



Cultivated Meat in Singapore: The Road to Commercialization

Kit Lim LW*

Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Malaysia

***Corresponding author:** Leonard Whye Kit Lim, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia, Email: limwhyekitleonard@gmail.com

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Abstract

Cultivated meat is meat produced from animal stem cells, outside of the animal, under controlled laboratory conditions. It is deemed as one of the most promising protein production alternatives that protects the welfare of animal, environment as well as human, without compromising the conventional sensory of animal meat. The Singapore Food Agency is the first regulatory authority in the world to approve the vending of cultivated meat in December 2020. Since then, a number of start-ups have emerged to provide consumers with a myriad of dishes and delicacies produced from cultivated meat. In the review, the potentials of all available cultivated meat products in Singapore were presented. Furthermore, the challenges and limitations of this industry were briefly highlighted and discussed. Finally, the future perspectives of this industry have been included to drive future researches and endeavours. It is hoped that this industry can boost the country's economy and provide sufficient job opportunities post pandemic, without having to compromise the betterment of our environment.

Keywords: Meat; Lab-Grown Meat; *In Vitro* Meat; Cultivated Meat; Cell-Based Meat

Introduction

The cultivated meat (also going by the name of clean meat, lab-grown meat, in vitro meat and cell-based meat) is one of the novel protein sources established when the world is in the midst of searching for alternative protein sources such as plant, insects and cellular agriculture. One great advantage the cultivated meat has over all alternative protein sources is none other than the conventional sensory of animal meat as well as its nutritional contents, as these are cultured directly from animal cells (outside of the animal) in a growth medium filled bioreactor [1]. Besides, the production of these cultivated meat is wholly in vitro, which indirectly means the significant alleviation of the global environmental water and carbon footprints from animal farming [2].

The first regulatory authority across the globe to permit the vending of cell-based meat products (bite-sized chicken) is the Singapore Food Agency (SFA) in December 2020 [3]. A California start-up, Eat Just was the one that gained the approval to produce Good Meat cultivated chicken for sale in a JW Marriott Singapore South Beach Cantonese restaurant and via foodpanda food delivery platform [3]. Esco Aster had supported Eat Just through their supply of technology and tools, mainly the bioreactor, and their production design complied strictly to the SFA regulations for food production (in terms of production method safety and food safety risks like toxicity) [3]. All in vitro meats must undergo safety assessment before they are allowed to be traded.

In this review, the fundamental concepts of clean meat production were first covered. Then, we explored the various

cultured meat products available in the Singapore markets and their potentials. Next, we looked into the challenges and limitations faced in the sale of these lab-grown meats. Lastly, we ventured into the future perspectives of this industry before concluding.

Cultivated Meat Production

The fundamental concepts of cultivated meat production were built on tissue engineering. This technology is not a novel one, and it is used widely on medical implementations, to name a few, on regenerative medicine, drug development and toxicology research [4]. First, stem cells are harvested from embryos or muscle tissues of the host animal before expanding and differentiating them into muscle cells [4,5]. Small scale clean meat production can be conducted in a culture plate or flask supplied with growth medium under controlled conditions in an incubator [5,6]. Large scale cultured meat production involves one additional step, which is the incubation of muscle cells in a bioreactor where the cells multiply and eventually they are transferred to a scaffold or matrix to further grow into larger tissue and muscle fibers.

Current Cultivated Products in Singapore and Their Potentials

There are several start-ups in Singapore that had started to sell their products to restaurants and via food delivery platforms, such as Umami Meats, Gaia Foods, Shiok Meats and Sing Cell (Table 1). Some of the major clean meat produced are pork, crab, fish, lobster, shrimp, dairy products and chicken.

Eat Just is a California start-up that (first in the world) received the green light to sell lab-grown meat in Singapore under their brand Good Meat. The first Singapore restaurant to offer a venue for the sale of this product was 1880. Not long after, Eat Just gained extra approvals for various in vitro chicken products, namely tenders, chicken breast and shredded chicken. This start-up had not only served 700 Singaporeans to date but also had spent over \$267 million of capital increment on systems and vessels building that will scale up production in both Singapore and the United States. With investors pouring in over \$2 billion between 2020 and 2022, Eat Just aimed to attain approval from the Department of Agriculture and Food and Drug Administration in the United States as early as end of 2023.

