Malaysian Journal of Social Sciences and Humanities (MJSSH) (e-ISSN : 2504-8562)
2025, Volume 10, Issue 2, e003256
DOI: https://doi.org/10.47405/mjssh.v10i2.3256

RESEARCH ARTICLE

Halal Compliance in Cultivated meat Production: Risks and Strategic Management

Aimi Shafinaz Shaharudin[1], Nur Farhani Zarmani[2*]
Mohammad Naqib Hamdan[3]

[1]Academy of Contemporary Islamic Studies (ACIS), Universiti Teknologi MARA (UiTM), 40450, Shah Alam, Selangor, Malaysia
Email: aimishafinaz7@gmail.com
[2]Academy of Contemporary Islamic Studies (ACIS), Universiti Teknologi MARA (UiTM), 40450, Shah Alam, Selangor, Malaysia
Email: nurfarhani@uitm.edu.my
[3]Academy of Islamic Civilization, Faculty of Social Science and Humanities, Unoversiti Teknologi Malaysia (UTM), 81310, Johor Bahru, Johor, Malaysia
Email: mohammadnaqib@utm.my

CORRESPONDING AUTHOR (*):
Nur Farhani Zarmani
(nurfarhani@uitm.edu.my)

KEYWORDS:
Cultivated Meat
Halal Control Points
Risk Management

CITATION:
Aimi Shafinaz Shaharudin, Nur Farhani Zarmani, & Mohammad Naqib Hamdan. (2025). Halal Compliance in Cultivated meat Production: Risks and Strategic Management. *Malaysian Journal of Social Sciences and Humanities (MJSSH), 10*(2), e003256. https://doi.org/10.47405/mjssh.v10i2.3256

ABSTRACT

The production of meat without involving conventional livestock, known as cultivated meat, is one of the latest innovations in the field of food biotechnology. Cultivated meat is produced in laboratories through the cultivation of stem cells. However, cultivated meat raises several issues, such as the absence of halal guidelines and safety standards provided by the Food Safety and Quality Division (FSQD), Department of Veterinary Services Malaysia (DVS), and Department of Islamic Development Malaysia (JAKIM). This article aims to identify potential hazards at Halal Control Points (HCPs) in the cultivated meat production and analyse strategies for managing these hazards within a halal risk management framework. To achieve these objectives, an exploratory research design, also referred as formative research, was employed. Interviews were conducted with subject matter experts in cultivated meat field, including academics, regulatory authorities, and start-up companies. The collected data were analysed using thematic analysis. The potential hazards and strategies for managing the risks can serve as a reference not only for the industry but also for regulatory authorities in monitoring the safety and halal aspects of cultivated meat production. Halal compliance in cultivated meat production has the potential to ensure the halal integrity and safety of cultivated meat, making it reliable, consistent, and trustworthy not only at the local but also capable of penetrating global markets.

Contribution/Originality: The paper's primary contribution is finding potential hazards at Halal Control Points (HCPs) and strategies for managing these hazards within a halal risk management. This study refers to existing fatwas and previous research but

does not focus on Muslim acceptance of cultivated meat, leaving these topics for future research.

1. Introduction

The development of science and technology in the era of globalization is a blessing and an intellectual advantage bestowed by Allah SWT upon humanity. However, this advantage must align with the principles of Shariah. Cultivated meat is a new innovation in food biotechnology, resulting from the ideas and scientific discoveries of researchers and scientists. Cultivated meat is produced in laboratories from animal stem cells or tissues, cultivated in a growth medium to produce meat. Various terms are used by scientists and researchers, such as cultured meat (Post, 2012), cultured beef (Post, 2014), artificial meat (Orzechowski, 2015), in vitro meat (Bhat et al., 2015), clean meat (Mian N Riaz & Fariha Arshad, 2018), stem cell meat (Mohammad Shahadat Hossain, 2019), lab-based meat (Ching et al., 2022), cultivated meat (Leung et al., 2023; Mancini & Antonioli, 2022), and meat produced in vitro using tissue engineering techniques (Moritz et al., 2022).

Currently, the commercialization of cultivated meat is limited to minced meat and nuggets, and have not yet achieved the shape of real meat or 3D forms. But in 2020, 3D vegan steak was successfully created using plant-based meat. 'Alt-Steak,' a 3D vegan steak created by Redefine Meat, effectively mimicked the texture, taste, and appearance of real meat (Ahmad Syukran et al., 2020). In 2020, Eat Just launched a cultivated meat product and served it to guests during its launch event. Eat Just is the first cultivated meat company to receive approval from the Singapore Food Agency (SFA). Singapore was also the first country to allow the sale of cultivated meat under novel food guidelines. Investors are attracted to this field, seeing the potential profitability of technological advancements. But currently, neither halal regulations nor businesses that have earned halal certification for cultivated meat products. Therefore, this technology must be explored by Muslims as part of the obligation to ensure the availability of halal food. Given the global necessity for various alternatives to meet the world's food needs, halal guidelines must be developed for the benefit of Muslims. Islam has established several guidelines to determine the halal and haram status of food. All food is considered halal except for what has been prohibited by Shariah, such as animals not slaughtered according to Islamic law, blood, pork, and the like.

