

CULTURED MEAT PRODUCTION TECHNOLOGY: CHALLENGES AND FUTURE DEVELOPMENT

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SUMMARY

- Meat substitutes are currently gaining attention as a way to overcome the shortage of meat supply against the growing global population and conserve the environment. There are two types of meat substitutes: plant-based meat and cultured meat. Cultured meat can be artificially produced indoors: therefore, compared with plant-based meat substitutes, cultured meat is said to have a smaller environmental impact and be less susceptible to the effects of climate change.
- Production of cultured meat is faced with technological challenges in the materials used in production (e.g., culture medium) and the method of mass production. Not only many startups but also large companies have begun efforts to resolve these issues.
- If a company operates a business related to cultured meat, it should focus not only on companies producing cultured meat, but also on those that possess important technologies in the supply chain overall.

1. MEAT SUBSTITUTES

1-1. Background to increased demand for meat substitutes

There are two types of meat substitutes: plant-based meat and cultured meat. Plant-based meat substitutes are already on the market, and their demand is rising every year.¹ Although cultured meat is not yet commercially available, research and development is underway to meet the demand for such as high value- beef. This increase in demand for meat substitutes can be considered from two points of view: response to meat supply shortage and environmental protection.

The shortage in meat supply is attributed to the increase in the global population. The world population, which stands at 7.7 billion people in 2020, is expected to rise to 9.7 billion by 2050. This population growth is projected to increase the demand for meat 1.7 times from 2020 to 2050, and the demand is estimated to double, particularly in developing countries where incomes are expected to improve.² In terms of agricultural land use, as much as 77% of the total agricultural land is used for livestock breeding or feed cultivation. Further increase in livestock breeding is considered to be unlikely in the face of climate change, which makes it difficult to expand agricultural land. Producing meat substitutes, which requires the use of less land compared to livestock rearing, is expected to resolve concerns about the shortage of meat supply.³

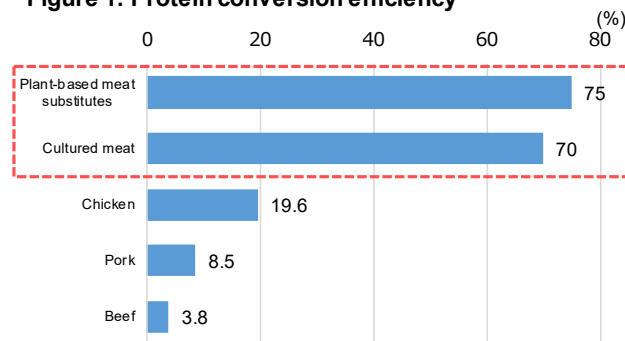
¹ “Plant-based market overview,” The Good Food Institute <https://www.gfi.org/marketresearch> (Last accessed on October 23, 2020, same below)

² Hannah Ritchie, “Half of the world’s habitable land is used for agriculture,” Our World in Data, Nov. 11, 2019 <https://ourworldindata.org/global-land-for-agriculture>

³ “World Livestock 2011 Livestock in food security,” FAO

From the second point of view—environmental protection, meat substitutes are gaining attention for their high production efficiency. In terms of protein conversion efficiency (the amount of protein obtained in relation to the amount of protein supplied), even chicken, the most efficient among all livestock, is at 19.6%, whereas meat substitutes (plant-based meat substitutes, cultured meat) are extremely high at over 70% (Figure 1). Therefore, meat substitutes are considered to be one of the options to obtain higher output (protein) with lower input (protein such as fertilizers, forage, culture medium), without causing much impact on the environment.

Figure 1: Protein conversion efficiency



Source: Prepared by MGSSI based on AT Kearney reports and Our World in Data

A notable new trend is to consider meat substitutes from an animal welfare point of view. From this point of view, the number of livestock animals that can be raised per unit area is now restricted (control on livestock production efficiency). In addition, an increasing number of consumers are avoiding meat which involves animal slaughter. A survey conducted in Germany and France in December 2019 shows that animal welfare and environmental protection rank high among the reasons favoring meat substitutes.⁴

Against this background, plant-based meat is taking the lead as a meat alternative. However, for the procurement of raw materials, particularly soybeans, stable supply is a concern because climate change may affect it. When compared to plant-based meat substitutes, cultured meat has the following advantages: 1) it does not need to undergo a growth process lasting over a couple of years; 2) it is less impacted by climate change because it is artificially produced indoors; and 3) it can be produced anywhere as long as the facilities are in place, regardless of the country or region.

