Chapter N

Innovation in the food sector: development prospects for synthetic meat production

Vito Tommaso§\*, Roberto Leonardo Rana§#, Caterina Tricase§ç

§Department of Economy, University of Study of Foggia – via Romolo Caggese n°1

\*vito.tommaso@unifg.it and ORCID: 0000-0001-6386-0276; #roberto.rana@unifg.it and ORCID: 0000-0003-0611-2049; çcaterina.tricase@unifg.it and ORCID: 0000-0002-8828-5551.

Corresponding author: Vito Tommaso, vito.tommaso@unifg.it

**Abstract.** Currently, the production of meat appears to be unsustainable due to its environmental impact and because cause natural resources depletion. Furthermore, in the next few years the situation going to be worsened due to the increase of the human population and the lifestyle change of some nations such as Chine or India. Moreover, according to scientists, conventional meat production would be insufficient to satisfy the growing demand of this food.

To solve these problems, an innovative technology has recently been developed that can produce meat in laboratory so that the first synthetic meat production has started in 2016. To date there are different methodology that try to overcome some problems link to the pour quality and high cost of this new food. In the light of these premises, the present study aims to present an overview of synthetic meat production techniques, analysing advantages and disadvantages that its production can entail. Results shown that synthetic meat could contribute to reduce environmental pollution and natural resources depletion as well as feed the growing world population. However, some technological problems should be resolved such as its taste not always appreciated by consumers and the huge energy consumption that its production needs.

**Keywords.** Synthetic meat, cultured meat, tissue engineering, innovation.

# Introduction

Hunger is one of the major plagues that afflict the human population. Although during the last decades the United Nations (UN) has started several initiatives to reduce this problem in 2020 the percentage of world hunger has increased of around 9.9%. This result has not allowed achieving the goal Zero Hunger within 2030 by the UN (FAO, 2021). Despite to this, meat consumption is expected to double in the year 2050 due to population growth and increase income of some countries such as China or India (FAO, 2021; Bai et al., 2020). Therefore, conventional meat production would be insufficient to produce enough meat for supply the global meat demand. Moreover, the conventional meat production contributes to release high quantities of greenhouse gasses (principally carbon dioxide, methane and nitrous oxide), to consume natural resources (i.e., water, soil, etc.) and destroy natural ecosystems (i.e., rain forests) (FAO, 2021). To answer to these future challenges, it has been proposed the synthetic meat (or in vitro meat) production, an innovation technology, which could represent a valid alternative to conventional one. Furthermore, in vitro meat also seems to contribute to solve environmental problems and the natural resources depletion. In this contest, the present study aims to present an overview of synthetic meat production techniques, analysing advantages and disadvantages that its production can entail. This study could also provide useful information for improving challenges that this innovation implies and for policymakers which intent to know the main elements that have to be taken into account to support the use of this novel food.

# Currently techniques for producing synthetic meat

According to Pandurangan and Kim (2015) synthetic meat has the same characteristics of an animal meat product but developed artificially starting from living cells. The term synthetic meat is also known as cultured meat, clear meat, in vitro meat or lab grown meat. Originally researches on in vitro meat production was initiated in the late 90’s, by the National Aeronautics and Space Administration (NASA) for space travel (Kumar et al., 2021), using fish cells (muscle tissue from *Carassius auratus*). Since then, researches on cultured meat are increased. Thus, in 2003, Mark Post, in his laboratory at Maastricht University (Netherlands) cultured the first in vitro-meat beef. Subsequently, the revolutionary progress was recorded in the year 2012 (Post, 2012) when the first in vitro meat-based burger was prepared and presented in an exhibition at the Riverside Studios of London.