In general, cultivated meat is produced outside of the animal's body using cultivated techniques tissue or stem cells derived from animals. These cells are then placed in a growth medium that serves as a source of nutrients and energy to proliferation and differentiation until they form meat (Bhat et al., 2015; Zuhaib Bhat & Sunil Kumar, 2021). According to Mohammad Naqib and Mohd Anuar (2016), cultivated meat can be examined from several aspects, including its source, process, and product. First, cultivated meat must be sourced from adipose-derived stem cells (ADSCs) or embryonic stem cells (ESCs), alongside the use growth medium to ensure the meat can proliferate and differentiation. Second, the production process of cultivated meat is carried out outside the animal's body (ex vivo) but requires an environment similar to that inside the animal's body and safe for consumption.

Muslims in Malaysia particularly trust in food that has been certified halal, and cultivated meat must adhere to halal guidelines to penetrate the halal market. However, no halal guidelines have been issued by religious authorities. Cultivated meat must be produced

in accordance with Shariah principles, and neglecting this innovation would be a loss for both Muslims and the industry (Ahmad Syukran et al., 2020). Therefore, stakeholders must consider to make cultivated meat accessible to Muslims (Reza Adnan et al., 2021). There are fatwas regarding cultivated meat, such as Pejabat Mufti Wilayah Persekutuan (2021) and Majlis Ugama Islam Singapura (MUIS) (2024). Several guidelines must be followed before cultivated meat can be considered halal. Cultivated meat is a new issue that has never been discussed or debated by earlier Islamic scholars (fuqaha'). Thus, any ijtihad made by contemporary Islamic scholars must examine the technology used and the critical halal issues in the cultivated meat production to determine whether it aligns with Shariah requirements. To ensure that cultivated meat complies with halal principles, the cells used must come from halal-slaughtered animals, as stated in the Quran and Hadith (Reza Adnan et al., 2021). However, Nahdlatul Ulama (NU), one of the largest Islamic organizations in Indonesia, has declared that cultivated meat derived from living animal cells is impure and prohibited (haram) for consumption. They argue that cultivated meat must be discussed in the context of animal body separation because the stem cells used are taken while the animal is still alive or before it is slaughtered. This implies that cultivated meat should be considered part of the animal's body (Qotadah et al., 2022).

In summary, the absence of halal guidelines for cultivated meat is a significant issue for Muslims as involves matters of halal and haram. This study is crucial for developing halal compliance framework to regulate the production process of cultivated meat as a reference for producing halal-certified cultivated meat. The need to ensure the halal status of cultivated meat is significant in ensuring permissible for Muslim consumers. Concerns about food security must be addressed, especially with the emergence of several crises related to meat imports at both local and global levels. As a temporary solution, Malaysia has been forced to import beef, primarily from India; however, some irresponsible parties have exploited this situation to engage in fraud within the meat import-export process The "meat cartel" controversy, for instance, rocked Malaysia by revealing flaws in the security and management of the nation's entry gateways and the country's incapacity to satisfy Muslim consumers' demands for halal meat. This cartel crime has reportedly been concealed for several years, with claims that it has been ongoing for 40 years, serving as a lesson for Malaysia to seriously address the livestock industry (Mohd Farhan Md Ariffin et al., 2021). Brunei also faced a similar crisis when 4,000 kg of meat was brought in illegally without a halal import permit. Following the revelation of the meat smuggling case in Asia, Brunei announced its intention to reduce dependence on imported meat (The Star, 2021).

1.1. Research Objectives

This article aims to identify potential hazards at Halal Control Points (HCPs) in the cultivated meat production and analyze strategies for managing these hazards within a halal risk management framework.

2. Literature Review

2.1. History of cultivated meat

The history of cultivated meat involves a combination of ideas and scientific discoveries. The concept of cultivated meat was first mentioned by Kurd Lasswitz from Germany in his book "Auf Zwei Planeten" in 1897 (Chodkowska et al., 2022). In 1907, biologist and

anatomist Ross Harrison pioneered animal tissue culture with frog tissue in a medium supplemented with lymph. Alexis Carrel succeeded in keeping the embryonic chicken heart alive ex vivo for an extended period in 1912, marking the first breakthrough (Mohammad Naqib, Post, Ramli, et al., 2021). The earliest success in tissue culture techniques occurred in 1971 when Russell Ross successfully cultured cells from the guinea pig aorta tissue (Ye et al., 2022). In 1930, Frederick Edwin Smith predicted that humans wouldn't need to wait long to obtain buffalo meat, since single cell could multiply and produce high-quality meat. In 1931, Winston Churchill proposed the idea that humans could produce parts of chicken like wings and breasts by placing cells in growth medium, eliminating the need to raise an entire chicken, in his book "Fifty Years Hence," later published in "Thoughts and Adventures" (Balasubramanian et al., 2021). Furthermore, in 1943, French science fiction writer René Barjavel mentioned in vitro meat in his novel "Ravage," later published as "Ashes, Ashes" in 1967. In 1953, Willem Frederik van Eelen, known as the "godfathers of cultured meat," who pioneered the creation and development of cultivated meat and successfully patented in 1997 (Zuhaib Bhat & Sunil Kumar, 2021).

