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Promoting and Regulating Cellular Agriculture in Malaysia and Indonesia: Analysing the Adequacy of the Regulatory Framework

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Abstract

Cellular agriculture is a nascent manufacturing technology that holds significant potential to strengthen global food security. Globally, the number of food manufacturing companies producing food using cellular agriculture is rapidly increasing. Products of cellular agriculture are also available for consumers in the marketplace. Hence, the objective of this study is to analyse the extent to which the food regulatory framework in Malaysia and Indonesia is ready to promote and regulate products and activities of cellular agriculture. The analysis is essential as cellular agriculture poses opportunities and regulatory challenges. Despite the benefits, it also poses potential safety and health risks to the consumers, owing to its novelty. This study adopts a doctrinal legal analysis by analysing the adequacy of the current food regulatory framework, i.e., national food policies and legislation in Malaysia and Indonesia. It is found that cellular agriculture is not part of the national food policy and food regulatory framework in Malaysia and Indonesia. Both jurisdictions are lacking regulatory preparedness to embrace the presence of products of cellular agriculture in the marketplace. Hence, there is a need to reform the current food regulatory framework. Such reform includes the formulation of national policy for cellular agriculture to promote the adoption

of cellular agriculture in food manufacturing. The current food safety legislation also needs to be amended to incorporate the provisions to regulate the safety aspects.

Keywords
Cellular Agriculture, Food Security, Food Safety Law, Food Technologies, National Polic.

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Introduction

The rapid growth of the world population challenged traditional agriculture, as population growth is far greater than the volume of food produced using traditional methods. The growth of traditional agriculture has significantly stalled, with only a 1% increase in a year, much lower than the world's population growth.[1] Additionally, the world is also experiencing unprecedented levels of global warming. It is largely driven by intensive livestock production, which accounts for about 20% of anthropogenic greenhouse gas emissions.[2] Consequently, global warming has resulted in reductions in crop yields.[3] According to the Food Agriculture Organization (FAO), climate change reduced global average crop yields between the year 2000 and 2019 by approximately 0.1 t/ha, which exceeds 10 percent of the average observed yield during that period.[4] It is also estimated that feeding the world population of 9.1 billion people in 2050 would require raising overall food production by some 70%.[5] To meet the demand, novel and advanced technology is integrated into the food manufacturing industry.

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1 Hemathilake, D.M.K.S., and D.M.C.C. Gunathilake. "Agricultural Productivity and Food Supply to Meet Increased Demands." *Future Foods*, 2022, 539–53. https://doi.org/10.1016/b978-0-323-91001-9.00016-5.

2 Xu, Xiaoming, Prateek Sharma, Shijie Shu, Tzu-Shun Lin, Philippe Ciais, Francesco N. Tubiello, Pete Smith, Nelson Campbell, and Atul K. Jain. "Global Greenhouse Gas Emissions from Animal-Based Foods Are Twice Those of Plant-Based Foods." *Nature Food* 2, no. 9 (September 13, 2021): 724–32. https://doi.org/10.1038/s43016-021-00358-x.

3 Liu, Rong, Yiyun Hu, Xiangsheng Zhan, Jiawang Zhong, Peng Zhao, Hao Feng, Qin'ge Dong, and Kadambot H.M. Siddique. "The Response of Crop Yield, Carbon Sequestration, and Global Warming Potential to Straw and Biochar Applications: A Meta-Analysis." *Science of The Total Environment* 907 (January 2024): 167884. https://doi.org/10.1016/j.scitotenv.2023.167884.

4 Food and Agriculture Organization. (n.d.). Linking Climate Change to Agricultural Production Loss. Food and Agricultural Organization. https://www.fao.org/4/k2595e/k2595e00.pdf

5 Food Agriculture Ogranisation. (2009). Global agriculture towards 2050 (High Level Expert Forum). https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

Cellular agriculture is one of the promising technologies in food science that could stabilise global food production.[6]

Cellular agriculture allows food manufacturers to produce food based on in vitro cell cultivation techniques using bioreactors in a laboratory or factory instead of growing or slaughtering animals.[7] Advancements in this area of food innovation are being driven by a range of technologies, including molecular biology, synthetic biology, and tissue culture.[8] Globally, leading food manufacturing companies such as Nestlé, Maple Leaf Foods, Bell Food Group, Tyson, Cargill, Thai Union, and Pulmuone have started to invest in the cellular agriculture industry.[9] According to Strait Research, a globally recognized market research and market intelligence organization, by 2030, the global market for cellular agriculture is expected to reach USD 515.24 billion, growing at a CAGR of 16.2% during the forecast period (2022–2030).[10] The market's trajectory strongly suggests a surge in both the volume and demand of food products derived from cellular agriculture, signalling significant growth in global consumption patterns.

Likewise, Malaysia also contributed to the growth of the global market for cellular agriculture by embarking on the journey of utilising cellular agriculture in food manufacturing. Cell Agritech is a local

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6 Nyika, Joan, Joby Mackolil, Endashaw Workie, Chaitanya Adhav, and Sendhil Ramadas. "Cellular Agriculture Research Progress and Prospects: Insights from Bibliometric Analysis." Current Research in Biotechnology 3 (2021): 215–24. https://doi.org/10.1016/j.crbiot.2021.07.001.

7 Räty, Niko, Hanna L. Tuomisto, and Toni Ryynänen. "On What Basis Is It Agriculture?" *Technological Forecasting and Social Change* 196 (November 2023): 122797. https://doi.org/10.1016/j.techfore.2023.122797.

8 Eibl, Regine, Yannick Senn, Géraldine Gubser, Valentin Jossen, Christian van den Bos, and Dieter Eibl. "Cellular Agriculture: Opportunities and Challenges." Annual Review of Food Science and Technology 12, no. 1 (March 25, 2021): 51–73. https://doi.org/10.1146/annurev-food-063020-123940.

9 Howard, Philip H. "Cellular Agriculture Will Reinforce Power Asymmetries in Food Systems." *Nature Food* 3, no. 10 (October 18, 2022): 798–800. https://doi.org/10.1038/s43016-022-00609-5.

10 Straits Research. (2022). Cellular Agriculture Market Size, Share & Trends Analysis Report by Product (Tofu, Tempeh, Seitan, Quorn, Other), by source (soy protein, wheat protein, pea protein, other), by type (isolates, concentrates, textured) and by region (North America, Europe, Apac, Middle East and Africa) *Forecasts*, 2022-2030. https://straitsresearch.com/report/cellular-agriculture-market.

company pioneering in cellular agriculture that will revolutionise domestic meat production. In early 2023, the company started growing fish and eel meat in the laboratory. It is expected that the cultured meat can be harvested in two years and be available for domestic consumption.[11] Additionally, at the time of writing, no such meat products have entered the domestic market. Meanwhile, Indonesia is still in the early stages of exploring cellular agriculture. The country has not yet produced any products from cellular agriculture. The absence of such products in the Malaysian and Indonesian markets mainly contributed to the infancy and immaturity of cell-cultured technology. This study contended that the insufficiency of the regulatory framework to promote and regulate products derived from cellular agriculture has also collectively constrained the market's entry and consumers' acceptance.