However, synthetic meat was not yet ready for commercial purpose since its production was very expensive due to: a) the high costs of culture media; b) the absence of commercial infrastructures; c) and the early stage of research. Indeed, the initial price of a cell-cultured burger (composed with 200g of meat) obtained with this technology was about 330,000$. A few years later, the introduction of new technologies reduced the price of a cell-cultured meat reaching 9.00/9.50$ per burger (Kantono et al., 2022). Currently, in vitro meat production is spreading worldwide, and this obviously affects some economic aspects. It is estimated that there is an increase aggressive trend in the creation of start-ups in this sector. Due to the improvement of these technologies in the last decade, in fact, according to Kumar et al., (2021) there are approximately 32 start-ups/companies producing cultured meat on an industrial scale. These companies are continuously searching for better technological inventions by focusing their R&D on cultured beef (25%), poultry (22%), pork (19%), seafood (19%) and exotic meat (15%). Moreover, 40% of these companies based in North America, 31% in Asia and 25% in Europe. The estimated global market for synthetic cell-based meat will amount about $214 and $593 million respectively by 2025 and 2032 (Mateti and Laha, 2022). Furthermore, according to research, the low cost of synthetic meat will probably allow an increasing consumption from 0% to 10% up to 2030 and about 35% to 2040. On the other hand, conventional meat supply will drop by 33% from now to 2040 (Gerhardt et al., 2020). Although these trends will have positive effects such as decrease the environmental impact and reduce the use of natural resources, they could cause economic problems for farmers who profit from conventional meat production. The synthetic meat technology has improving in the last three decades. The first technology consisted in the monoculture of satellite cells[[1]](#footnote-1) which, when fusing, produce structural muscle cells fibres. In the second step, the muscle fibres were physically stretched allowing their development in the proper direction (Booner et al., 2010; Post, 2012). However, this typology of meat lack of bones scaffold and fat cells and consequently its taste was not like the conventional meat. Moreover, the absence of specific multiple stimuli led to a cell culture without a complex structural organization. Therefore, this synthetic meat had a much lower protein source than a conventional meat[[2]](#footnote-2). On the contrary, differentiating and fusing, thanks to appropriate stimuli, these mature cells produced a sufficient amount of protein sources, improving nutritional properties of meat. Another typology of technology uses different cells like stem cells and induced pluripotent stem cells[[3]](#footnote-3). Several stem cells have been identified for producing in vitro meat culture. In recent decades, technology developed for their isolation, identification, cultivation and engineering has allowed possible to take a big step forward in the production of synthetic meat. In fact, until then, cells usually grew in two-dimensional (2D) form because no structural interaction there was between the cells (there is only contact interaction) and the cultured meat had a low quality compared to conventional one[[4]](#footnote-4). It is believed that 2D culture system is less reliable than the 3D co-culture system in vitro since the latter closely mimics cell physiology in vivo. Indeed, the 3D co-culture system allows the interactions between different cell types, producing meat with good taste and quality (Boonen et al., 2010). Since the 2013 co-culture of myoblasts and fibroblasts was believed to be one of the main techniques for synthetic meat production. Indeed, co-culture of these two specific cell lines have established the analysis of fat regulation and deposition of muscle (made by myoblasts) in a 3D structure (made by fibroblasts). As a relevant result, several biochemical markers related to muscle/fat formation and regulation are studied in the myoblasts and fibroblasts co-culture (Zhang et al., 2010).

One of the newest technologies for cultured meat production uses Fibro-adipogenic progenitor cells (FAPs)[[5]](#footnote-5). According to Dohmen et al., (2022) FAPs have high potential to produce fat and a significant potential to proliferate in vitro. Consequently, they could potentially be used for a better scalable cultured meat production process. From the hydrogel culture of FAPs, a 3D-structured meat (thanks to the hydrogel that acts as a scaffold) can be produced, obtaining a product that accurately mimics traditional beef fat in terms of lipid profile and taste. Thus, this technology represents the most used technology for the commercial production of cultured beef, especially because it is high in fat (Dohmen et al., 2022).