The progress of cultivated meat became more apparent with government agencies and research divisions taking steps. In 1995, the U.S. Food and Drug Administration (FDA) approved the use of in vitro techniques for commercial meat production, paving the way for cultivated meat products to enter the market (Kumar et al., 2021). In the late 1990s, NASA, in collaboration with Morris Benjaminson and his team from Germany, successfully cultured goldfish muscle tissue in Petri dishes and provided it as food for astronauts, after receiving ethical approval in 1999. In 2000, the Australian laboratory SymbioticA produced muscle biopsies from frogs and cultured the cells in vitro, while Van Eelen patented a similar theoretical concept (Chodkowska et al., 2022; Rodríguez Escobar et al., 2021).

This revolutionary advancement was recorded in 2013 when the first cultivated beef burger was prepared and presented to a panel by Riverside Studios of London (Ramani et al., 2021). In the same year, New Harvest invited startups like Sholin Meat Project, Memphis Meat, Super Meat, and Finless Foods to engage in cultivated meat production. Eventually, in 2020, Eat Just introduced cultivated chicken meat in Singapore and received novel food approval from the Singapore Food Agency (SFA) (Balasubramanian et al., 2021). Cultivated meat has become an intriguing topic not only for scientists and investors but also for artists like Oron Catts and Lonat Zurr, who showcased frog cell-based steak in the "Disembodied Cuisine" project at the L'Art Biotech exhibition in France in 2003 (Catts & Zurr, 2003). Table 1 summarizes the history of cell culture and cultivated meat, highlighting time frame and developments in these fields. It provides an overview of significant advancements in technology, from the earliest experiments in cell culture to the emergence of cultivated meat as a viable food source.

Table 1: History of cell culture and cultivated meat.

Time frame	Expertise	Historical summary
1897	Kurd Lasswits (Writer)	The concept of cultivated meat was first mentioned in his book "Auf Zwei Planeten" (Chodkowska et al., 2022).
1907	Ross Harrison (Biologist & Anatomist)	Successfully cultured frog neuroblasts in a lymph medium (Mohammad Naqib, Post, Mohd Anuar Ramli, et al., 2021)

1912	Alexis Carrel (Biologist)	Pioneer in tissue culture from an embryonic chicken heart (Mohammad Naqib Hamdan, Post, Ramli, et al., 2021).
1930	Frederick Edwin Smith (Politician)	The prediction that animal cell can multiply into edible meat (Balasubramanian et al., 2021).
1931	Wiston Churnchill (Politician & writer)	The idea of in vitro meat in the essay as a solution to the problem of food sources and animal welfare in "fifty years hence" and "thoughts and adventures"(Balasubramanian et al., 2021).
1943	Rene barjavel (Writer)	In vitro meat technology in his novels “Ravage” and “Ashes.Ashes”(Bhat et al., 2015).
1953 & 1999	Willem Frederik van Eelen (Researcher & businessman)	“Godfathers of cultured meat” who pioneered the creation and development of cultivated meat (Fernandes et al., 2022).
1971	Russell Ross (Researcher)	Pioneer in culturing techniques by growing guinea pig aortic tissue (Ye et al., 2022).
1995	US FDA	Approving the in-vitro techniques for commercial meat production (Kumar et al., 2021).
1997	Morris Benjaminson (Researcher)	Benjaminson and his research team collaborate with NASA, cultured the muscle tissue from Carassius auratus in petri dishes and supplied as food to astronauts (Rodríguez Escobar et al., 2021; Chodkowska et al., 2022).
2000	SymbioticA	Harvested muscle biopsy from frogs and engineered in vitro cells (Rodríguez Escobar et al., 2021; Chodkowska et al., 2022).
2013	Mark Post & New Harvest (Organization)	Introduced the world’s first cultivated beef burger. New Harvest invited the start-up companies to enhance the cellular agriculture for cultivated meat production. (Ramani et al., 2021).
2020	Singapore Food Agency (SFA) & Eat Just (Company)	The first country to approve the cultivated meat. Eat Just was the first company successfully obtain approval to sell cultivated meat to the public (Balasubramanian et al., 2021).

2.2. Factors in Cultivated meat production

Recent global challenges, such as natural disasters, population growth, environmental pollution, animal welfare concerns, and health issues, have driven scientists to develop cultivated meat. The world population has grown significantly, from 1 billion in 1830 to 7 billion in 2014, and is expected to reach 9.7 billion by 2050 (Zhang et al., 2022). This population increase has led high demand of meat, which is the most popular protein source worldwide. The number of cattle slaughtered for food increased from 2.1 billion in 1950 to 4.4 billion in 1990. According to the Food and Agriculture Organization (FAO), per capita meat consumption increased from 10 kg per year in 1960 to an estimated 37 kg by 2030. Additionally, fish catches are expected to increase due to rising global demand (Mohammad Naqib et al., 2019).