Nevertheless, research on cellular agriculture has begun to be developed. While countries like Malaysia and Indonesia are making progress, several Asian nations are ahead in certain areas. For example, Singapore became the first country in the world to approve the commercial sale of cultured meat in December 2020, which represents an important turning point in the development of cellular agriculture and its goal of ensuring long-term food security.[12] In addition, both China and Japan recognised cellular agriculture in 2020 as a key strategy to improve the sustainability and resilience of their food supplies.[13] This highlights that these countries are pushing the boundaries of innovation in ways that set them apart in the region.

Although several countries in Asia, such as Singapore, China, and Japan, have made significant progress in the field of cellular agriculture, major challenges remain, particularly related to regulation. According to

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[11] Thian., S. Y. (2023, June 28). Capable of mass production: Industry collaboration to to scaling cultivated meat- Malaysia's Cell Agritech. *Food Navigator*. https://www.foodnavigator-asia.com/Article/2023/06/28/Malaysia-s-Cell-AgriTech-Industry-collaboration-key-to-scaling-cultivated-meat

[12] Ho, Shirley S., Stanley Arvan Wijaya, and Mengxue Ou. "Examining Muslims' Opinions Toward Cultured Meat in Singapore: The Influence of Presumed Media Influence and Halal Consciousness." *Science Communication* 46, no. 2 (February 28, 2024): 151–77. https://doi.org/10.1177/10755470231225684.

[13] ProVeg. (2022). Cellular agriculture: A general introduction. *ProVeg*. https://corporate.proveg.com/wp-content/uploads/2022/03/ProVeg_Cell-Ag_GeneralIntro_2022_V2.pdf

Johnson, the regulatory framework these products will confront is still uncertain. Products of cellular agriculture present various regulatory questions, inter alia, safety oversight, labelling, and consumers' right to choose.[14] Furthermore, policy, regulation, and legislation have yet to engage with cellular agriculture.[15,16] Meanwhile, Miyake and others[17] contended that regulation is the basis for developing cellular agriculture.

Furthermore, the swift rise of cellular agriculture in the food manufacturing industry has generated mounting safety and regulatory concerns. While technology promises a sustainable solution to food security issues, it simultaneously raises scientific uncertainties about the potential adverse effects on safety and health. Additionally, it is uncertain whether the existing food regulatory framework in Malaysia and Indonesia is sufficient to regulate the activities and products of cellular agriculture. The subsequent subtopics will analyse in detail the benefits and risks of cellular agriculture as well as the food regulatory framework in both jurisdictions. In this context, the urgency of the present study is underlined by three philosophical reasons.

First, demand for a novel and sustainable food processing technique to strengthen the food security provisions as mandated by the United Nations Sustainable Development Goals. Next is to exercise precaution against potential safety and health risks associated with products of cellular agriculture. A comprehensive and suitable regulatory

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[14] Bakhsh, Allah, Bosung Kim, Ismail Ishamri, Seongho Choi, Xiangzi Li, Qiang Li, Sun Jin Hur, and Sungkwon Park. "Cell-Based Meat Safety and Regulatory Approaches: A Comprehensive Review." *Food Science of Animal Resources* 45, no. 1 (January 2025): 145–64. https://doi.org/10.5851/kosfa.2024.e122.

[15] Sanchez, A. (2018) Laws and Regulations Concerning Cell-Cultured Meat and Cellular Agriculture. Food and Drug Law Institute. https://www.fdli.org/2018/02/update-laws-regulations-concerning-cell-cultured-meat-cellular-agriculture/

[16] Helliwell, Richard, and Rob J.F. Burton. "The Promised Land? Exploring the Future Visions and Narrative Silences of Cellular Agriculture in News and Industry Media." *Journal of Rural Studies* 84 (May 2021): 180–91. https://doi.org/10.1016/j.jrurstud.2021.04.002

[17] Miyake, Yoshitaka, Masashi Tachikawa, and Ryo Kohsaka. "Policy Frameworks and Regulations for the Research and Development of Cell-Based Meats: Systematic Literature Review." *Food Research International* 167 (May 2023): 112599. https://doi.org/10.1016/j.foodres.2023.112599.

framework enables the regulators to take pre-emptive measures in protecting consumers against the adverse effects.[18] Lastly, as compliance with the principle of consumer protection. The Association of Southeast Asian Nations (ASEAN) has considered consumer protection as an integral part of a modern, efficient, effective and fair marketplace. This study supports the ASEAN consumer rights on the right to safety, the right to be informed, and the right to choose. Likewise, this study is also consistent with Principle 3 laid down in the ASEAN High-Level Principles on Consumer Protection, i.e., consumers are protected from harmful goods and services.[19]

Hence, it is essential to analyse the extent the current food regulatory framework in Malaysia and Indonesia is ready to embrace the technology in increasing the volume of food production and regulate the potential safety and health risks associated with products of cellular agriculture. The analysis is to facilitate the introduction of products derived from cellular agriculture into the domestic market and to straighten out the regulatory uncertainty. This paper adopts a doctrinal legal analysis by analysing the relevant literature from research journals and books on cellular agriculture. The aim is to identify the conceptual aspect of cellular agriculture. The analysis of the regulatory framework for cellular agriculture consists of national policies on agriculture and food products, including food safety and food security, together with the relevant legislation.

This paper is organised as follows. The first part offers an overview of the concept of cellular agriculture together with the benefits and risks. The overview provides the foundation for assessing the adequacy of the existing regulatory framework in promoting and regulating the products of cellular agriculture. The second part analyses the adequacy of the existing regulatory framework in Malaysia and Indonesia. The analysis focuses on national policies and food legislation in respective

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[18] Hasmin, Nor Akhmal, Basir, Sayidah Asma, Mahmood, Anida., Matmin, Juan, and Tarigan, Vita Cita. "Formulating the Regulatory Framework for The Pre-Market Approval of Novel Food in Malaysia". International Journal of Public Law and Policy (2025). https://doi.org/10.1504/IJPLAP.2025.149435

[19] Association of Southeast Asian Nations. "ASEAN High-Level Principle on Consumer Protection." (2026) https://aseanconsumer.org/cterms-regional-cooperation-in-asean/asean-high-level-principles-on-consumer-protection

jurisdictions. The third part is findings and recommendations. The proposed legislative reforms aim to optimize the adoption of cellular agriculture through three key measures: (i) explicitly integrating cellular agriculture as a strategic technology within national food security policies in the respective countries, (ii) amending the existing food laws to incorporate provisions addressing safety and health considerations specific to cellular agriculture, and (iii) implementing a soft-law framework to guide the regulation of products and activities associated with this emerging technology. This paper ends with a conclusion.