# Advantages and challenges

In this paragraph, it will analyse the advantages and challenges of the synthetic meat production. One of the best advantages is that in vitro meat production, compared to meat produced by conventional methods, is characterised by reducing energy consumption up to 40%, land use by 99%, water consumption by 90% and greenhouse gas emissions (GHGs) by the 90% (Tuomisto and Teixeira De Mattos, 2011; Kumar et al., 2021; Mateti and Laha, 2022; Dohmen et al., 2022). Another advantage is that synthetic meat production could also prevents the contamination of meat to bacteria and pathogens such as *Salmonella spp.*, *Campylobacter spp.* and *Clostridium perfringens* which cause dangerous diseases to consumers (Scallan et al., 2011). For instance, avian and swine influenza viruses often spread when intensive livestock farming is adopted (Borkenhagen et al., 2019). Therefore, synthetic meat products can ensure safety for consumers. In addition, replacing conventional meat with synthetic meat could improve the quality of health and reduce/prevent diseases due to the consumption of red meat. In fact, the known composition of synthetic meat and the protocols for its production can reduce the intake of fats and cholesterol and therefore reduce atherosclerosis and thrombosis events. The biochemical composition of in vitro meat, such as the increase in polyunsaturated fatty acids, can also lead to dietary and healthier products (Capper, 2011). However, the in vitro meat production involves some disadvantages specifically because its production system is still in the early stage. One problem is linked to its taste. Rosenfeld and Tomiyama (2022), in fact, state that many people find synthetic meat too disgusting to eat. In this study it was estimated that 35% of meat-eaters and 55% of vegetarians felt too disgusted eat this new food. Working on the feeling and the perceiving of synthetic meat as similar to conventional meat can improve consumer acceptance of cultured meat in the next years, allowing the consumption of meat also by vegetarians, avoiding the ethical problems that lead to this choice of life. A fundamental point regarding the synthetic meat production is the ethical and legal aspect. In fact, as a disadvantage, producers could try to sell cultured meat as conventional meat, to still have a profit but thus deceiving the consumer. Furthermore, cultured meat producers could produce meat of species other than those declared or for which they are authorized, also trying to produce meat of protected animal species, thus expanding the illegal meat market. Even more concerned is the possible use of human cells which could even lead to cannibalism. Unfortunately, the regulatory frameworks are currently unclear and under development (Mateti and Laha, 2022). Furthermore, although the production of synthetic meat leads to a reduction in greenhouse gas emissions, the use of land and water and the realise of pollutants, its industrial production would have the disadvantage of a significant energy consumption. Indeed, its production system requires much more energy (18-25 GJ/t) than the conventional one (4.5 GJ/t) (Tuomisto and Teixeira De Mattos, 2011; Alexander et al., 2017; Hong et al., 2021). By switching to renewable energy sources, less GHGs would be emitted and the positive effects on the environment due to the only reduction of intensive farming would not be eliminated. A further controversial point in the replacement, albeit partial, of conventional meat with cultured meat is the reduction of obtainable by-products (wool, leather, bone objects, hormones, etc.) deriving from farms. This can be considered a further disadvantage from an economic point of view, but on the other hand the production of synthetic meat produces a much lower quantity of waste than those produced by slaughtering to obtain conventional meat (carcasses, sewage, non-edible waste), resulting in their waste disposal problem (Kumar et al., 2021).

# Conclusion

In conclusion, considering all these aspects, synthetic meat could be a possible solution in the coming years to most of the problems due to environmental pollution by large meat production and intensive livestock farming companies, even if it would cause them economic damage. It would also make a huge contribution to world meat needs, especially in developing countries.

But as a young technology still evolving, its development in research must be accompanied by a parallel growth of regulations and laws. Only in this way will we avoid all the possible frauds and illegalities that could sink this new market sector, and its development in safety would lead to greater acceptance by the consumer and its ever-increasing diffusion globally.

# References

Alexander P, Brown C, Arneth A, Dias C, Finnigan J, Moran D et al (2017) Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? Glob. Food Sec. 15, 22–32. <https://doi.org/10.1016/j.gfs.2017.04.001>

Bai J, Seale JL and Wahl TI (2020) Meat demand in China: to include or not to include meat away from home? Aust. J. Agric. Resour. Econ. 64, 150–170. <https://doi.org/10.1111/1467-8489.12362>

Boonen KJM, Langelaan MLP, Polak RB, van der Schaft DWJ, Baaijens FPT and Post MJ (2010) Effects of a combined mechanical stimulation protocol: Value for skeletal muscle tissue engineering. J. Biomech. 43, 1514–1521. <https://doi.org/10.1016/j.jbiomech.2010.01.039>