To meet the growing food demand, the FAO estimates that food production will need to increase by 70% by 2050 (Ahmad Syukran et al., 2020). As conventional livestock farming consumes significant natural resources, alternatives like cultivated meat are being explored to reduce environmental impact. Mohammad Naqib et al. (2017) reported that 30% of land and 8% of freshwater are used for livestock farming, with 50,000 to 100,000 litres of water required to produce one kilogram of beef. Additionally, Chen et al. (2022) highlighted that half of the Earth's land is used for agriculture, with 77% allocated to animal feed production. Cultivated meat could reduce the need for extensive land and

water use and decrease environmental pollution. The European Union reports that livestock farming contributes 9.1% of greenhouse gas emissions, while cultivated meat could reduce emissions by 78%-96% and soil pollution by up to 99%.

In addition to the environmental benefits, cultivated meat also offers advantages in terms of cost and logistics. It requires less land, water, and resources compared to conventional livestock farming, and can be produced quickly without the need for extensive imports or exports. While the total costs of cultivated meat production, including reactor operations and electricity use, have not yet been fully documented, further research is needed to compare the costs and benefits of conventional and cultivated meat (Mohammad Naqib et al., 2019). Furthermore, cultivated meat has garnered support from animal welfare activists, as it reduces the need for animal slaughter and ensures better welfare standards for animals (Bhat et al., 2015). cultivated meat can also be a healthier alternative, with customizable nutritional content that can reduce risks associated with excess consumption of saturated fats and cholesterol, offering a safer, more sustainable food option (Rubio et al., 2020).

2.3. Cultivated meat from a Halal Perspective

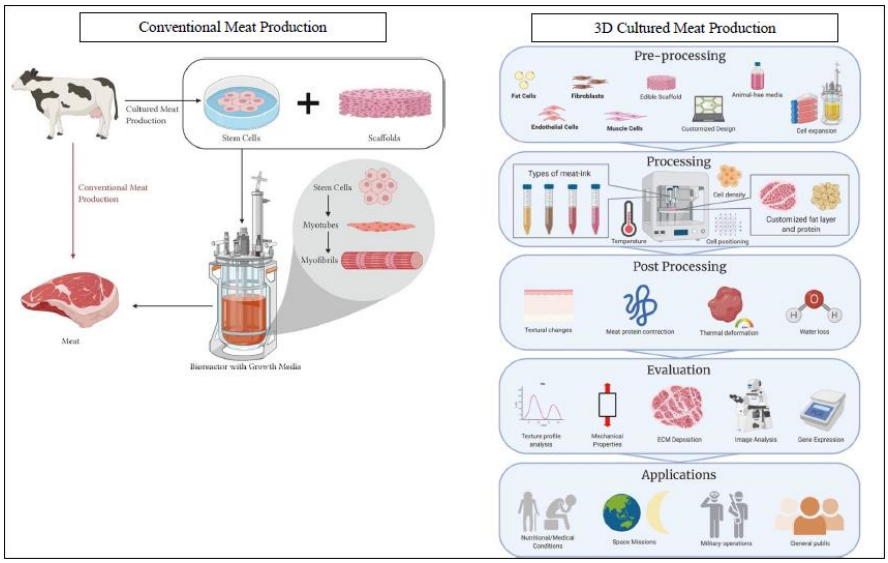
Mohammad Naqib and Mohd Anuar Ramli (2016) discussed the concept, history, and techniques involved in producing cultivated meat. Their study focused on the status of animal embryonic stem cells (ESCs), noting that cultivated meat derived from ESCs is considered pure, as the impure blood (mudghah) transforms into flesh. However, the fetus must be sourced from mother that has been slaughtered in accordance with Islamic law. Islamic scholars have stated that when the 'alaqah turns into mudghah, it becomes pure for those who believe mudghah is pure. For those who consider mudghah impure, it becomes pure once it develops into a fully-formed fetus. Mohammad Naqib Hamdan et al. (2017) expanded their research to Adipose-Derived Stem Cells (ADSCs) or Non-Embryonic (Adult) Stem Cells (ASCs) used in the production of cultivated meat. They concluded that ADSCs/ASCs must be sourced from animals that have been slaughtered, as using meat from animals not slaughtered according to Islamic guidelines is prohibited. For marine animals is exempted, as they do not need to be slaughtered. Regarding the halal status of the growth medium, they emphasized that blood serum, such as Fetal Bovine Serum (FBS), should be avoided unless it can be proven that the cultivated meat undergoes *istihalah* (transformation). Additionally, blood is classified as medium-level impure (*najs al-mutawassitah*).

