SINGAPORE EMERGING AS A HUB FOR CELLULAR AGRI-FOOD PRODUCTION AND SALES

— TACKLING THE ISSUE OF FOOD SECURITY —

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SUMMARY

- Singapore is promoting the environment development for the production and sales of "novel foods" (foods and food ingredients that do not have a history of being consumed), especially cellular agri-foods to solve the issue of food security arising from the country's 90% reliance on imports for its food requirements due to its scarcity of agricultural land.
- Since cellular agri-food production is a new technology that involves specialized equipment and facilities, it requires substantial amounts of research funding, and government support is essential for its commercialization. Consumer understanding is also vital for the continuation of the business. For this reason, the public and private sectors are working together on research and development to foster the industry's growth.
- Singapore is home to cellular agri-food companies from around the world and is expected to become an important hub for the production and sale of such food in the future.

1. FOOD SECURITY IN SINGAPORE

1-1. Vulnerability of the food supply chain

Singapore relies on imports for more than 90% of its food, with only 1% of its land area devoted to agriculture. As a result, Singapore's food supply chain was disrupted by the COVID-19 pandemic and the conflict in Ukraine, prompting the government to begin efforts to strengthen food security.

1-2. The "30 by 30" policy to strengthen food security

There are three pillars to Singapore's food security policy. The first pillar is the diversification of import sources, the second is the "Grow Local" strategy aimed at achieving the national goal of "30 by 30", which seeks to raise food self-sufficiency to 30% (of which 10% is to be protein) by 2030, and the third is the "Grow Overseas" strategy to support local companies to grow food overseas by migrating farms overseas. Among the three, the "30 by 30" strategy focuses on vertical farming[1] and cellular agriculture. Cellular agriculture is a new production method whereby animal cells are cultivated in vitro to produce a product that is identical to the meat, seafood, or dairy product from which the cells are derived. Products produced using this method include cultivated meat, seafood, and milk. Cellular agriculture has the potential to reduce both environmental impact and costs compared to the existing livestock industry. In addition, it is attracting attention as a technology for producing alternative proteins.

[1] Vertical farming is a new farming technique in which crops are grown on elevated levels or sloping surfaces rather than horizontally in regular fields. This allows higher productivity per acreage land area and more efficient cultivation in multi-story buildings.

2. POLICY ON CELLULAR AGRI-FOOD

2-1. Singapore Food Agency (SFA) policy

The Singapore Food Agency (SFA) expects novel foods (foods and food ingredients that do not have a history of being consumed), including cellular agri-food, to contribute to increasing food self-sufficiency. The agency aims to support the development of new technology while ensuring the safety of novel foods, and to create a mechanism for rapid approval. In addition to working with the Food and Agriculture Organization of the United Nations (FAO) to strengthen the international food security system, the SFA has established cooperative arrangements with Food Standards Australia New Zealand and the French Agency for Food, Environmental and Occupational Health and Safety, which set strict standards regarding food safety. The SFA has also established a regulatory and marketing authorization system to ensure food safety in collaboration with cellular agri-food companies. Moreover, they also launched a system for verifying the safety of food products developed by start-ups conducting pioneering research. Shiok Meats, a local company pioneering the research and development of cultured crustaceans, revealed the SFA's support for the commercialization of cellular agri-foods and for the development of an approval system for novel foods through a public-private partnership[2]. Encouraged by Shiok Meat's efforts, in March 2020, the SFA established a working group on cellular agri-foods made up of domestic and international experts and regulatory authorities, which led to the world's first approval of cultivated meat sales in December 2020.

