential to obtain muscle (Fig 1) and then gently proliferate the number of cells in a bioreactor (Post 2012). With an adequate supply of nutrients and gases through a gradient by diffusion and by giving stimulation (mechanical or electrical). In this environment, it is possible to proliferate and differentiate cells in a controlled environment (Orzechowski, 2015).

Medium and supplementation: Growth medium and supplementary proteins are added for the proliferation of the cells. Commonly used ones are fetal calf serum, serum of the horse or embryo extract from chicks or sericin may be an alternate substitute for fetal serum (Fujita *et al.,* 2010). Antibiotics are generally added to the culture in order to prevent infection. Many factors like vitamins, hormones, amino acids, and fatty acids are also added for growth, development, and maintaining viability in the cell. These cytokines havea potential role in regenerating muscle tissue (Arora, 2013).

Formation of myotubes: The muscle formed after culturing meat needs to be stretched to mimic the conventional meat. Physically these can be done by stem cells (fibroblast) as these have the power to arrange collagen or collagen/matrigel into fibers that are tightly organized between the anchors which develop tension within the developing muscle fibers (Grinnell, 2000). An external electrical stimulus can also be enforced for the organization of mature muscle fibers. More number of myotubes which are of greater length can be induced by proliferating of myoblasts on electrically conductive fibers (Jun *et al.,* 2009)

Scaffolds: To produce lab-grown meat, the initially isolated cells can be perfectly grown on a meshwork of collagen (van Eelen *et al.,* 1999) or collagen beads (Edelman *et al.,* 2005). But these scaffolds can only be able to produce a very thin layer of myocyte which is only 100–200 µm thick, however, the only possible solution is adding several cell cultures layers which can be added together to produce a muscle or a meat tissue of a consumer acceptable size (Dennis *et al.,* 2009).Much research is going on for the development of suitable scaffolding techniques to produce cultured meat. Among them, fibrin hydrogel is the most suitable scaffold for many researchers mainly for culturing muscle tissue from skeletal cells which can migrate, proliferate, and produce their own extracellular matrix (Lam *et al.,* 2009).

Challenges in culturing meat

Technical challenges: Techniques followed for obtaining cultured meat tissue via different procedures only focuses on muscle tissue but not carcass development. So, these thin 3D cultured meat can be only utilized as minced meat patties in form of processed meats (burgers, sausages) but are not optimized for the carcass (Thermo Fisher, 2017).

Scaffolds: To mimic the conventional meat and naturally occurring 3D structure, the major requirement is a scaffold. Scaffolds should possess the characteristics to allow the adhesion of cells, proliferation, and development of tissues. The only alternative is to develop a cell line that is non-adhesive. This would greatly reduce the economic factors in the production of meat in the lab and lowers carbon footprints. Scaffolds derived from animals have advantages such as the adhesion of cells, and the alignment of fibres are mainly used for 3D skeletal muscle formation. Added cost. Edibility and reuse of scaffolds (Kawazoe and Chan 2015).

Culture media challenge: Usually foetal calf or horse serum is added in the range of 0.5–2% Even the extract from the chicken embryo is also sometimes used to some cultures. Growth medium and supplementary proteins are added for the proliferation of the cells. Commonly used ones are fetal calf serum, serum of the horse, or embryo extract from chicks or sericin can be used as a substitute for fetal serum (Fujita *et al.,* 2010).

Bioprocessing: Establishing scaffold and bioreactor conditions that enable differentiation in larger bioreactors is the major challenge to making cultured meat a commodity.

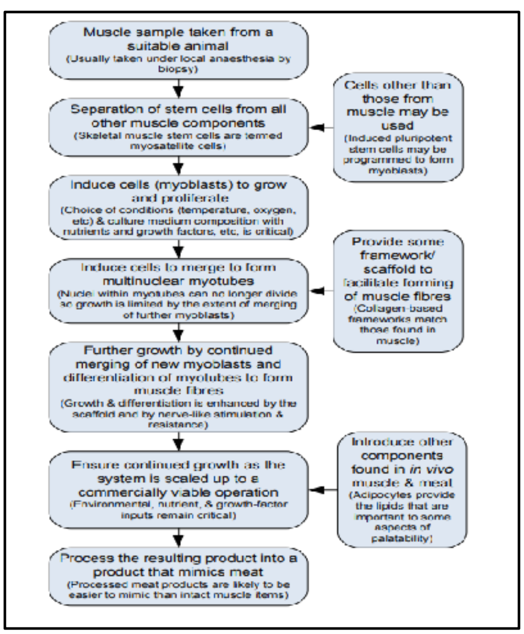

Fig. 1. Steps in the culturing of meat. Source: Isam *et al.* (2015).