Ants Innovate has 18 years of precision tissue engineering experience before stepping into the cultured meat industry.

The generation of GMO-free pig muscle cells has been their focus since 2017 [7]. They patented novel scaffold technology for cell culture later that year before attaining A*STAR patents and creating their first meat snack prototype from slice pork cuts. Currently, they are focusing on filing intellectual property protection for tissue building block technology [7]. ProCYTE is a cultivated meat product from Cellivate Technologies. During the 2020 Asia-Pacific Agri-Food Innovation Summit, its founder and CEO, Dr Viknish Krishnan-Kutty made a speech about their confidence in making these cells accelerate in growth multiple times and at the same time minimizing the media usage and overall cost [8].

Shiok Meats offer a variety of cultivated meat products ranging from chicken to lobster, shrimp and crab. One signature product from Shiok Meats is the shrimp dumpling or more widely known as "Siew Mai", launched in March 2019 [9]. Besides, they have also launched the world's first cell-based lobster meat product in late 2020. The versatility of their cell-based seafood was presented through a myriad of dishes invested using creativity and innovation. Some of the seafood dishes available are Shiok shrimp and beet spheres (root vegetable infused broth with Shiok shrimp flavouring), Shiok lobster gazpacho (blend of tomatoes, leeks, red peppers, cucumbers, and extra virgin olive oil with Shiok lobster flavouring), as well as terrine of Shiok lobster (Shiok lobster blended with plant-based meat, served on a crostini with Shiok lobster mayonnaise) [9]. The feedback from the tasting event was mainly positive and the major praise point is on the umami flavours unleashed. Commercialization of these clean seafood will be realised by 2023 [9].

SingCell is a contract development and manufacturing company (CDMO) that offers clean meat in the form of adipose fat cells, myoblasts, mesenchymal stem cells and fibroblasts. Their current research and development is to produce automated scalable bioreactor that is capable of elevating cell count and viability for the goal of cost reduction [10]. Turtle Tree Labs secured a \$30 million fund raiser in 2021 to launch their cell-based milk products in the United States via multiple business to business partnerships. Commercialization of these cell-based dairy products was targeted within the next four to five years [11]. Umami Meats had recently closed a \$2.4 million pre-seed investment round in March 2022 [12]. This start-up is focusing on a myriad of cultured fish and seafood varieties. Besides improving their clean seafood maturing processes, they are actively conducting product demonstrations and taste tests to increase brand awareness [12].

Company	Focus	Total disclosed funding (\$M) in 2020	Founder(s)	Year founded
Ants Innovate	Full stack	-	Henry Yu, Shujian Ong	2020
Cellivate Technologies	Cell culture media	-	Viknish Krishnan- Kutty, Thirumalai Venkatesan	2019
Gaia Foods	Full stack	\$0.13	Vinayaka Srinivas, Hung Nguyen	2017
Shiok Meats	Full stack	\$20.30	Sandhya Sriram, Ka Yi Ling	2018
SingCell	Bioprocess design	Undisclosed	Karolis Rosickas, Steve Oh, Colby Colasanto	2020
TurtleTree Labs *DAIRY*	Full stack	\$9.47	Fengru Lin, Mkulima Britt, Max Rye	2019
Umami Meats	Cell lines, cell culture media	-	Mihir Pershad	2020

Table 1: The list of Singapore start-ups involved in the cultivated meat production and sale in 2020 [13].