1-2. Meat substitute production process and the current status of market entrants

As previously mentioned, there are two types of meat substitutes at present: plant-based meat and cultured meat. Plant-based meat substitutes are produced by cooking existing protein-rich plants, such as soybeans, and then extruding them into a meat shape. For companies, the hurdles to entry into this business are considered low because reusing existing technologies and facilities make production possible. Beyond Meat, a US startup producing plant-based meat substitutes, became listed in 2019 and started selling its products to Starbucks in China. Another US company, Impossible Foods, provides its products at more than 1,000 restaurants and other businesses in the entire country. Other food giants such as Nestlé (Switzerland), Kellogg's (US), and Tyson Foods (US) have also entered or announced their entry into the plant-based meat substitute business. This field is now the focus of attention among not only food companies but also chemicals manufacturers. In Japan, Shin-Etsu Chemical has entered into the manufacturing of additives used for processing plant-based meats. There are still many challenges, such as recreating the taste and texture of meat and exploring product line-ups (at present, only chicken nuggets and hamburgers are available). Nonetheless, the technology has achieved a level where production volume can meet market demand and the products can meet market needs. As more improvements are made, further market penetration is expected in the future.

Cultured meat refers to meat produced by using artificial cell culture. It is made by growing master cells produced by collecting samples from cattle, pigs, and other livestock. The meat is artificially produced: Except for when cells are collected, existing livestock is not used in the production processes. Cultured meat is seen as a new field in food products, where livestock meat is recreated without killing farm animals. On the back of this, the number of startups involved in development of cultured meat is rising year after year and has now reached 60 as of June 2020, compared to four or so in the world in 2016.⁵

⁴ Hanna L Tuomisto (2019) "The eco-friendly burger," EMBO Rep 20 e47395

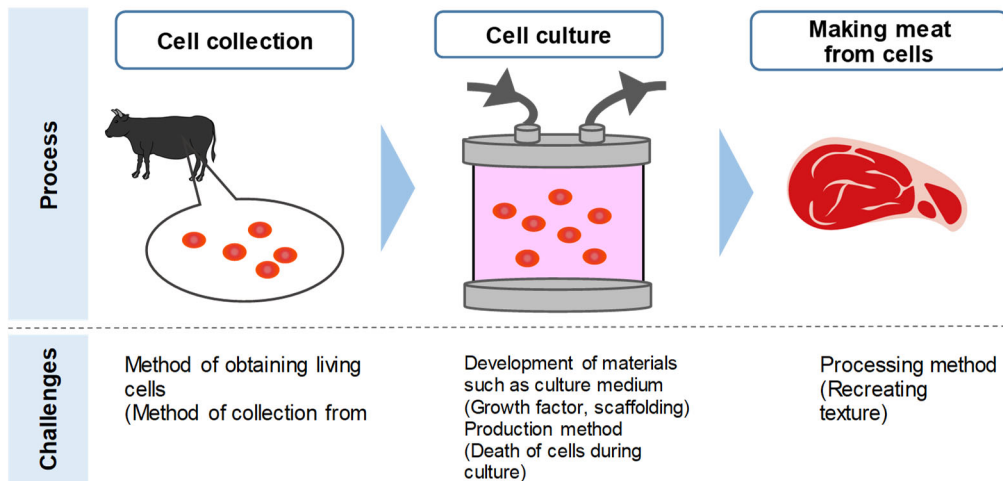
⁵ Christopher Bryant, Lea van Nek, and Nathalie C. M. Rolland "European Markets for Cultured Meat: A Comparison of Germany and France," Foods 2020, 9(9), 1152