Moreover, Mohammad Naqib (2018) examined the concept of alteration of Allah's creation (*taghyir khalqillah*) of cultivated meat, analysing journals, books, and fatwas. Allah forbids any form of alteration to His creation, such as changing religion or making permanent physical changes for deceptive purposes. However, some categories of alteration are permitted by Islamic law for beneficial purposes. They concluded the production of cultivated meat is allowed because it does not involve deception, and a positive effort to preserve the environment and provide benefits to humanity. Subsequently, Mohammad Naqib Hamdan, Post, Ramli, et al. (2021) discussed the acceptance of cultivated meat from the perspective of various religions. A key factor in Islam is the consideration of the materials and sources of cells obtained according to Islamic teachings. Therefore, the acceptance of cultivated meat in Islam depends on further research into whether the process aligns with the halal principle. In Christianity, Judaism, Buddhism, and Hinduism, acceptance is based on moral, ethical, and religious regulations. While there is no absolute prohibition in most religions, aspects such as

animal suffering reduction, adherence to dietary laws, and principles of non-violence play important roles in determining whether cultivated meat is accepted or rejected. He anticipates that the acceptance of cultivated meat will increase depending on how it is produced and how closely it aligns with religious teachings and values. Furthermore, Mohammad Naqib Hamdan, Mohd Anuar Ramli, Nek Mohd Farid Zaman Huri et al. (2021) compared the legal status of consuming conventional meat and cultivated meat during two special Islamic occasions which is *Aqiqah* and Hari Raya Korban, which involve animal slaughter. The ruling on slaughtering livestock is considered *thawabit* (unchanging) with mandatory adherence. Therefore, using cultivated meat to replace the practice of sacrificial slaughter is not valid. The unprecedented advancements in science and technology will not alter the fundamental characteristics of these immutable rulings.

Mian N Riaz & Fariha Arshad (2018) uses the term "clean meat" and explores the opportunities and challenges in the development of cultivated meat. To enhance the quality and integrity of cultivated meat, they recommend sensory research, ethics, consumer acceptance, and cost management for large-scale production. Cultivated meat manufacturing shows potential for halal certification, but it requires clear guidelines to assess halal compliance. Mohammad Shahadat Hossain (2019) evaluates the legal status of cultivated meat according to Islamic law, referring to books, research articles, and expert opinions. The study highlights several Shariah issues related to cultivated meat, such as the source of cell and growth medium. He emphasizes that while Islam supports the use of technology to improve human life, its application must align with the *maqasid* shariah. He emphasizes that Islamic countries must establish halal regulations and safety standards for cultivated meat products to ensure consumer protection. Additionally, he advocates for further scientific research to keep up with advancements in biotechnology. Meanwhile, Ahmad Syukran et al. (2020) also support the need for the development of standards and regulations for halal 3D cultivated meat product (Figure 1). They urge that existing standards for conventional halal meat processing be reviewed in line with advancements in food bio technology. The urgent need for regulations is believed to prevent any non halal and safety for human.

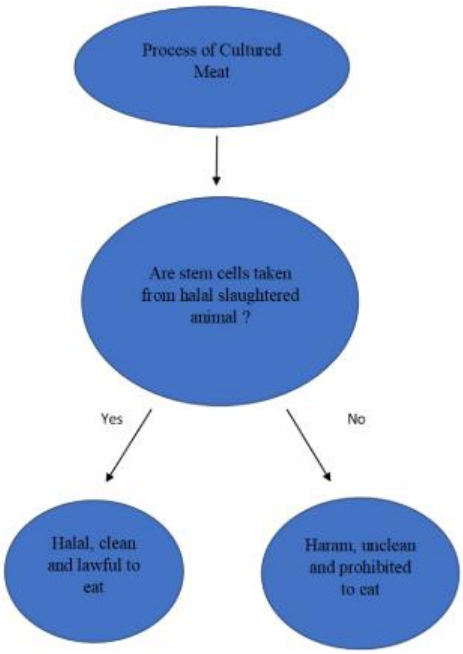
Figure 1: The comparison between cultivated meat products and conventional meat



Source: Ahmad Syukran et al. (2020)

Reza Adnan et al. (2021) used a qualitative approach to identified the legal status of consuming cultivated meat from the perspective of *maqasid* shariah (Figure 2). They concluded that cultivated meat is halal as food biotechnology that aligns with *maqasid* shariah, particularly in preserving life (*hifz an-nafs*). Muslims are encouraged to lead the development of cultivated meat technology to prevent the use of any haram elements in its production. However, this recommendation is challenging to implement without established for halal cultivated meat production guidelines.

Figure 2: Factors determining the halal status of cultivated meat



Source: Reza Adnan et al. (2021)

3. Research Methods

Using a qualitative research methodology, this study examines the hazards of halal compliance and strategic management in the production of cultured meat through expert interviews and a literature review. The qualitative method was chosen to provide an in-depth understanding of the complexities and challenges associated with halal compliance in this field.

Secondary data was collected to address the research objectives through a library research approach. This involved reviewing journals, dissertations, books, news articles, and existing guidelines related to cultivated meat. Key terms used for document searches included "cultivated/ cultured/lab-grown/in vitro/clean/victimless meat", "novel food," "halal," "halal food", "halal risk management" and "halal strategy".