A. The Concept of Cellular Agriculture

Cellular agriculture consists of both long-standing food production practices and cutting-edge technological innovations driven by new biotechnology. Centuries ago, humans discovered a technique to harness microorganisms for food production. For instance, the fermentation process uses microorganisms like yeast (single-cell microorganisms) to produce bread, beer, and tempeh. Nowadays, emergent technologies are adopted in cellular agriculture to produce more advanced food products, such as food products cultured from cells or tissues of host organisms in a bioreactor rather than production using animals or crop plants.[20] For example, cell-cultured meat produced using stem cell technology replicates muscle cells and induces these cells to grow and proliferate.[21]

There are two categories of food products derived from cellular agriculture. First, acellular products that are manufactured using protein-based engineering or also termed "fermentation-based cellular

[20] Nyyssölä, Antti, Anniina Suhonen, Anneli Ritala, and Kirsi-Marja Oksman-Caldentey. "The Role of Single Cell Protein in Cellular Agriculture." *Current Opinion in Biotechnology* 75 (June 2022): 102686. https://doi.org/10.1016/j.copbio.2022.102686.

[21] Garrison, Greg L., Jon T. Biermacher, and B. Wade Brorsen. "How Much Will Large-Scale Production of Cell-Cultured Meat Cost?" *Journal of Agriculture and Food Research* 10 (December 2022): 100358. https://doi.org/10.1016/j.jafr.2022.100358.

agriculture",[22] or traditional fermented products.[23] This technique enables the fermentation of biologically engineered microorganisms to produce proteins and lipids that can be processed into food ingredients, such as lab-grown milk, eggs, gelatine, collagen, and plant proteins.[24] The process does not require actual animals or plant cells. For example, in producing lab-grown milk, yeast is altered by inserting the gene to carry the blueprint for milk protein. The yeast cells read the same genetic code and carry so-called recombinant DNA, which makes milk protein identical to the protein cows make in their milk.[25] Furthermore, products derived from protein-based engineering tend to be produced using GMOs.[26]

On the contrary, cellular products are manufactured using tissue-based engineering or also known as tissue engineering-based cellular agriculture.[27] This technique enables the proliferation of actual cells originating from multicellular organisms such as plants and animals in bioreactors. The proliferation creates cell-cultured meat, poultry, and seafood by replicating the entire cell of the animal, making the product molecularly identical to animal-based meat.[28] The final products are

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[22] Stephens, Neil, and Marianne Ellis. "Cellular Agriculture in the UK: A Review." *Wellcome Open Research* 5 (October 12, 2020): 12. https://doi.org/10.12688/wellcomeopenres.15685.2.

[23] Miyake, Yoshitaka, Masashi Tachikawa, and Ryo Kohsaka. "Policy Frameworks and Regulations for the Research and Development of Cell-Based Meats: Systematic Literature Review." *Food Research International* 167 (May 2023): 112599. https://doi.org/10.1016/j.foodres.2023.112599.

[24] Saavoss, Monica. "How might cellular agriculture impact the livestock, dairy, and poultry industries?." *Choices* 34, no. 1 (2019): 1-6.

[25] Garrison, Greg L., Jon T. Biermacher, and B. Wade Brorsen. "How Much Will Large-Scale Production of Cell-Cultured Meat Cost?" *Journal of Agriculture and Food Research* 10 (December 2022): 100358. https://doi.org/10.1016/j.jafr.2022.100358.

[26] Rischer, Heiko, Géza R Szilvay, and Kirsi-Marja Oksman-Caldentey. "Cellular Agriculture — Industrial Biotechnology for Food and Materials." *Current Opinion in Biotechnology* 61 (February 2020): 128–34. https://doi.org/10.1016/j.copbio.2019.12.003.

[27] Ercili-Cura, Dilek, and Dorothee Barth. Cellular Agriculture: Lab Grown Foods. Vol. 8. American Chemical Society, 2021.

[28] Stephens, Neil, Lucy Di Silvio, Illtud Dunsford, Marianne Ellis, Abigail Glencross, and Alexandra Sexton. "Bringing Cultured Meat to Market: Technical, Socio-

similar on a molecular level to the products of traditional agriculture. The cellular product is exclusively non-genetically modified organisms (GMOs).

Grounded in the analysis articulated in the previous paragraph, the process of producing cellular products is more complex and intricate compared to acellular products. There are three main distinctions between cellular and acellular products as illustrated in Table 1, namely the production technique, the materials or substances used, and the incorporation of GMOs. Furthermore, acellular products such as lab-grown milk or gelatine have been on the market for a long time.

Table 1. Distinction between Cellular Product and Acellular Product

Ground of distinction	Cellular product	Acellular product
Production technique	Tissue-based engineering	Protein-based engineering (precision fermentation)
Material/substance use	Animal or plant cells	Living microorganisms
Incorporation of GMOs	Free from GMOs	Using GMOs

Source: Authors' owns interpretation

B. Benefits and Risks of Cellular Agriculture

The adoption of cellular agriculture in promoting food security offers numerous benefits and risks. The benefits offered by this technology include public health, animal welfare, environmental protection, and economic interest. First, cellular agriculture promotes public health. According to Sneeringer,[29] traditional livestock meat is exposed to contamination of bacteria and high antibiotic residue and may cause antibiotic resistance. This technology does not require the use of any antibiotics and the risk of contamination from fecal material or bacteria could be avoided as the cells or protein are cultured in a

Political, and Regulatory Challenges in Cellular Agriculture." *Trends in Food Science & Technology* 78 (August 2018): 155–66. https://doi.org/10.1016/j.tifs.2018.04.010.

[29] Sneeringer, Stacy, James M. MacDonald, Nigel Key, William D. McBride, and Kenneth Mathews. "Economics of antibiotic use in US livestock production." *USDA, Economic Research Report* 200 (2015).

bioreactor.[30] In addition, products of cellular agriculture could improve human nutrition since the technology allows the alteration of nutritional properties through the development of novel nutrient profiles to meet consumer needs.[31]

Second is the positive impact on animal welfare. According to the Food and Agricultural Organization,[32] it was estimated that 77 billion land animals are slaughtered each year for meat. The proliferation of cell-cultured meat eliminates the need to raise and slaughter animals. It is considered more animal-friendly as huge amounts of muscle could be proliferated in a bioreactor using a small amount of animal cells, either from farm animals or from cell lines[33] and only involving minor veterinary procedures using anaesthetic.[34] Third is environmental protection. Study conducted by El Wali and others indicates that the transition to cellular agriculture by 2050 could reduce annual greenhouse gas emissions by 52%, compared to current agriculture emissions, reduce demand for phosphorus by 53%, and use 83% less land than traditional agriculture.[35] Most importantly, cellular agriculture is the technology

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30 Hanley, Laura, Brenda Zai, Caroline Reisiger, and Alesandros Glaros. "Cellular agriculture and public health, nutrition, and food security." In *Cellular Agriculture*, pp. 407-422. Academic Press, 2024.

31 Chandrababu, Aswathy, and Jayesh Puthumana. "CRISPR-Edited, Cell-Based Future-Proof Meat and Seafood to Enhance Global Food Security and Nutrition." *Cytotechnology* 76, no. 6 (July 26, 2024): 619–52. https://doi.org/10.1007/s10616-024-00645-y.