2. TECHNOLOGICAL CHALLENGES AND ADVANCEMENT IN CULTURED MEAT PRODUCTION

2-1. Technological challenges in cultured meat production

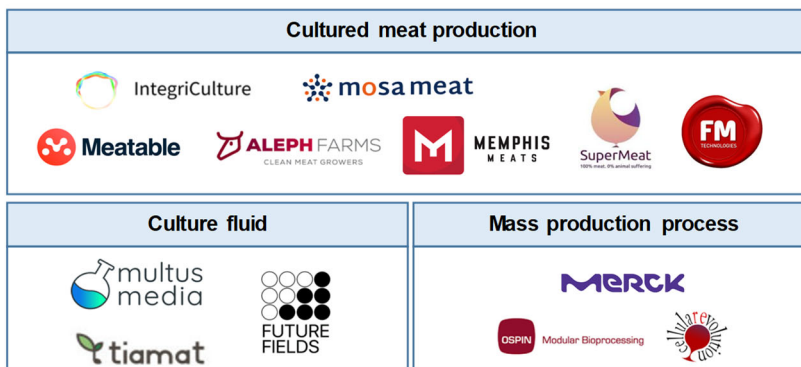
Cultured meat entails issues such as meat safety and consumers' acceptability. On top of such issues, there are still some production technology challenges to be addressed in order for cultured meat to go on the market. The production process for cultured meat can be divided into three parts: cell collection, cell culture, and cultured meat production and at each of the parts, the challenge lies in the method. At cell collection, the method of obtaining living cells; at cell culture, the method of developing and mass-producing culture medium and other materials; and at cultured meat production, the processing method (Figure 2). A report by Good Food Institute, a US non-profit organization promoting meat substitutes, and many other materials show that the biggest challenge is the method of developing and mass-producing culture medium.⁶ Even startups developing cultured meat do not carry out the entire process of production. Many companies have come up now that specialize in the method of developing and mass-producing culture medium (Figure 3). This indicates that even though many have pointed out challenges regarding the method of developing and mass-producing cultured fluid, the optimal solution has not yet been found.

Figure 2: Cultured meat production process and challenges



Source: Prepared by MGSSI

Figure 3: Major cultured meat related startups



Source: Prepared by MGSSI. Company logos were taken from their respective websites

2-2. Culture medium development technology

Culture medium generally contains amino acids, vitamins, inorganic salt, glucose, growth factors (hormones), and other nutrients required for cell growth. Of these, growth factors are the most important content of culture medium. It is generally said that cells cannot multiply in the absence of growth factors; therefore, the use of

⁶ “An analysis of culture medium costs and production volumes for cultivated meat,” Good Food Institute

growth factors is essential for existing cell culture. Currently, growth factors are collected from the fetuses of livestock such as cattle and horses but they are difficult to obtain in large quantities, and the purification method is complex and expensive. Although growth factors are already used in the field of pharmaceutical manufacturing, they are costly to use for cultured meat, which should be provided at a lower cost than pharmaceuticals. The high price of growth factors is driving up the cost of the cultured meat itself, and a number of startups are pursuing research and development to solve this problem.

A Japanese startup for cultured meat, IntegriCulture, has successfully made cultured meat without adding growth factors from external sources by building a system that mimic organs in living bodies and then producing growth factors within the system. The company estimates that making cultured meat at 300 yen/kg will be possible after mass production technology is established.⁷ Moreover, Dutch company Mosa Meat has announced having succeeded in developing culture medium with growth factors of non-animal origin, which reportedly reduces production cost to one-eightieth (1/80).⁸

Meanwhile, there are also startups focused only on developing culture medium without producing cultured meat, as previously mentioned. These include Multus Media (UK), Future Fields (Canada), and Tiamat Sciences (Germany). Each of these companies is promoting development to eliminate the growth factors in culture medium or to supply culture medium with growth factors not derived from animals in a stable and affordable manner (Figure 4).