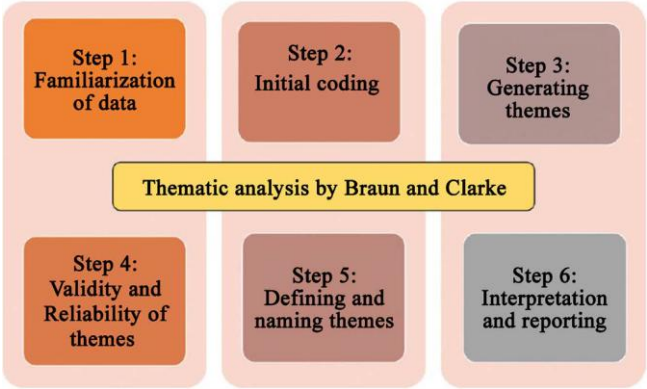
The study was executed in Malaysia and Singapore due to its important role in the halal industry and the presence of important players in the development of cultivated meat. The target population consists of halal industry experts, scholars in Islamic jurisprudence, regulatory authorities, and cultivated meat industry stakeholders. This group was selected to provide diverse perspectives on halal compliance risks and strategic management. The study involved seven (7) informants from the target population. The sample size was determined using purposive sampling, ensuring that only experts with

direct knowledge and experience in halal compliance and cultivated meat were selected. A purposive sampling method was also employed to ensure that informants meet the inclusion criteria below:

i. Background in food biotechnology
ii. Expertise in food produced through modern biotechnology or cultivated meat
iii. Directly involved in research, management, or training related to halal
iv. Able to communicate in Malay or English

Data were gathered using semi-structured interviews following a predetermined interview protocol. The gathered data were examined utilizing thematic analysis, adhering to the framework established by Braun and Clarke (2006) in Figure 3.

Figure 3: Thematic Analysis by Braun and Clarke (2006)



Source: Braun and Clarke (2006)

Thematic analysis was selected to discern principal themes of halal compliance issues and strategic management in cultured meat production. The analytical procedure encompassed data familiarization, coding, topic identification, and interpretation, guaranteeing a thorough comprehension of professional views. Content analysis was applied to transcript data collected from both primary and secondary sources using thematic analysis. Atlas.ti software has facilitated thematic analysis by organizing the collected data, in text, graphics, or audio recordings from informants. The data is also recorded in transcript form, then codes based on identified themes and compares the data across different informants and secondary sources.

4. Results

4.1. Potential Hazards at Halal Control Points (HCP) in the Cultivated meat Production Process

Potential hazards, as defined by MS 2400:2019-Part 1/2/3, refers to any non-halal or harmful substance intentionally or unintentionally added that could render the product non-halal. According to Informant RCW, Interview (21 August 2022), identifying these potential hazards at the Halal Control Points (HCPs) is crucial in ensuring the halal status of cultivated meat. The HCPs are identified along the supply chain where control measures are implemented to prevent or eliminate contamination, ensuring compliance with halal standards (Jabatan Kemajuan Islam Malaysia [JAKIM], 2020). The study identifies three potential hazards during cultivated meat production, categorized into three stages:

i. pre-processing of cultivated meat;

ii. during the processing of cultivated meat;
iii. post-processing of cultivated meat.

4.1.1. Pre-processing of cultivated meat

a) Sources of animal cells

The source and animal cell extraction method for cultivated meat production involves several key steps to separate cells from the animal's tissues, such as the extraction process to obtain cells that can proliferate and differentiate before producing cultivated meat products on a large and complex industrial scale with high quality. Informant SNAM, Interview (25 July 2022), stated that there are two extraction methods: cells from slaughtered animals or biopsy methods, which do not involve slaughter, as supported by Informant SASZA, Interview (28 July 2022), Informant NA, Interview (10 August 2022), and Informant DA, Interview (2 September 2022). Additionally, Informant DA, Interview (2 September 2022) added embryonic stem cells (ESCs), adult stem cells and mesenchymal stem cells. They all agree that the source of the cells must be taken from slaughtered animals.

To produce halal cultivated meat, cells must be obtained from halal animals that have been slaughtered according to Islamic law, with the condition that the cells are still alive, and the extraction process must be carried out immediately (Chodkowska et al., 2022). Ahmad Syukran et al. (2020), Mian N Riaz & Fariha Arshad (2018), Mohammad Naqib Hamdan et al. (2017), and Mohd Izhar Ariff Mohd Kashim et al. (2023) also agree that cultivated meat can be produced from cells of animals slaughtered according to Islamic law. Messmer et al. (2022) successfully produced cultivated meat using cells from a "Belgian Blue" cattle breed and serum-free media. Furthermore, Dutta et al. (2022) also successfully produced 3D cultivated meat using animals that had already been slaughtered. These findings prove that it is possible to produce cultivated meat from the cells of animals that have been slaughtered.