32 Food and Agricultural Organisation (2021). World food and agriculture statistical yearbok. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/522c9fe3-0fe2-47ea-8aac-f85bb6507776/content

33 Yang, Ming, Qiong Wang, Yuyan Zhu, Kuichuan Sheng, Ning Xiang, and Ximing Zhang. "Cell Culture Medium Cycling in Cultured Meat: Key Factors and Potential Strategies." *Trends in Food Science & Technology* 138 (August 2023): 564–76. https://doi.org/10.1016/j.tifs.2023.06.031.

34 Melzener, Lea, Karin E Verzijden, A Jasmin Buijs, Mark J Post, and Joshua E Flack. "Cultured Beef: From Small Biopsy to Substantial Quantity." *Journal of the Science of Food and Agriculture* 101, no. 1 (July 27, 2020): 7–14. https://doi.org/10.1002/jsfa.10663.

35 El Wali, Mohammad, Saeed Rahimpour Golroudbary, Andrzej Kraslawski, and Hanna L. Tuomisto. "Transition to Cellular Agriculture Reduces Agriculture Land Use and Greenhouse Gas Emissions but Increases Demand for Critical Materials."

that enables the achievement of Sustainable Development Goal 2 which focuses on eliminating global hunger and strengthening food security.[36]

However, the potential benefits of cellular agriculture could also pose risks. The risk of contamination during production and the introduction of novel compounds may pose health risks.[37] Furthermore, the toxicology data on the potential health risks associated with products of cellular agriculture are not yet fully understood owing to the novelty of the technology and lack of toxicology studies.[38] The existing safety assessment methodology is inadequate and poorly adapted to address the unique hazards of these products. International food regulatory bodies, i.e., the Food Agriculture Organisation (FAO) and Codex Alimentarius Commission are still generating data to develop safety assessment methodology for cell-based food.[39] Hence, the safety status of products manufactured using cellular agriculture is still uncertain, and there is a possibility that the consumption could lead to unintended health effects.

The farmers are also at risk. The reduced number of slaughtered animals could negatively impact conventional livestock farmers, the farming profession, and rural development. The scale of rearing animals as cell sources for cultured meat would be smaller than conventional livestock production. The big food manufacturing company will be the first to arrive with investment resources and set aside the farmers'

Communications Earth & Environment 5, no. 1 (January 31, 2024). https://doi.org/10.1038/s43247-024-01227-8.

36 Rao, Varsha V., Bianca Datta, and Kai Steinmetz. "The Role of Natural Scientists in Navigating the Social Implications of Cellular Agriculture: Insights from an Interdisciplinary Workshop." *Frontiers in Sustainable Food Systems* 7 (June 16, 2023). https://doi.org/10.3389/fsufs.2023.1134100.

37 Nyika, Räty, Niko, Hanna L. Tuomisto, and Toni Ryynänen. "On What Basis Is It Agriculture?" Technological Forecasting and Social Change 196 (November 2023): 122797. https://doi.org/10.1016/j.techfore.2023.122797.

38 Fytsilis, Vaios D., Miriam J.E. Urlings, Frederik-Jan van Schooten, Alie de Boer, and Misha F. Vrolijk. "Toxicological Risks of Dairy Proteins Produced through Cellular Agriculture: Current State of Knowledge, Challenges and Future Perspectives." Future Foods 10 (December 2024): 100412. https://doi.org/10.1016/j.fufo.2024.100412.

39 Food Agriculture Organisation & World Health Organisation. (2023). Food safety aspects of cell-based food. https://doi.org/10.4060/cc4855en

interest.[40] For the environment, the usage of bioreactors to culture the cell requires significant energy input primarily due to the need for controlled bioreactor environments. If we use non-renewable energy sources, this high energy demand could potentially lead to increased greenhouse gas emissions.[41]

Lastly, there are risks of animal cruelty. Several methods exist for extracting and growing muscle cells. Fetal bovine serum (FBS) and animal body parts used for scaffolding tissue growth are regarded as highly invasive or deadly extraction methods. FBS is a blood derived from a bovine fetus taken from pregnant cows during slaughter or harvested by means of a cardiac puncture without any form of anaesthesia.[42] This discussion in this subsection demonstrates that products and activities of cellular agriculture offer opportunities and challenges. Such opportunities must be exploited, while the risks must be eliminated with an effective regulatory framework. The following subsections analyses the adequacy of the food regulatory framework in Malaysia and Indonesia for cellular agriculture.

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[40] Räty, Niko, Hanna L. Tuomisto, and Toni Ryynänen. "On What Basis Is It Agriculture?" Technological Forecasting and Social Change 196 (November 2023): 122797. https://doi.org/10.1016/j.techfore.2023.122797.

[41] Tuomisto, Hanna L. "Environmental Impacts of Cellular Agriculture." *Cellular Agriculture*, 2024, 379–92. https://doi.org/10.1016/b978-0-443-18767-4.00017-2.

[42] Jochems, Carlo E. A., Jan B.F. van der Valk, Frans R. Stafleu, and Vera Baumans. "The Use of Fetal Bovine Serum: Ethical or Scientific Problem?" *Alternatives to Laboratory Animals* 30, no. 2 (March 2002): 219–27. https://doi.org/10.1177/026119290203000208.

C. The Regulatory Framework for Cellular Agriculture

1. Malaysian National Policy Framework

Malaysia is vulnerable to food insecurity. In 2022, Malaysia ranked 113th on the Global Food Security Index (GSFI), with heavy reliance on imports for essential food products such as rice and meat.[43] In tackling the issues, the government has formulated various national policies to strengthen food security. The 12th Malaysia Plan (2021-2025) includes the initiative to boost the productivity growth of agricultural produce by 2.5% and expand the export market of agricultural products by RM 90.6 billion. Unfortunately, the plan is silent on the adoption of cell-cultured technology as an initiative to increase food productivity. The plan only confines itself to the (i) adoption of high-tech farming methods such as precision tools, drones, robotics, and sensors, (ii) developing and customising agricultural machinery and equipment to suit local conditions, and (iii) organic farming.

The Ministry of Agriculture and Food Security (MAFS) has formulated policies on food security that align with the four pillars of food security outlined by the Food and Agriculture Organisation (FAO) namely, availability, accessibility, utilisation, and stability. There are two main national policies related to agriculture and the food industry under the purview of MAFS as listed in Table 1, namely (i) National Agrofood Policy 2021-2030 (NAP 2.0), and (ii) National Food Security Policy Action Plan 2021-2025. The themes in Table 1 were extracted by characterising the policy text.