2-2. Efforts to form a cellular agri-food research hub in Singapore by government agencies

The SFA has launched the Singapore Food Story R&D Programme in collaboration with Singapore's Agency for Science, Technology and Research (A*STAR). As shown in Figure 1, Tier 1 of the program provided support for research in genetics and nutrition, while Tier 2 provided equipment for research and development as well as mass production of cellular agri-food and plant-based meat. In Tier 3, in addition to providing funding to support businesses relating to novel foods, an institute was established, with the participation of Singapore's Nanyang Technological University, to train personnel involved in the research and development of novel food products and to support their commercialization. A*STAR is an organization overseen by Singapore's Ministry of Trade and Industry, established to promote world-class research and human resource development. It promotes projects to develop agri-food production technologies, including for cellular agri-foods. Some researchers have gone on to start their own businesses to produce cellular agri-food products with the support of A*STAR, and details are provided in Figure 6 below.

Figure 1: Government R&D program on cellular agri-food conducted by the SFA and A*STAR – Research environment and funding status

Source: Created by MGSSI based on information on the Agency for Science, Technology and Research (A*STAR) website

[2] Enterprise Singapore (EDB) "Growth Islands: Navigating Regulation with Shiok Meats" Apr 27, 2022 (Accessed Nov 30, 2022, the same hereafter)

3. OUTLOOK AND CHALLENGES FOR THE CELLULAR AGRI-FOOD INDUSTRY

3-1. Benefits of cellular agri-foods

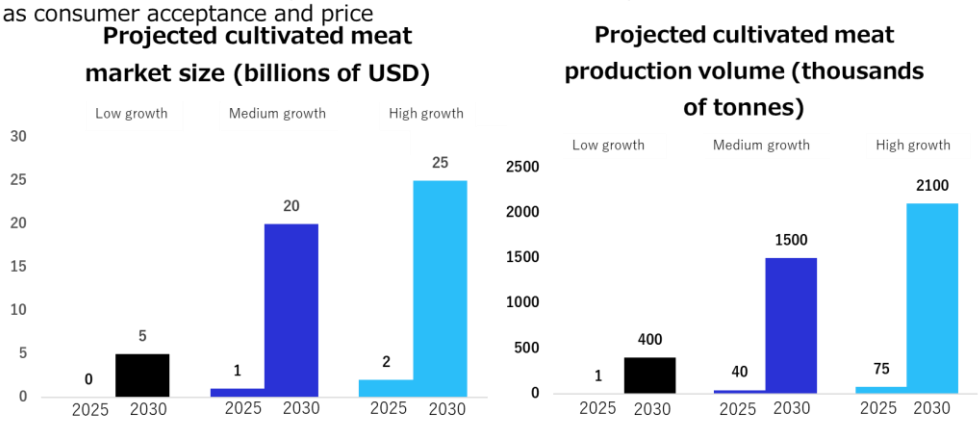
Cellular agri-foods offer commercial advantages over existing livestock and aquaculture operations and are also expected to contribute to the environment. In terms of the commercial advantages, while it takes several months or years to produce a product in the regular livestock and aquaculture industries, production period is reduced to two to eight weeks for cellular agri-foods, allowing for efficient production with low resources and at low cost.

In terms of environmental advantages, for example, cultivated meat can reduce water use by 82-96%, greenhouse gasses by 78-96%, land use by 99%, and energy use by 7-45% compared to existing livestock production[3]. Moreover, because cellular agri-foods do not use hormones or other chemicals, they are expected to lower drug costs and health risks.

zAs shown in Figure 2, McKinsey & Company projects that if cellular agri-foods replace processed and other meat products in some Western and Asian countries, the market size will grow to $20 billion by 2030, and to $25 billion if they spread to other countries with high meat consumption rates[4].

Figure 2: Projected growth of cellular agri-food market

Cultivated meat market expected to reach US$25 billion by 2030 based on factors such as consumer acceptance and price



● **Low growth:** Only processed meat (burgers, sausages, etc.) is replaced by cultivated meat. Markets are limited to North America, the EU, and certain Asia-Pacific countries.
● **Medium growth:** Cultivated meat can replace processed meat and whole-cut meat. Markets are limited to North America, the EU, and certain Asia-Pacific countries.
● **High growth:** Cultivated meat can replace a wide range of processed and whole-cut meats. Can be sold in various countries and regions where meat consumption is high (China, US, EU, Brazil, India, etc.).