The biopsy method, which involves obtaining cells while the animal is still alive, can be classified as taking a severed and separated part, and therefore, this method is considered carrion and is prohibited for consumption (Pejabat Mufti Wilayah Persekutuan, 2021). Mohammad Naqib Hamdan et al. (2019) concluded that most scholars believe that the use of cells taken from living animals is impure and forbidden to consume, similar to meat, fat, or bones severed while the animal is still alive. In addition, the biopsy method raises ethical considerations related to animal welfare as it may cause harm or discomfort to the animal (Schaefer & Savulescu, 2014). Although the cells obtained through biopsy are minimal (0.5 grams–15 grams), this method is still considered haram because the animal is not slaughtered according to Islamic law. This is consistent with the principle Al-asl baqa' ma kana 'ala ma kana (the original state remains as it was), meaning the default ruling of a halal animal that is not slaughtered is that it remains haram. In conclusion, cells taken from halal land animals must be slaughtered according to Islamic law, and the use of biopsy in cultivated meat production is prohibited.

4.1.2. Processing of cultivated meat

a) Growth Media (FBS)

The use of growth media is crucial in the production of cultivated meat to stimulate cell proliferation and differentiation. Fetal Bovine Serum (FBS) have raised ethical and halal concerns as it is from blood. Numerous studies have been conducted to replace FBS with serum-free media to avoid ethical issues and the use of animals in cultivated meat production. Serum-free media do not contain animal-derived ingredients; instead, they are made from plant-based or synthetic materials and are considered more ethical. However, serum-free media are more expensive and require a more complex formulation to replace the components found in animal serum. As a result, this technology has raised concerns among Muslim consumers regarding the use of serum or blood in the production of cultivated meat.

FBS is a liquid extracted from animal blood using separation techniques (centrifugation) to separate blood cells, platelets, and clotting factors. Typically, blood-containing serum is collected before slaughter (Mohd Kashim et al., 2017). SNAM, Interview (25 July 2022), commented that the serum used for cultivated meat production comes from cattle that may not have been slaughtered or living cattle, considered carrion in Islam. SASZA, Interview (28 July 2022), Informant NA, Interview (10 August 2022), and Informant DA, Interview (2 September 2022), agreed FBS comes from cattle fetus and is very expensive. Furthermore, this media raises halal concerns in Islam due to its origin from blood. WZ, Interview (August 24, 2022), stated that FBS is not certified halal not only because of blood but also because of unclear production process. This opinion aligns with Lee et al. (2022) study on fetal bovine serum in Food Science of Animal Resources, addressing that the ambiguity of serum components could pose risks to cells.

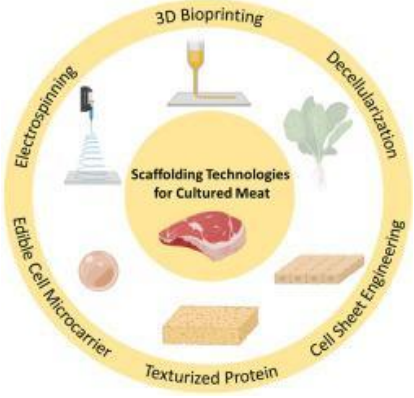
Mohammad Naqib Hamdan et al. (2017) argue that cultivated meat using serum media can be thoroughly cleaned by rinsing with water to remove the serum, likening it to the halal status of al-jallalah animals. He suggests that cultivated meat does not need to be quarantined because the serum used does not alter its physical properties (smell, taste, and color). While the serum is considered impure (najis), it undergoes a process of istihalah and transforms into cultivated meat, making it permissible for consumption. This is compared to the case of al-jallalah animals, which consume impure food. However, this view differs from Mohd Izhar Ariff Mohd Kashim et al. (2022), which examines the use of plasma blood in food products such as minced meat, fish balls, and surimi. Plasma blood contains harmful bacteria, such as Salmonella sp., which can pose health risks. Despite its use in the food industry for its ability to dissolve and emulsify, plasma blood can be detected using methods like heat treatment, immunoassay, ELISA, and PCR.

Mohd Izhar Ariff Mohd Kashim et al. (2023) analyzed the halal status of FBS for cultivated meat by detecting specific DNA in the serum using PCR analysis targeting mitochondrial cytochrome oxidase II (COII) gene sequences. Their findings showed the presence of cow DNA in all serum and plasma blood samples tested, indicating that serum does not undergo a complete transformation (*istihalah tammah*), and therefore, cultivated meat produced with FBS is haram. This is in line with the opinions of Mian N Riaz and Fariha Arshad (2018), Ahmad Syukran et al. (2020), who argue that serum, similar to blood, is impure and haram due to the lack of istihalah tammah in the transformation process. Misnu Bin Haji Taha (2021) from Islamic Council of Sarawak also issued a fatwa declaring plasma blood as haram. Cultivated meat production still uses FBS, while alternatives like serum-free media are still being researched.

b) Scaffolding

Scaffolds are crucial for cell proliferation and should be made from food-grade, edible, plant-based, or animal-free materials that promote stem cell development and nutrient supply. Porosity and mechanical properties are also important factors to consider, as it is affecting media perfusion and tissue maturation. Scaffolds should also meet the requirements of taste, texture, heat stability, nutrition, and low cost for large-scale production. Figure 4 (Levi et al., 2022) illustrates various scaffold production techniques for cultivated meat, including 3D bioprinting, decellularization, cell sheet engineering, electrospinning, texturized proteins, and edible cell microcarriers. These methods are shown to offer unique advantages in creating tissue scaffolds that support cell growth, with considerations for scalability, biocompatibility, and tissue functionality.