[43] Economist Impacts. (2022). Global food security index 2022. https://impact.economist.com/sustainability/project/food-security-index/explore-countries/malaysia

Table 2. Malaysia's Policies on Agriculture, Agrofood, and Food Security

Policy/ Theme	**National Agrofood Policy 2021-2030 (NAP 2.0)**[44]	**National Food Security Policy Action Plan (DSMN Action Plan) 2021-2025**[45]
Objectives	- to safeguard food security by increasing production output; - to address the challenges of sustainability and socio-economic development in agrofood; - to develop modern technology for the agrofood sector; - to boost income and improve the quality of life for food producers; - to establish agile and resilient value chains with high value activities; - to enhance food safety and nutritional well-being.	- to increase internal resources and diversify import resources; - to ensure the availability of safe food at affordable prices and a healthy eating style; - to increase private and societal involvement in the food system; - to ensure the country's preparedness in the face of the food crisis.
Food security	√	√
Food safety	√	√
Sustainability	√	x
Modern technology and technological innovation	√	x
Economic growth	√	√

Source: Authors owns interpretation

[44] Ministry of Agriculture and Food Security, (2021). National Agrofood Policy 2021-2030 (NAP 2.0) https://www.kpkm.gov.my/images/04-dasar-agromakanan/national_agrofood_policy_2021-2030_nap%202.0.pdf

[45] Ministry of Agriculture and Food Security, (2023). National Food Security Policy Action Plan 2021-2025, https://www.kpkm.gov.my/images/04-dasar-agromakanan/pelan_tindakan_dasar_sekuriti_makanan%202021-2025/Pelan_Tindakan_DSMN_2021-2025-min.pdf

As analysed in Table 1, the shared objectives between the two policies are to strengthen national food security provision i.e., increasing the productivity of agricultural produce and supporting national economic growth. The NAP 2.0 stresses the importance of sustainability in achieving food security and adopting modern technology as well as technological innovation to increase production. The first thrust of NAP 2.0 is to embrace modernisation and smart agriculture. It encourages farmers, food manufacturers, innovators, and investors to focus on smart agriculture technologies that can provide a better control over pests and diseases, resulting in more predictable and efficient processes for raising livestock and cultivating crops. Meanwhile, the DSMN Action Plan does not expressly emphasise the adoption of modern technology and technological innovation in achieving food security (Chuang et al., 2020).[46]

This study contended that Malaysia national policies are lacking on utilising the benefits and promoting cellular agriculture as enabling technology to strengthen national food security. Although the policies promote the utilisation of technology, the focus is toward smart technologies. This technology focuses on the use of digital technology to create precision farming solutions when combined with the application of information and communication technologies and other new interconnected equipment and technique.[47] The government should consider cell-cultured technology as one of the enabling technologies to achieve the objectives of the NAP 2.0 and DSMN Action Plan. As explained earlier, cellular agriculture will be able to replace conventional agriculture, as it is a novel food processing technology that fosters sustainability and offers solutions for food insecurity issues.

2. Malaysian Food Legislation

The legal framework for cellular agriculture in Malaysia is still developing, with no specific legislation enacted to regulate the technology. The existing legislation governs the activities and products

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[46] Chuang, Jui-Hsiung, Jiun-Hao Wang, and Yu-Chang Liou. "Farmers' Knowledge, Attitude, and Adoption of Smart Agriculture Technology in Taiwan." *International Journal of Environmental Research and Public Health* 17, no. 19 (October 3, 2020): 7236. https://doi.org/10.3390/ijerph17197236.

[47] Ibid.

of cellular agriculture. Hence, there is a need to analyse the adequacy of the existing legislation regulating the products and activities of cellular agriculture. The analysis focuses on the Food Act 1983 [Act 281] and Fisheries Act 1983 [Act 317].

The Food Act 1983 and its subsidiary, the Food Regulations 1985, are the key legal frameworks for food safety and consumer protection. Section 2 of the Food Act 1983 defines food as:

> *Every article manufactured, sold, or represented for use as food or drink for human consumption or which enters into or is used in the composition, preparation, preservation, of any food or drink and includes confectionery, chewing substances, and any ingredient of such food, drink, confectionery, or chewing substances.*

The term 'food' under section 2 covers any article manufactured, sold, or represented for human consumption, including food manufactured using specific or emerging technology. Hence, food products of cellular agriculture must be subjected to safety provisions of the Food Act 1983 and Food Regulations 1985. Furthermore, the analysis of the Food Regulations 1985 indicates several provisions explicitly applicable to acellular products.

Table 3: Provisions related to cellular agriculture in the Food Regulations 1985

Provision	**Regulatory Requirements**
Regulation 26A Probiotic culture	- The prebiotic cultures must obtain prior written approval from the Director before placing in the market; - Permitted probiotic cultures may be added to food; - The permitted dosage of probiotic culture; - Prohibition of transmissible antibiotic-resistant genes; - Labelling requirements and details for probiotic culture
Regulation 113 Cultured milk	- Statutory definition of cultured milk;

	- List of ingredients, colouring, food conditioner permitted for cultured meat; - Labelling requirements for cultured milk
Regulation 221 Fermented soya bean products	- Fermented using harmless microorganisms - May contain permitted preservatives, colouring enhancers, and flavour enhancers - Examples, tauju and tauceong

Source: Food Regulations 1985

Table 3 lists three types of food products, namely probiotic culture, cultured milk, and fermented soya bean. These products are cultured or fermented using microorganisms and protein-based engineering. Hence, these products are categorised as products of acellular agriculture. The regulations required these products to comply with safety and labelling requirements.

Meanwhile, Regulation 147 laid down the safety requirements for manufactured meat. Manufactured meat refers to:

> *[...] meat product prepared from meat, whether cut, chopped, minced or comminuted, cooked or uncooked, with or without the addition of salt, sugar, vinegar, sorbitol, spice, edible fat or edible oil and other food, and is sold as cuts in packages or shaped in casings or packages.*

It is important to note that manufactured meat is different from cell-cultured meat, i.e., the product of cellular agriculture. Manufactured meat refers to meat derived from conventional livestock production that is cut, chopped, minced or comminuted, cooked or uncooked before being sold in packages. According to studies, there are significant differences between conventional and cell-cultured meat, such as metabolic profile (nutrient metabolism),[48] the nutritional composition is

[48] Park Heejung, IHyeon Cho, Sojeong Heo, Kisoo Han, Young-jin Baek, Wan-sup Sim, and Do-Won Jeong. "Metabolomic insights of cultured meat compared to conventional meat." *Scientific Reports* 15, no. 1 (2025): 15668. https://doi.org/10.1038/s41598-025-00719-7

still unclear, especially for micronutrients and iron,[49] enriched with health-beneficial fatty acids, such as omega-3, as the cells can be engineered to incorporate certain nutritional benefits,[50] and risks of allergies from the scaffold materials rendering them less suitable for consumption by vulnerable consumers.[51] Therefore, the conventional safety requirements for manufactured meat are not fully applicable to cell-cultured meat due to fundamental differences in the production process and the composition.