Figure 4: Main Startups Related to Culture Fluid Development

Classification of Companies	Company	Overview
Cultured meat production startups Companies developing culture medium in-house for cultured meat production	IntegriCulture, Japan	Producing growth factors artificially by mimicking organs in living bodies
	Meatable, Netherlands	Using pluripotent stem cells (growth factor substitutes) from cattle umbilical cords
	Mosa Meat, Netherlands	Developing culture medium without animal-based growth factors
Culture medium specialized startups	Multus Media, UK	Producing growth factor substitutes based on yeast cells
	Future Fields, Canada	Producing growth factor substitutes from specific cells through gene editing
	Tiamat Sciences, Germany	Producing plant-based growth factor substitutes

Source: Prepared by MGSSI

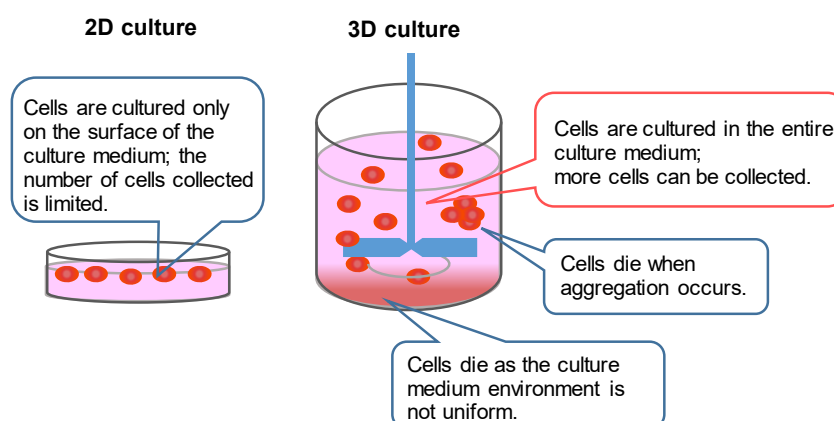
Culture medium is a key ingredient for future cultured meat production. If its low-cost, stable supply is made possible, the supplier will not only connect with many producers in the culture medium market but also have more flexibility in business options. Among them is fables production, which does not require investment in cultured meat production facilities. Companies producing culture medium should be watched most carefully because they are expected to have a huge impact even though they do not directly produce cultured meats.

2-3. Mass production technology

Until now, two-dimensional cell culture using a culture dish has been the most common method for cell culture. However, this method limits the number of cells to be cultured, thus making mass production extremely difficult. This led to the idea of three-dimensional cell culture. With a change from two dimensions to three dimensions, cells can grow in all directions, and mass production is now possible. On the other hand, the challenges have also become clear, and these include cell aggregation and the method of creating a uniform environment (content concentration, temperature, pH, etc.) inside bioreactors. Each cell breathes, but if cells aggregate, they die because they are unable to breathe. Furthermore, if the environment in the bioreactor is not uniform, the cells do not get sufficient nutrition. Too high or too low temperatures make the environment inappropriate for the cells to multiply, and they die (Figure 5).

⁷ IntegriCulture’s business overview <https://www.slideshare.net/YukiHanyu/ss-166477453>

⁸ Michael Wolf, “Mosa Meat Achieves 80x Reduction in Medium Cost For Creating Lab-Grown Meat,” The Spoon <https://thespoon.tech/mosa-meat-achieves-80-reduction-in-medium-cost-for-creating-lab-grown-meat/>

Figure 5: 2D Versus 3D Cell Cultures

Source: Prepared by MGSSI

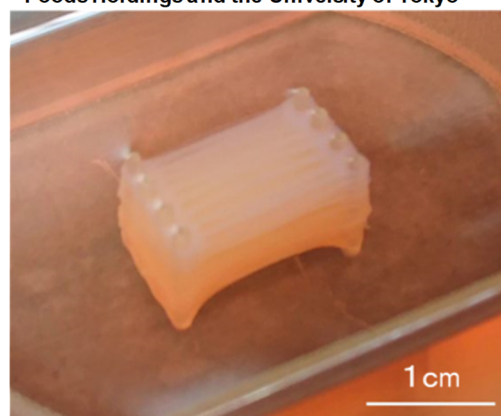
There are four key points to solve these issues and facilitate cell culture: 1) the number of cells in the bioreactor, 2) the number of days to complete culture, 3) the yield per batch, and 4) the amount of culture medium required per batch. To optimize these elements, the Cultivated Meat Modeling Consortium has been established in the US. Formed by startups, major enterprises, and non-profit organizations, the consortium aims to resolve mass-production challenges through computer-based modeling of cell culture technology. Germany's Merck, a world-leading chemical and pharmaceutical company, is part of this consortium. It is anticipated that they provide the scale-up technologies that they have acquired in pharmaceutical manufacturing, in order to gain a foothold in the production of cultured meat using culture technology ahead of others. Mass production of cultured meat requires cell culture at an unprecedented scale, and what is essential is the knowledge of companies that have cultured cells in various fields such as regenerative medicine and food fermentation.