Source: "Cultivated meat: Out of the lab, into the frying pan", McKinsey & Company
https://www.mckinsey.com/industries/agriculture/our-insights/cultivated-meat-out-of-the-lab-into-the-frying-pan

3-2. Concentration of cellular agri-food companies

Currently, Singapore is the only country in the world that has approved the commercial production and sale of cultivated meat. The reason that Singapore has become the world forerunner in this field is that, in addition to the SFA-led mechanism for rapid approval, there is no lobbying or other obstruction by livestock industry groups as is the case in the US and the Netherlands. In addition to in-house operations, the production of cellular agri-foods requires outsourcing to a drug contract development and manufacturing organization (CDMO), and, again, Singapore is the only country in the world to have granted approval to a food CDMO company. It is likely that some of the cellular agri-food companies, which are more the 100 companies around the world, will locate in Singapore, in order to commercialize their products.

[3] Tuomisto, H.L et al. 2022. "Prospective Life Cycle Assessment of a Bioprocess Design for Cultured Meat Production in Hollow Fiber Bioreactors", Science of the Total Environment 851, pp.1-11.
[4] Brennan, T. et al. 2021. "Cultivated Meat: Out of the Lab, into the Frying Pan", McKinsey & Company, Jun 16, 2021

Figure 3: Cellular agri-food CDMO companies

Company	Nationality	Established	Profile (business activities, special remarks)
Esco Aster	Singapore	2017	Received approval to produce cultivated meat from the SFA in September 2021 as the world's first cellular agri-food CDMO.
NURASA	Singapore	2021	Formerly the Asia Sustainable Food Platform. An incubator established by the state-owned investment company Temasek with the aim of promoting the commercialization of sustainable food. The Food Tech Innovation Centre (FTIC), which will provide R&D support and pilot-scale facilities to food-related companies, is scheduled for construction in the first half of 2023. Announced in 2021 a three-year investment of S$30 million in FTIC together with A*STAR.
Scale Up Bio	Singapore	2022	Established as a CDMO in August 2022 by grain major ADM and NURASA. Plans to open two food-specific precision fermentation facilities in 2023. One facility will be established with A*STAR's Singapore Institute of Food and Biotechnology Innovation (SIFBI) at the Food Tech Innovation Center in Biopolis to create an environment for research and development by start-ups, and will be capable of handling 100 litres of microbial fermentation and associated downstream purification processes. The other facility will serve as the company's HQ and will be located at the LOGOS Food21 food manufacturing zone. It will be established in the second half of 2023 for the use of novel food-related start-ups worldwide and will have an area of 2,300 cubic meters and a capacity of 10,000 litres of fermentation microorganisms and associated downstream purification processes.

Source: Created by MGSSI based on various media reports

Figure 4 summarizes the scale up trend by Eat Just (US), a pioneer in the production and sale of egg substitutes and cultivated meat, to develop its cultured chicken meat division, GOOD Meat, in Singapore for the establishment of a mass production system. Figure 5 shows the status of Shiok Meats' efforts to reduce the cost of cellular agri-food products as it strategically plans to expand into other Asian countries from its hub in Singapore. If an optimal environment is established in Singapore where cellular agri-food can be obtained at low prices through cost reductions, it can be expected that the country will attract more cellular agri-food companies with an eye on entering the Asian market. In addition to the CDMO-related companies listed in Figure 3, Figure 6 shows the concentration of foreign and local cellular agri-food companies in Singapore, which is expected to bring about economies of scale through the mass production of cellular agri-food products.