As explained earlier, the production of cell-cultured meat includes fishery products, such as meat from fish and eels. Hence, reference is made to the Fisheries Act 1983. The long title of the Fisheries Act 1983 inter alia states that:

> *[...] the conservation, management and development of maritime and estuarine fishing and fisheries, in Malaysian fisheries waters [...]*

The application of the Fisheries Act 1983 as stated in the long title is limited to the conservation, management, and development of saltwater and freshwater fishing and fisheries in Malaysian waters. Section 2 covers fish that is propagated and raised through husbandry during the whole or part of its life cycle, i.e., by aquaculture technique. The techniques employed for aquaculture include on-bottom culture, cage culture, hanging-net culture, pen culture, pond culture, pole or stick culture, raceway culture, raft culture, rope culture and hatchery. Hence, the provisions of the Fisheries Act 1983 could not be extended to fisheries

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[49] Chriki, Sghaier, and Jean-François Hocquette. "The myth of cultured meat: a review." *Frontiers in Nutrition* 7 (2020): 507645.https://doi.org/10.3389/fnut.2020.00007

[50] Kardas, Marek, Wiktoria Staśkiewicz-Bartecka, and Aleksandra Kołodziejczyk. "Cultured Meat Reformulation: Health Potential and Sustainable Food Challenges—Narrative Review." *Comprehensive Reviews in Food Science and Food Safety* 24, no. 6 (2025): e70262. https://doi.org/10.1111/1541-4337.70262

[51] Kang, Kyu-Min, Dong Bae Lee, and Hack-Youn Kim. "Industrial research and development on the production process and quality of cultured meat hold significant value: A review." *Food Science of Animal Resources* 44, no. 3 (2024): 499.https://doi.org/10.5851/kosfa.2024.e20

products manufactured using cellular agriculture. The aquaculture technique does not involve the use or growth of fish cells in a bioreactor or laboratory.

The production of cell-cultured meat requires the extraction of animal muscle cells from living animals. Therefore, this study also analyses the legislation that protects the welfare of the animals i.e., the Animal Act 1953 [Act 647] and Animal Welfare Act 2015 [Act 772]. The long title of the Animals Act 1953 among others states that:

> *An Act for preventing the introduction into, and the spreading within, Peninsular Malaysia of diseases of animals; for the control of the movement of animals into, within and from Peninsular Malaysia; for the control of the slaughter of animals; for the prevention of cruelty to animals [...]*

The Animal Act 1953 controls the slaughter of animals and protects the animals from cruelty, and the Animal Welfare Act 2015 is *inter alia* promoting the welfare as well as responsible ownership of animals. The earlier discussion indicates that cellular agriculture will not end animal cruelty as animals are often involved in the production process, providing both the extracted cells and the medium or scaffolding required for cell growth. Therefore, this study contended that there must be a law to regulate methods and procedures of extracting the stem or cells. It is to ensure the extraction process eliminate animal suffering and cruelty, extracted muscle cells are safe for human consumption, and comply with food manufacturing standards such as Halal, good manufacturing practice, and hazard analysis and critical control point.[52]

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[52] The determination of essential conditions that must be fulfilled by platform service providers to benefit from the safe harbor principle reflects a nuanced balance between the need to facilitate digital innovation and the imperative to uphold legal accountability. Read on Indung Wijayanto, Cahya Wulandari, and Rasdi Rasdi, "Safe Harbor Principle, Exclusion of Criminal Liability for Platform Service Providers," *Indonesian Journal of Criminal Law Studies* 8, no. 2 (2023), https://doi.org/10.15294/ijcls.v8i2.48040.

3. Indonesian National Policies Framework

The Indonesia is striving to achieve food security while promoting sustainable food production. In 2022, Indonesia ranked 63rd in the Global Food Safety Index.[53] The ranking highlights significant challenges, including a heavy dependence on imports for various staple food products such as rice, wheat, sugar, soybeans, beef, fresh fruits, and animal feed. This reliance makes Indonesia vulnerable to price fluctuations and supply disruptions in international markets.

To address these issues, through Presidential Regulation No. 18 of 2020 on the National Medium-Term Development Plan 2020–2024, the Indonesian government prioritizes improving food availability, accessibility, and the quality of food consumption. The government realizes these efforts by implementing several strategic steps that aim to improve food availability, affordability, and utilization. To guarantee food availability, government policies include strengthening national food reserves, controlling food exports and imports, and monitoring food availability at the domestic level. These policies aim to ensure stable food availability, even during emergencies or external disruptions.

Additionally, the government strives to enhance food production capacity through land optimization, farmer empowerment, and the adoption of modern agricultural technologies. In terms of food accessibility, the strategies implemented include strengthening the food logistics system to reduce distribution costs, maintaining food price stability, and enhancing the early warning system for food and nutrition. These measures aim to ensure that food is not only available but also accessible to all segments of society, including the most economically vulnerable groups. The government also provides direct assistance to economically disadvantaged groups to maintain their purchasing power for basic food needs. Strengthening food safety and quality assurance, promoting food consumption diversification, and encouraging diverse, nutritious, balanced, and safe eating patterns all contribute to improved

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[53] Economist Impact. (2022). Global Food Security Index 2022: Indonesia https://impact-economist-com.translate.goog/sustainability/project/food-security-index/explore-countries/indonesia

food utilization. Food diversification is also expected to reduce dependence on imported food and maximize the use of local resources.

4. Indonesian Food Legislation

The Indonesian government recognizes the importance of adopting technology to support a more efficient and sustainable food system. The adoption of this technology aligns with Article 44, Paragraph (2) of Law Number 18 of 2012 on Food, which mandates the government to develop and implement technologies to address food crises and environmental pollution. However, the regulations governing cellular agriculture in Indonesia remain unclear, as there are currently no specific laws addressing this area. Nonetheless, existing regulations can serve as a reference for the development and promotion of cellular agriculture, particularly in terms of food safety.[54]

Food, as defined in Article 1 of Law Number 18 of 2012 on Food, is described as follows:

> *"Anything derived from biological sources, including agriculture, plantation, forestry, fisheries, livestock, aquatic products, and water, whether processed or unprocessed, intended for human consumption as food or drink, including food additives, food raw materials, and other ingredients used in the preparation, processing, and/or manufacturing of food or beverages."*

[54] The development of legal scholarship extends beyond theoretical construction to include practical recommendations for strengthening sustainable land protection policies. Technological adaptation reshapes legal certainty and administrative justice in Indonesia's agrarian reform, yet regulatory challenges persist in innovative sectors such as cellular agriculture, which still lacks a specific legal framework Read on Zidney Ilma Fazaada Emha et al., "Legal Policy and Challenges in Protecting Sustainable Food Agricultural Land in Indonesia: A Constitutional and Criminal Law Perspective," *The Indonesian Journal of International Clinical Legal Education* 6, no. 3 (2024), https://doi.org/10.15294/iccle.v6i3.17008; Clarabella Marella and Ana Silviana, "Digital Revolution in Land Affairs: Transformation of Land Certificates Through Electronic Mortgage Service," *The Indonesian Journal of International Clinical Legal Education* 6, no. 4 (2025), https://doi.org/10.15294/iccle.v6i4.18929; Sofyan Arief, "Law Construction in Modern Society," *The Indonesian Journal of International Clinical Legal Education* 1, no. 1 (2019), https://doi.org/10.15294/iccle.v1i1.36328.