CONCLUSION

Cultured meat offers enormous benefits in terms of human, animal, and environmental health. Production of meat by culturing obtained from desired cell samples and grown in a controlled environment is perceived as ethical compared to the conventional meat system, which involves the killing of animals and the usage of resources. So, producing meat in the lab is the practical solution to meet the growing meat demand of the people. Cultured meat would minimize reliance on land and water resources making it a sustainable source of food.

FUTURE SCOPE

Cultured meat technology is still in its experimental stage and has so far been limited to producing a small number of processed meat items in laboratory settings for demonstrative purposes.

Conflict of interest. None.

REFERENCES

Arora, M. (2013). Cell culture media: A review. *Material Methods*, *3*, 175.

Benjaminson, M. A., Gilchriest, J. A. and Lorenz, M. (2002). In vitro edible muscle protein production system (MPPS): stage 1, fish. *Acta Astronautica*, *51*(1), 879-889

Bhat and Fayaz (2011). Prospectus of cultured meatadvancing meat alternatives. *Journal of Food Science and Technology*, *48*, 125-131.

Bhat, Z. F., Kumar, S. and Fayaz, H. (2015). In vitro meat production: challenges and benefits over conventional meat production. *Journal of Integrative Agriculture*, *14*(2), 241-248.

Bohnes, F. A. and Laurent, A. (2021). Environmental impacts of existing and future aquaculture production: comparison of technologies and feed options in Singapore. *Aquaculture* 532, 736001.

Chemnitz, C. and Becheva, S. (2014). Meat Atlas. from:www.foeeurope.org/meatatlas.

Datar, I. and Betti, M. (2010). Possibilities for an in vitro meat production system. *Innovative Food Science and Emerging Technologies*, *11*, 13–22.

Dennis, R. G., Smith, B., Philip, A., Donnelky, K. andBaar, K. (2009). Bioreactors for guiding muscle tissue growth and development. *Advances in Biochemical Engineering (Biotechnology)*, *112*, 39–79.

Edelman, P. D., McFarland, D.C., Mironov, V. A. and Matheny, J.G. (2005). Commentary: In vitro-cultured meat production. *Tissue Engineering*, *11*, 659–662.

European Commission. Regulation (EC) No. 1829/2003 of the European Parliament and of the Council of 22 September 2003 on Genetically Modified Food and Feed. Available online: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A320 03R1829 (accessed on 25 November 2020).

FAO (2009). How to feed the world in 2050. *Population and Development Review*, *35*.

Fujita, H., Endo, A., Shimizu, K. and Nagamori, E. (2010). Evaluation of serum-free differentiation conditions for C2C12 myoblast cells assessed as to active tension generation capability. *Biotechnology and Bioengineering*, *107*, 894-901.

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A and Tempio, G. (2013). Tackling Climate Change through Livestock—A Global Assessment of Emissions and Mitigation Opportunities. *FAO*: Rome, Italy.

Grinnell, F. (2000). Fibroblast-collagen-matrix contraction: growthfactor signaling and mechanical loading. *Trends in Cell Biology*, *10*, 362–365.

Haagsman, H. P., Hellingwerf, K.J. and Roelen, B. A. J. (2009). Production of animal proteins by cell systems, Desk study on cultured meat myogenic satellite cell in a serum-free medium. *Comparative Biochemistry and Physiology*, *99*, 1-58.

Hocquette, J. F., Gondret, F., Beaza, E., Medale, F., Jurie, C. and Pethwick, D.W. (2010). Intramuscular fat content in meat-producing animals: development, genetic, and nutritional control, and identification of putative markers. *Animal*, *4*, 303–319.