Figure 4: Development of Eat Just's GOOD Meat cultivated chicken in Singapore

Date	Activities
Oct 2020	Eat Just builds Asia's first and the world's largest plant for the production of plant-based egg substitutes in Singapore with support from the Singapore Economic Development Board (EDB) using $20 million of a $100 million investment from the investment agency Proterra.
Dec 2020	Eat Just receives approval from the SFA to sell cultivated meat, and launches its cultivated chicken division GOOD Meat in Singapore.
Dec 2020	Cultivated chicken produced by GOOD Meat is served in the 1880 restaurant, the world's first case of the commercial sale of cultured meat.
Apr 2021	1880 begins home delivery of meals containing cultivated meat from GOOD Meat.
May 2022	Enters into a joint development agreement with grain major ADM. This is ADM's first strategic partnership agreement with a cultivated meat company.
May 2022	Announces plans to produce 250,000 litres of bioreactors in collaboration with leading US bioreactor manufacturer ABEC, and to begin producing cultivated meat in the first quarter of 2023.
Jun 2022	Announces its plan to build Asia's largest cutivated meat plant with an annual production capacity of several tens of thousands of pounds (10,000 pounds ≒ 4.5 tonnes) in JTC Bedok Food City, an industrial park developed as a production base for the food industry, by the first quarter of 2023.
Nov 2022	Cultivated meat is served at COP27 in Egypt on November 11, 12, and 14 as part of a project with Enterprise Singapore. The statement that cultivated meat is expected to contribute to the reduction of greenhouse gas in the 2022 report of the UN Intergovernmental Panel on Climate Change (IPCC) prompts the company to hold a tasting event at COP27. This is the first attempt to serve cultivated meat outside of Singapore.

Source: Created by MGSSI based on various media reports and information on company websites

Figure 5: Shiok Meats' efforts to reduce the cost of cellular agri-food

Date	Details of efforts
Aug 2018	Established as a cell cultivated food company focused on crustaceans
Apr 2019	Introduced cultivated shrimp. The cost of producing eight cultivated shrimp dumplings was USD4,000-5,000
Dec 2019	Reduced cost of cultivated shrimp to USD7,000 per kilo and USD300 per shrimp dumpling
Sep 2020	Raised USD12.6 million in a Series A round to fund R&D and construction of a production facility over the following three years
Nov 2020	Announced production of the world's first cultured lobster prototype
Aug 2021	Purchased cultured meat company Gaia Foods (acquiring more than 90% of shares), and announced its intention to enter the Asian market by developing a wide variety of products incorporating cultured red meat and cultured seafood. Announced production of cultured crab meat by holding tasting events for interested parties.
Nov 2021	Set up a mini factory at Singapore's food accelerator Innovate 360 facility.
Aug 2022	Declared that the cost of cultured shrimp has been reduced to USD50 and production scale will be expanded.

Source: Created by MGSSI based on various media reports and information on company websites