Article 1 of Law Number 18 of 2012 on Food presents a pervasive definition of food product, which shall include any biological source, including agriculture, fisheries, livestock, and aquatic products. This study contended that such a definition applies to food manufactured using cellular agriculture, rendering all the food safety regulations stated in Law Number 18 of 2012 on Food equally applicable to products of cellular agriculture. Although the Food Law has been revised through the Job Creation Law, the revision does not alter the definition of food as provided under Law Number 18 of 2012 on Food. The amendments are primarily focused on simplifying regulatory procedures and licensing mechanisms.[55] Consequently, while the existing definition of food may potentially encompass products derived from cellular agriculture, Indonesian Food Law does not expressly regulate or recognise food produced through in vitro cell cultivation techniques. This situation gives rise to legal uncertainty regarding the classification and regulatory oversight of cellular agriculture-based food products.

Additionally, Article 67 of Law No. 18 of 2012 on Food stipulates that food safety management must ensure that food remains safe, hygienic, of high quality, nutritious, and in accordance with religious beliefs, cultural values, and community norms. Food safety management also aims to prevent potential biological, chemical, and physical contamination that could harm human health.

When utilizing cell-based agriculture technology to support food security, regulatory aspects become a primary concern. Any new food products, including those based on cell-based agriculture technology, must undergo a stringent approval process overseen by the National Food and Drug Authority. This authority ensures that all new food products in the market are safe for consumption and comply with applicable regulations. The approval process involves comprehensive

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[55] Rozi, Fahrur, Muchamad Ali Safa'at, and Istislam Istislam. "Constitutional Responsibility for Regulating Food Sovereignty." *International Journal of Business, Law, and Education* 5, no. 2 (2024): 1771-1779. https://doi.org/10.56442/ijble.v5i2.725Park, Heejung, IHyeon Cho, Sojeong Heo, Kisoo Han, Young-jin Baek, Wan-sup Sim, and Do-Won Jeong. "Metabolomic insights of cultured meat compared to conventional meat." *Scientific Reports* 15, no. 1 (2025): 15668.

evaluations, including food safety testing, health risk assessments, and adherence to quality standards and labelling requirements.[56]

The approval process begins with the manufacturer submitting documentation detailing the production methods, laboratory test data, and evidence of product safety. Subsequently, the National Food and Drug Authority conducts a phased evaluation, which includes expert reviews, facility inspections, and independent testing when necessary. This process aims not only to protect consumers but also to enhance transparency and public trust in new market products.[57] Through a rigorous approval process, the government aims to foster an ecosystem that supports innovation while maintaining public trust in technology-based food products. This crucial step ensures the widespread adoption of technologies like cellular agriculture without compromising food safety and quality.

In addition to ensuring the safety of cellular agriculture products, the government must also consider consumer protection as stipulated in Article 4 of Law Number 8 of 1999 on Consumer Protection. One of the rights outlined is the right to accurate, clear, and honest information regarding the condition and guarantees of goods and/or services. Based on this provision, the promotion of cellular agriculture products must include comprehensive information about the product. Failure to comply with these provisions results in a ban on the production and trade of cellular agriculture products. Article 8 of Law Number 8 of 1999 on Consumer Protection states that goods that do not meet the prescribed standards or violate regulations cannot be circulated. This category includes standards such as net weight, net content, quality, and expiration dates, all of which must be clearly stated. Misinformation or failure to fulfil promises made on labels, tags, or promotions may also result in a ban on circulation.

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[56] Aziz, Abd. "Tugas Dan Wewenang Badan Pengawas Obat dan Makanan (BPOM) Dalam Rangka Perlindungan Konsumen." *Al-Qanun: Jurnal Pemikiran Dan Pembaharuan Hukum Islam* 23, no. 1 (June 19, 2020): 193–214. https://doi.org/10.15642/alqanun.2020.23.1.193-214.

[57] Njatrijani, Rinitami. "Pengawasan Keamanan Pangan." *Law, Development and Justice Review* 4, no. 1 (May 27, 2021): 12–28. https://doi.org/10.14710/ldjr.v4i1.11076.

With supportive regulations and the proper application of technology in cellular agriculture, Indonesia has a significant opportunity to enhance national food security while building a sustainable food system. In the long term, this achievement could make Indonesia more self-sufficient in meeting its national food needs and reduce dependence on imports.

5. Findings and Recommendations

Cellular agriculture is the next big thing in food manufacturing technology that could overcome the global food security issues. However, the food and agriculture industry views cellular agriculture as a complex issue. We must fully exploit the technology's benefits to bolster national food security and foster sustainable food development. Nonetheless, the potential risks to safety and health must be effectively mitigated and regulated to protect consumers and the environment. As previously analysed, the risks of utilizing cellular agriculture involve possible contamination during the production process, negative impact on conventional livestock farming, including the increase of greenhouse emissions, and animal cruelty for the cell extraction. However, this study argued that an effective regulatory framework could overcome and mitigate the risks. By designing a framework for risk assessment and risk management for products derived from cellular agriculture, we could overcome the potential contamination. Meanwhile, the increases in greenhouse emissions caused by bioreactors could be restored by using green energy or renewable technology, such as wind, solar, biogas, biohydrogen, and bioethanol.[58]

Cellular agriculture also poses regulatory challenges. According to Amaru Sanchez (2018), cellular agriculture has the potential to overwhelm the food regulatory system owing to its unique nature.[59] The

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[58] Maity, Suvojit, Soham Sarkar, Kakoli Dutta, Tina De, and Ruchira Mukherjee. "Renewable energy and green technology." In Green Chemistry for Environmental Sustainability-Prevention-Assurance-Sustainability (PAS) Approach. *IntechOpen,* 2023. 10.5772/intechopen.1003716

[59] Sanchez, Amaru. "Laws and regulations concerning cell-cultured meat and cellular agriculture." *FDLI Update* (2018): 18. https://heinonline.org/HOL/LandingPage?handle=hein.journals/fdliup2018&div=8&id=&page=

above analysis strongly indicates that the food regulatory framework in Malaysia and Indonesia is not ready to fully utilise the benefits of cellular agriculture and regulate the potential risks on the following grounds.

First, national food policies in Malaysia and Indonesia are silent on the utilisation of cellular agriculture as an enabling technology for sustainably achieving food security. While these policies advocate for the adoption of modern technology and innovation to enhance food safety and security, this study contended that there is a need for a specific national policy promoting and utilising the benefits of cellular agriculture. National policy is a pivotal instrument that outlines the government plan and guidance in achieving national goals. This study contended that such policies could be the contributing factor that cellular agriculture is not popular among food manufacturers in Malaysia and Indonesia. Only one company in Malaysia, and none in Indonesia, is involved in cellular agriculture.

Second, Malaysia and Indonesia do not have specific legislation regulating the activities and products of cellular agriculture. In Malaysia, there are only three provisions in the Food Regulations 1985 applicable to acellular agriculture products, i.e., probiotic culture, cultured meat, and fermented soybean. However, cellular agriculture products developed through tissue-based engineering are regulated using the statutory provisions designed for conventional food products, predating the emergence of this technology.