Major food product companies, such as Tyson Foods and Cargill of the US, have also invested in early-stage startups that use culture technology. It can be said that, in the future, food companies, chemical producers, and many enterprises related to foodstuffs will plan to make inroads in the market by scaling up their culture technologies through the leverage of the culture technologies that startups possess.

2-4. Other technological challenges

The texture of meat comes from the tissues contained in the muscles. Cultured meat obtained from the bioreactor does not contain muscle tissues; only paste-like meat cells are currently available. Therefore, as with existing plant-based meat substitutes, cultured meat can only be processed into products that utilize minced meat, such as hamburgers. What is needed to solve this problem is the reproduction of muscle tissue. Studies are underway to develop a technology that can recreate the original texture of meat, such as steak meat, by placing scaffolding (muscle tissue substitute) to which cells are attached in the culture medium. Scaffolding materials include collagen and mushroom fiber. In March 2019, Nissin Foods Holdings, in collaboration with the University of Tokyo, announced that it had succeeded in producing dice steak-shaped bovine muscle tissue (Figure 6).⁹ Although it will take some more time before steak can be recreated, this must be a big step forward. A series of startups emerged that produce mushroom fiber scaffolding: in the US, Matrix Meats and Atlas

Figure 6: Cultured meat developed by Nissin Foods Holdings and the University of Tokyo



Source: Nissin Foods Holdings press release titled "The First Step Toward the Practical Use of 'cultured Steak Meat' with the Original Texture of Meat! World's First Successful Production of Bovine Muscle Tissue in the Shape of a Diced Steak" [in Japanese]

⁹ "The First Step Toward the Practical Use of 'cultured Steak Meat' with the Original Texture of Meat! World's First Successful Production of Bovine Muscle Tissue in the Shape of a Diced Steak" [in Japanese], Press release by Nissin Foods Holdings <https://www.nissin.com/jp/news/7707>

Food were set up in 2019 and 2020, respectively. After mass culture technology is established, scaffolding will be an essential material to increase the use of cultured meat, and as with culture medium, low-cost, stable mass production will be sought for.

3. FUTURE OUTLOOK

Until now, the focus was on the fact that the production of cultured meat had become possible. From now on, there will be demand for a price comparable to that of conventional meat, in anticipation of a rollout in the market. To overcome the challenges faced in the production of cultured meat, startups specializing in developing culture medium have emerged, and large companies with experience in mass production are establishing scale-up technology based on their knowledge. They are likely to speed up their efforts to optimize each process. In such circumstances, it is necessary to pay more attention to companies that have widely acceptable solutions to technological problems throughout the production of cultured meat, such as manufacturing methods and mass-production technologies for key materials like culture medium.

As of 2020, cultured meat is still not sold in the market. Even though Japan's IntegriCulture has conducted a small-scale tasting event for the media, trial sales and other activities still seem distant. In terms of price, cost estimation is currently difficult because the mass production method is not yet established. However, it is predicted that the first product sales will begin in 2022, and by 2026 the price will be competitive with the beef production price (4.5 dollars/kg).¹⁰ If cultured meat is at the same price level as existing beef, it is likely that vegetarians, vegans, and generations concerned about animal welfare will become early adopters. Cultured meat will be widely spread in the market thereafter.

In the future, as large companies enter the market and countries move to establish regulations, cultured meat will gradually be accepted by consumers who value trust and safety. In this context, it is necessary to keep a close eye on how related companies become involved in this field.

¹⁰ "Rethinking Food and Agriculture 2020-2030," RethinkX, Sep.2019