Challenges and Limitations of the Cultivated Meat Industry

Some of the major challenges of the cultivated meat industry are production costs, cell line quality control, and consumer acceptance. One of the major production costs comes from the growth media, and the conventional growth media still necessitates animal source material such as the fetal bovine sera. Scientists have worked towards the formulation of cheaper and animal-free growth media that would not compromise the normal cell growth and at the same time provides additional enhancement in terms of nutrients and cell growth elevation [14,15]. The cell line quality control is imperative to avoid the resultant unstable genetic content leading to undesirable functional and phenotypic variations. To solve this predicament, periodical quality control measures such as single cell sequencing are necessary to ensure the genetic stability of these cell lines [16]. The consumer acceptance and social image motivation are other challenges to the cultivated meat industry. Interestingly, a cross-country investigation across Singapore and the United States revealed that Singaporeans have shown stronger social image eating motivations and greater acceptance of cell-based meats [1]. These traits are believed to be contributed by the Singaporean's kiasuism (fear of being left behind) and 'trailblazers' (vis-a-vis other nationalities) cultures [1].

Several main limitations and downsides of the cultivated meat industry has been highlighted by scientists like Roy, et al. [17] and Treich [4], namely the high energy consumption, carbon dioxide emission, ethical issues as well as effect on health. Cultured meat production requires at least 32710 MJ of energy (constant electricity) to keep the bioreactor running albeit its minimal land usage, this amount is 1.4, 1.2 and 2-fold more than the electricity sheep (23100 MJ), beef

(27410 MJ) and pork (16300 MJ) farming utilized [17-19]. Moreover, the carbon dioxide amount produced from cell-based meat production is much higher than the methane synthesized from conventional farming and the period for these carbon dioxides to fully dissolve is longer comparatively [20]. To minimise the adverse effects of clean meat production to the environment, green energy is the proposed solution coupled with proper carbon dioxide gas conversion prior to release into the atmosphere. The use of fetal bovine sera in clean meat production has raised ethical issues as the bovine fetuses are obtained by the slaughtering of the pregnant cows [21]. Besides, the growth factors included in the growth medium of the in vitro meat production may impact human health in the long run [17]. The latter two limitations can be solved with the halt of utilizing fetal bovine sera in clean meat production and replace the growth medium with plant-based and animal-free medium.

Future Perspectives

In 2021, FAIRR Initiative named 2021 as the year of cultivated meat as a total of \$506 million were invested globally into the clean meat firms, surpassing the past years [22]. This amount is a sixfold increment from 2020 [22]. This clean meat drive has been supported by celebrity investors like Leonardo DiCaprio, and industry giants like Tesco has made a commitment to opt for 3 times increment in meat alternatives sales by 2025 [22]. A study by Oxford Economics [23] uncovered that UK economy could receive a boost of £2.1 billion revenue and 16,50 jobs by 2030 from the cultivated meat industry alone. As mentioned in the previous sections above, the clean meat industry in Singapore is on an exponential growing trend. A number of start-ups such as Shiok Meats and TurtleTree Labs are preparing for commercialization of their products within a five-year window. One of the Shiok Meats co-founder, Sandhya Sriram

envisioned that people can grow meat at home within a decade [24].

The future of the cultivated meat production industry in Singapore is comparably promising and rewarding. Having the world's first advantages of SFA sale approval and high consumer acceptance rate, Singapore will rise as a hub for the world's leading clean meat and seafood producer in the near future. As the production costs decrease gradually with the scaling-up and alternative (plant-based and animal-free) growth media application, cultivated meat will be very competitive against conventional meat and even plant-based meat products. The production of seasonal, high value, unbreedable and near extinct seafood such as the empurau fish, unagi, salmon, striped catfish and groupers will be made possible with cultured meat to satisfy the increasing consumer demands [25-27]. And of course, with great power comes great responsibility, the advancement of this industry must be accompanied by the care for the environment. Ergo, green energy and waste gas release regulations must be implemented to the in vitro meat production industry, so that our main goal of employing cultivated meat to save the environment will not be corrupted.

Conclusion

In a nutshell, the potential of the cultivated meat industry in Singapore particularly is limitless. The sky is the limit when it comes to the creativity and innovation of Singaporean in creating dishes and delicacies from the cultivated meat and seafood. The exponential growth of this industry will make growing meat at home a reality in no time, strengthening the food security globally. There are no qualms that this industry will continue to flourish and bloom exponentially in the coming decade in Singapore. At the same time, food risk and environmental impact regulations and policies must be imposed to these industries in order to gain consumer trust and acceptance globally.

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