Hopkins, P. D. and Dacey, A. (2008). Vegetarian meat: could technology save animals and satisfy meat-eaters? *Journal Agriculture Environmental Ethics*, *21*, 579–596.

Islam, M. M., Anjum, S., Modi, R. J. and Wadhwani, K. N. (2016). Scenario of Livestock and Poultry in India and their Contribution to National Economy. *International Journal of Science, Environment and Technology*,*5*, 956-965.

Isam, Kadim., Mahgoub, O., Baqir, S., Faye, B. and Purchase, R. (2015). Cultured meat from muscle stem cells: A review of challenges and prospects. *Journal of Integrative Agriculture*, *14*(2), 222–233.

Jun, I., Jeong, S. and Shin, H. (2009). The stimulation of myoblast differentiation by electrically conductive sub-micron fibers. *Biomaterials*, *30*, 2038–2047.

Jung, S., Panchalingam, K., Rosenberg, L. and Behie, L. (2012). Ex vivo expansion of human mesenchymal stem cells in defined serum-free media. *Stem Cells International*, 123030.

Lam, M. T, Huang, C., Birla, R. K. and Takayama, S. (2009). Microfeature-guided skeletal muscle tissue engineering for highly organized three-dimensional free-standing constructs. *Biomaterials*, *30*, 1150–1155

Langelaan, M. L., Boonen, K. J., Polak, R. B., Baaijens, F. P., Post, M.J. and Van Der Schaft, D. W. (2010). Meet the new meat: tissue engineered skeletal muscle. *Trends in Food Science and Technology*, *21*, 7.

Orzechowski, A. (2015). Artificial meat: Feasible approach based on the experience from cell culture studies. *Journal of Integrative Agriculture*, *14*(2), 217-221.

Prabodh, S., Halde and Dsouza, D. (2019). The future of meat: Real or Unreal? PENDAI Bulletin *Food, Nutrition & Safety Magazine*. *7*, 9-12.

Pakseresht, A., Kaliji, A. S. and Canavari, M. (2022). Review of factors affecting consumer acceptance of cultured meat. *Appetite*, *170*, (105289).

Post, M. J. (2012). Cultured meat from stem cells: challenges and prospects. *Meat Science*, *92*(3), 297-301.

Post, M. J., Levenberg, S., Kaplan, D., Genovese, N., Fu, J., Bryant, C. J., Negowetti, N., Verzijden, K. and Moutsatsou, P. (2020). Scientific, sustainability and regulatory challenges of cultured meat. *National Food*, *1*, 403–415.

Rorheim, A., Mannino, A., Baumann, T., and Caviola, L. (2016). Cultured Meat: A pragmatic solution to the problems posed by industrial animal farming. *Sentience Politics*, *1*, 3-14.

Sharma, S., Thind, S. S. and Kaur, A. (2015). In vitro meat production system: Why and how. *Journal of Food Science and Technology*, *52*, 7599-7607.

Stehens, N., Silvio, L.D., Dunsford, I., Ellis, M., Glencross, A. and Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends in Food Science and Technology*, *78*, 155-166.

Thermo Fisher Introduction to cell culture. https://www.thermofisher.com/in/en/home/references/ gib co-cell-culture-basics/introduction-to-cell-culture.html

United Nations Department of Economic and Social Affairs. World Population Projected to Reach 9.8 Billion in 2050, and 11.2 Billion in 2100. Available online: https://www.un.org/development/desa/en/news/popula tion/world-population-prospects2017.html (accessed on 30 March 2021).

VanEelen, W. F., Van kooten, W. J. and Westerhof, W. (1999) Industrial production of meat from cultured cell cultures. Patent description. [2014-6-20].

Zaraska, M. (2013). Lab-grown beef taste test: 'Almost' like a burger. Health & Science T Washington post Published, 5.

How to cite this article: M. Kirthy Reddy, Rita Narayanan, V. Appa Rao, C. Valli and G. Sujatha (2022). Cultured Meat – A review. *Biological Forum – An International Journal, 14*(4): 363-367.