Figure 6: Cellular agri-food companies based in/with a base in Singapore

Company	Nationality	Established	Profile (business activities, special remarks)
Eat Just	US	2011	The company's egg substitute JUST Egg is its flagship product. Worked in collaboration with the Singapore Economic Development Board (EDB) and the SFA from 2019, and announced the construction of Asia's first alternative protein production facility in October 2020. It's GOOD Meat division began selling the world's first cultivated meat in December 2020.
Perfect Day	US	2014	Produced animal-free milk protein using microorganisms. Established the A*STAR Perfect Day Joint Lab, a joint research facility with A*STAR, in April 2021.
Mosa Meat	Netherlands	2016	In 2013, introduced the world's first hamburger made from cultivated meat. The company has since been engaged in research and development of cultivated meat at its hub in the Netherlands, making it possible to produce the equivalent of 80,000 hamburgers from cow cells the size of sesame seeds. On November 3, 2022, it announced that it will build a production plant in Singapore in collaboration with Esco Aster with the aim of commercializing its cultivated meat business.
Avant Meats	Hong Kong	2018	Gained the support of the EDB in April 2021, and established a joint research laboratory in Singapore with A*STAR's Bioprocessing Technology Institute (BTI) in September of the same year. Aims to commercialize its cultured fish meat by 2023.
Shiok Meats	Singapore	2018	Developed cutivated crustaceans (shrimp, lobster, crab). By cultivating crustacean meat, the company aims to reduce the environmental impact of aquaculture and achieve efficient production. Acquired cultivated meat company Gaia Foods. Since its inception, has worked with the SFA to develop a regulatory and supervisory system for cellular agri-food products. A founding member (March 2022) of the Asia-Pacific Society for Cellular Agriculture (APAC-SCA) and was instrumental in bringing the society to Singapore.
Turtle Tree	Singapore	2019	Developed an infant milk formula made from cultivated cow cells that is almost identical in composition to human breast milk. Aims to expand into the Asian market. Plans to apply its product to nutritional food for the elderly, cancer patients, and others with reduced physical strength and immunity.
GOOD Meat	Singapore	2020	The cultivated meat manufacturing division of the US company Eat Just. Began selling the world's first cultivated chicken after receiving approval from the SFA in December 2020. Plans to significantly expand production volume in 2023.
Umami Meats	Singapore	2020	A start-up that develops cultivated seafood such as eel, yellowfin tuna, and sea bream cultivated from stem cells. It is developing cultivated fish meat that is free from marine pollutants (microplastics) found in fish caught in the wild and is also targeting species of fish that are difficult to catch or farm.
Ants Innovate	Singapore	2020	A cultivated meat start-up company supported by A*STAR and composed of faculty and researchers from the National University of Singapore. It pursues the appearance, flavor, and texture of cultivated meat. Plans to build a laboratory and pilot plant in Bedok Food City similar to the GOOD Meat food manufacturing facility constructed in 2022. Presented NouMi, a brand of cultured meat at the prototype stage, at an exhibition in October 2022.
Fisheroo	Singapore	2021	A local start-up that researches and develops cultivated fish meat for sale as ground fish paste.
Meatiply	Singapore	2021	A start-up company based at the National University of Singapore that conducts research and development of cultivated meat from chickens, ducks, and pigs. Some of the founding members are researchers who received A*STAR scholarships, and the goal is to commercialize its product in 2024.
ImpacFat	Singapore	2022	A start-up company pursuing the commercial production of cultivated fish fat. A finalist in The Liveability Challenge 2022, Asia's largest public challenge to find solutions through advanced environmental technologies, sponsored by the Temasek Foundation. Founded by Shigeki Sugii, principal investigator at A*STAR's Institute of Molecular and Cell Biology (IMCB)

Source: Created by MGSSI based on various media reports and information on company websites

3-3. Risk management and legislation to ensure food safety

Companies involved in cellular agri-foods are working with regulatory authorities such as the SFA to promote consumer understanding of the safety for cellular agri-food products. In March 2022, companies in the industry from around the world gathered to launch the Asia-Pacific Society for Cellular Agriculture (APAC-SCA) in Singapore. The society works to create standards for cellular agri-food safety, and advises the Singapore government as well as the relevant authorities in other countries on risk management and legislation to ensure food safety.