Borkenhagen LK, Salman MD, Ma MJ and Gray GC (2019) Animal influenza virus infections in humans: A commentary. Int. J. Infect. Dis. 88, 113–119. <https://doi.org/10.1016/j.ijid.2019.08.002>

Capper JL (2011) The environmental impact of beef production in the United States: 1977 compared with 2007. J. Anim. Sci. 89, 4249–4261. <https://doi.org/10.2527/jas.2010-3784>

Dohmen RGJ, Hubalek S, Melke J, Messmer T, Cantoni F, Mei A et al (2022) Muscle-derived fibro-adipogenic progenitor cells for production of cultured bovine adipose tissue. npj Sci. Food 6. <https://doi.org/10.1038/s41538-021-00122-2>

FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO. <https://doi.org/10.4060/cb4474en>

Gerhardt C, Warschun M, Donnan D and Ziemßen F (2020) When consumers go vegan, how much meat will be left on the table for agribusiness? A.T. Kearney, 1–16.

Hong TK, Shin DM, Choi J, Do JT and Han SG (2021) Current issues and technical advances in cultured meat production: A review. Food Sci. Anim. Resour. 41, 335–372. <https://doi.org/10.5851/KOSFA.2021.E14>

Kantono K, Hamid N, Malavalli MM, Liu Y, Liu T and Seyfoddin A (2022) Consumer Acceptance and Production of In Vitro Meat: A Review. Sustainability. 14, 4910. <https://doi.org/10.3390/su14094910>

Kumar P, Sharma N, Sharma S, Mehta N, Verma AK, Chemmalar S et al (2021) In-vitro meat: A promising solution for sustainability of meat sector. <https://doi.org/10.5187/jast.2021.e85>

Mateti T and Laha A (2022) Artificial Meat Industry: Production Methodology, Challenges, and Future. JOM. <https://doi.org/10.1007/s11837-022-05316-x>

Pandurangan M and Kim DH (2015) A novel approach for in vitro meat production. Appl. Microbiol. Biotechnol. 99, 5391–5395. <https://doi.org/10.1007/s00253-015-6671-5>

Post MJ (2012) Cultured meat from stem cells: Challenges and prospects. Meat Sci. 92, 297–301. <https://doi.org/10.1016/j.meatsci.2012.04.008>

Rosenfeld DL and Tomiyama AJ (2022) Would you eat a burger made in a petri dish? Why people feel disgusted by cultured meat. J. Environ. Psychol. 80, 101758. <https://doi.org/10.1016/j.jenvp.2022.101758>

Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL et al (2011) Foodborne illness acquired in the United States-Major pathogens. Emerg. Infect. Dis. 17, 7–15. <https://doi.org/10.3201/eid1701.P11101>

Tuomisto HL and Teixeira De Mattos MJ (2011) Environmental impacts of cultured meat production. Environ. Sci. Technol. 45, 6117–6123. <https://doi.org/10.1021/es200130u>

Zhang Y, Li H, Lian Z and Li N (2010) Normal fibroblasts promote myodifferentiation of myoblasts from sex-linked dwarf chicken via up-regulation of β1 integrin. Cell Biol. Int. 34, 1119–1127. <https://doi.org/10.1042/cbi20090351>

1. Satellite cells, also known as myosatellite cells, are small multipotent cells. These muscle stem cells are found in mature muscle. Satellite cells are precursors to skeletal muscle cells, able to proliferate giving other satellite cells or differentiated skeletal muscle cells. [↑](#footnote-ref-1)
2. Generally, 100g of conventional meat has around 20g of proteins. [↑](#footnote-ref-2)
3. Stem cells differ from other cells in their uniqueness. In fact, being pluripotent, they can differentiate into different cell types. Stem cells have the ability to remain in a rather undifferentiated state for a significant number of cellular passages during culture. [↑](#footnote-ref-3)
4. It is recalled that conventional meat has a complex network, a highly ordered and three-dimensional (3D) structure. [↑](#footnote-ref-4)
5. FAPs are also multipotent cells, present in bovine muscle. These cells are transcriptionally and immunophenotypically different from the satellite cells seen above. FAPs have a higher adipogenic potential than satellite cells, which have a higher myogenic potential. [↑](#footnote-ref-5)