This study contended that the existing regulations for traditional food products are inadequate to regulate products and activities of cellular agriculture, owing to the unique nature of the technology. For instance, food products containing or derived from cultured meat could not be labelled as meat or meat products, as they are not derived from a slaughtered animal. The current food labelling requirements in the Food Act 1983 and Food Regulations 1985 are inappropriate for cultured meat. Likewise, in Indonesia, the food labelling provisions in Law Number 18 of 2012 is insufficient for cellular agriculture products.

In the United States, despite the absence of federal legislation for the labelling of cellular agriculture products, there are 21 states that have

enacted laws with labelling requirements for cell-cultivated products.[60] The United States Department of Agriculture (USDA) has issued a guidance document on the labelling of cell-cultured meat, which aims to dispel the misinformation about cell-cultured food. The label must explicitly contain the term, such as "cell-cultured" or "cell-cultivated", for example, "cell-cultivated chicken." The commercial use of the label is subject to the approval of the USDA and the Food Safety and Inspection Service (FSIS).[61] The introduction of the labelling guidance by federal agencies and the imposition of mandatory labelling at several state levels underscore a critical role of cell-cultured labelling in informing consumers about the nature of food products.

Third, the absence of an approved or standardized procedure for the extraction, cultivation, or testing of animal cells for cultured meat production. As previously discussed, scientists have discovered various methods for extracting cells from living animals; however, some of these methods raise ethical concerns, particularly those involving aggressive procedures that impact animal welfare. Additionally, large-scale extraction of animal cells for human consumption remains uncommon, as most applications of animal cell culture are currently focused on the medical and pharmaceutical industries (O'Neill et al., 2021).[62] There is also no universally accepted method for growing the cells, particularly one that ensures safety for consumers. Therefore, the existing food regulatory framework in Malaysia and Indonesia is inadequate to promote and regulate products and activities of cellular agriculture.

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[60] Stanley, Katherine Consavage, Katariina Koivusaari, Khara Grieger, Amanda Wood, Gregory Jaffe, William R. Aimutis, Norbert LW Wilson, and Rohan A. Shirwaiker. "Exploring the US Regulatory and Legislative Landscapes for Cell-Cultivated Meat and Seafood." Trends in Food Science & Technology (2025): 105527 https://doi.org/10.1016/j.tifs.2025.105527

[61] Association for Meat, Poultry and Seafood Innovation. USDA Ensures Consumer Transparency for Cultivated Meat with Labeling Regulation. (2023). https://ampsinnovation.org/resources/usda-ensures-consumer-transparency-for-cultivated-meat-with-labeling-regulation/

[62] O'Neill, Edward N., Zachary A. Cosenza, Keith Baar, and David E. Block. "Considerations for the Development of Cost-effective Cell Culture Media for Cultivated Meat Production." *Comprehensive Reviews in Food Science and Food Safety* 20, no. 1 (December 5, 2020): 686–709. https://doi.org/10.1111/1541-4337.12678.

According to Zandonadi and other,[63] the development and commercialization of cellular agriculture require clear and up-to-date regulations and supervision, which are being studied and formulated by regulatory agencies worldwide. To promote cellular agriculture and avoid legal complications on introducing the products of cellular agriculture in the marketplace, this study offers three recommendations. First, the national food policy in both jurisdictions must expressly incorporate cellular agriculture as an enabling technology to enhance national food security.

The national policy on cellular agriculture will operate as the governance for products and activities of cellular agriculture. This study recommended that the policy should include several important strategies to promote the adoption of the new technology among food manufacturers. Such strategies include (i) investment and financial assistance for food manufacturers who are using the technology, including activities for R&D, (ii) strategic approaches to commercialise products of cellular agriculture, (iii) proposals to enhance consumer perception and acceptance for products of cellular agriculture, and (iv) ethical evaluation, including public health and safety.

Second, the existing food laws must be amended to incorporate specific regulatory provisions to address the potential safety and health risks associated with products of cellular agriculture. The amendment to the Food Act 1983, Food Regulations 1985, and Law No. 18 of 2012 on Food must, *inter alia,* include (i) provisions on the statutory definition for cellular and acellular agricultural products, (ii) labelling requirements for products of cellular agriculture, (iii) provisions on safety requirements for manufacturing products of cellular agriculture.

The statutory definition serves two functions, namely (i) to indicate that products of cellular agriculture are different from food manufactured using traditional technologies and set the parameter for

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[63] Zandonadi, Renata Puppin, Maíra Catharina Ramos, Flavia Tavares Silva Elias, and Nathalia Sernizon Guimarães. "Global Insights into Cultured Meat: Uncovering Production Processes, Potential Hazards, Regulatory Frameworks, and Key Challenges—A Scoping Review." *Foods* 14, no. 1 (January 4, 2025): 129. https://doi.org/10.3390/foods14010129.

the new regulatory framework, and (ii) to draw a distinction between products derived from protein-based engineering and tissue- or cell-based engineering. The new amendment also needs to include requirements and relevant particulars for labelling. Labelling is pivotal, as it will inform consumers on the nature of the food products.

This study also contended that a specific law for cellular agriculture could increase consumers' acceptance of such products. A comprehensive regulatory framework would foster consumer confidence and ensure the safety and integrity of the market. Future research should explore the optimal formulation of such a regulatory framework to support the effective governance of cellular agriculture. Furthermore, the legislation protecting the animal's welfare must also be amended to incorporate provisions on standardized procedures for extracting cells from living animals. It is essential to establish a clear procedure for food manufacturers to ensure compliance with ethical standards and legal regulations, thereby mitigating potential ethical and legal challenges.

Third, adopting the soft-law approach. Since products of cellular agriculture are still being developed and there is an absence of statutory provision, a self-regulatory approach or soft-law approach could be adopted by food manufacturers. Effective hazard and safety assessment strategies, such standard Good Manufacturing Practice (GMP), Hazard Analysis and Critical Control Points (HACCP), and Halal, combined with best practices, should be implemented throughout the production process. Additionally, given the limited production volume of products derived from cell agriculture, the food safety authorities in each jurisdiction may issue a guidance document outlining the best practices in handling these products. These approaches are particularly advantageous in an evolving field where technological advancements often outpace regulatory development.

Conclusion

Products of cellular agriculture are already in the marketplace, and the technology holds so many abilities to address food security challenges currently faced by traditional agriculture. Unfortunately, Malaysia and Indonesia are not fully ready to embrace the technology. The national food policies are silent on the action plan promoting and utilising cellular agriculture. Likewise, products of cellular agriculture are regulated using the existing food safety provisions. The existing provisions are deemed inadequate for activities and products of cellular agriculture, owing to their unique and novel characteristics. Legal uncertainty will slow down the commercialisation efforts for products of cellular agriculture. Therefore, there is a need to reform the current food regulatory framework. A robust regulatory framework for cellular agriculture aims at promoting the technology as well as offering a safety network for potential safety risks.

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