Figure 7: APAC-SCA member companies

Company	Logo	Established	HQ	Special features
CellX	CellX	2020	China	Shanghai-based cultivated meat start-up utilizing 3D printers to produce cultured meat
Joes Future Food (Zhouzi Weilai)	JOES FUTURE FOOD	2019	China	Based at Nanjing Agricultural University, conducts research and development of cultured meat and introduced China's first cultivated pork belly
Avant Meats	avant	2018	HK	Cultivated fish start-up serving the Singapore and Hong Kong markets
Simple Planet	SIMPLE planet.	2021	S. Korea	Successfully produced cultivated meat with high unsaturated fatty acid content in June 2022
SeaWith	seawith	2019	S. Korea	Start-up developing scaffolds and cell culture media for growing cells from seaweed to reduce the cost of cultivated meat production
DaNAgreen	DaNAgreen	2017	S. Korea	Develops the cells, cell culture media, scaffolds, and bioreactors required for cultivated meat development
Integriculture	IntegriCulture	2015	Japan	Developed the CulNet technology, which creates an environment similar to that of the body to promote cell growth efficiently and cheaply
Gaia Foods	GAIA FOODS	2019	Singapore	Southeast Asia's first cultivated meat company. Acquired by Shiok Meat in 2021
Shiok Meats	Shiok Meats® Seafood, reinvented.	2018	Singapore	Produced the world's first cultivated crustaceans (shrimp, crab, lobster). Aiming for commercialization in 2023
Steakholder Foods	Steakholder FOODS	2019	Israel	Developing cultivated pork using iPS cells. Announced creation of cultured marbled beef using 3D printing technology in September 2022
Aleph Farms	ALEPH FARMS	2017	Israel	A start-up that has also made headlines for producing cultivated meat in space
SuperMeat	SuperMeat	2015	Israel	Announced a partnership with Japan's Ajinomoto in April 2022 to develop cultivated media for cultured meat and its raw materials.

Source: Compiled by MGSSI based on information on the APAC-SCA website. Logos from the APAC-SCA Members page (https://www.apac-sca.org/members)

3-4. Challenges for the cellular agri-food industry in Singapore

While Singapore is currently the only country in the world that has approved the sale of cultivated meat, if other countries follow suit in the future, Singapore's advantage could be diminished. Despite lobbying by livestock industry groups, and other obstacles in the US, industry insiders expect that marketing approval for cultivated meat will be granted there soon. The US Food and Drug Administration (FDA) has already approved the safety of cultured chicken submitted by UPSIDE Foods (US). Approval was granted on November 16, 2022, and the company is expected to begin marketing the product in the US once the United States Department of Agriculture

(USDA) approves the operation of its manufacturing facility and food labeling. In terms of investment in cellular agri-food companies in 2021, the $700 million and $500 million investments by the US and Israel, respectively, far outstrip Singapore's $41 million input[5]. The Israeli government has invested $18 million in cultivated meat research, and senior government officials have expressed active support. Some Israeli companies have already established manufacturing bases. Furthermore, GOOD Meat's announcement to build a manufacturing plant in Qatar has also raised interest in cellular agri-foods in the Gulf countries, which, like Singapore, have low food self-sufficiency and limited scope for producing food locally. Thus, there is a risk that companies may leave the small country of Singapore if larger cellular agri-food production and sales clusters are established in other countries.

Because cellular agri-food production is a new technology that involves specialized equipment and facilities, it requires enormous amounts of research funding. Since commercialization will require continuous financial support and the development of an R&D environment, government support is also essential. Reducing the high cost of culture media is also an issue, and it will be important to promote research and development on the production of culture media[6].

Consumer understanding is also indispensable for the continuation of the business. Studies have shown that Singaporeans, as a nation, have the desire to be pioneers in any field, and that they are more accepting of cellular agri-foods produced using pioneering technology than Americans.[7] For this reason, consumer understanding is more readily obtainable in Singapore. The key for business to grow forward will be providing consumers with safe and secure food products.

4. CONCLUSION

Singapore has introduced its "30 by 30" policy to strengthen food security and is focusing on locally produced novel foods, especially cellular agri-foods. Providing safe and secure cellular agri-food products requires, among other things, advanced technology and equipment, significant R&D expenditure to achieve commercialization, the development of regulations and evaluation standards, and consumer understanding. The country's public and private sectors are working together on research and development to this end. Singapore is expected to continue developing as a hub for cellular agri-food production and sales.

[5] The Good Food Institute, "Cultivated Meat and Seafood", 2021 State of the Industry Report

[6] Swartz, E. "Cell Culture Media and Growth Factor Trends in the Cultivated Meat Industry"The Good Food Institute, Sep 2021

[7] Chong, M. et al.2022. "A Cross-country Investigation of Social Image Motivation and Acceptance of Lab-Grown Meat in Singapore and the United States" Appetite, Vol. 173. pp.1-9.