Figure 4: Sources of scaffold production materials in the cultivated meat industry



Source: Levi et al. (2022)

Most cultivated meat startups still use animal-derived scaffolds like gelatin. However, there are companies and researchers who have successfully developed plant-based scaffolds, such as electrospun nanofiber scaffolds from Matrix Meats, which can be tailored for various cultivated meat developments. Types of scaffolds used include hydrogels (Dutta et al., 2022; Jeong et al., 2022), collagen or gelatin (Chen et al., 2023; Lee et al., 2022; Li et al., 2022; Liu et al., 2022), decellularized extracellular matrix (ECM) (Ahmad et al., 2021; Xiang et al., 2022; Zheng, Chen, et al., 2022), and plant-based materials (Ianovici et al., 2022; Rubio et al., 2020; Zheng, Shi, et al., 2022).

Liu et al. (2022) developed a cultivated meat scaffold using PoGelat-MC gelatin combined with a dynamic bioreactor for industrial-scale production. This successfully produced cultivated pork meatballs with higher protein content than conventional meat. Jeong et al. (2022) used gelatin methacrylate hydrogel (GelMA) scaffolds produced on a centimetre scale using bioink and digital light processing (DLP), creating complex geometric structures with high precision. Park et al. (2021) explored fish gelatin microsphere powders, which enhanced myoblast proliferation and reduced serum blood use in cultivated meat production. Li et al. (2022) investigated chitosan-based scaffolds as a cheaper alternative to collagen in cultivated meat production, offering good porosity, biocompatibility, and biodegradability. Other innovative scaffolds include soy and pea protein-based scaffolds (Ianovici et al., 2022) and wheat gluten for culturing osteoblasts and mesenchymal stem cells (Xiang et al., 2022). Lee et al. (2022) discussed the development of a gelatin/agar matrix in ACS Applied Materials and Interfaces, highlighting the synergistic effect with cells for producing high-quality and low-cost options for cultivated meat. Plant-based scaffold materials are preferred for halal

cultivated meat, offering low production costs and scalability, while ensuring compliance with halal standards. Animal-based scaffolds, such as gelatin, must come from halal sources, and the use of gelatin in cultivated meat production is not recommended due to its high cost. Therefore, plant-based scaffolds are considered the most suitable and halal option.

c) Supplementary Materials

Supplementary material in producing cultivated meat includes additives (Garrett et al., 2023; Levi et al., 2022), supplements (Canal & Bauermann, 2021; Kolkmann et al., 2020), reagents (Levi et al., 2022; Zagury et al., 2022), and processing aids (Bodiou et al., 2020). Supplementary material is essential in the cell culture process, from cell selection to the final product. Cultivated meat relies on primary and supplementary materials to improve structure, texture, flavor, and color (Levi et al., 2022). Additives such as flavor agents and preservatives are added post-culturing, with cultivated meat prioritizing cell proliferation and differentiation over flavor, texture, color, or preservation like conventional food.

Informant SNAM pointed out that some of the additives such as amino acids, fatty acids, antibiotics and vitamins have halal concerns. L-cysteine can come from non-halal sources because L-cysteine can be hydrolyzed from bird feathers, human hair, or pig hair. Additionally, fatty acids and vitamins derived from animals or plants achieve the desired texture, flavor, and product profile. Antibiotics, often derived from porcine, are used to prevent contamination during cell culture. A significant issue with additives in cultivated meat is the uncertainty about their source, mainly whether they come from halal animals that have been slaughtered according to Islamic law. Cholesterol, which supports cell development and helps to resemble conventional meat, typically comes from animals, and its halal status is unclear.

In conclusion, the use of supplementary materials in cultivated meat production must be regulated for safety and halal compliance. While some have been used in conventional food, new supplementary materials like bioactive molecules, binding agents, nutrients, and animal-derived components lack a history of usage. These supplementary materials improve texture, flavor, and quality and aid in the growth of animal cells in cultivated meat production. However, due to health concerns, halal standards discourage excessive use of additives (Fadzila Azni, 2019). The framework for cultivated meat guidelines is still under discussion, with varying regulations on supplementary materials used depending on the country (FAO & WHO, 2023). Therefore, the content of supplementary materials should be carefully examined, and proof of source is necessary for halal certification.

4.1.3. Post-processing: Logistics and Packaging

The potential hazards at post-processing encompass the entire production process, including packaging and logistics. Although cultivated meat is produced in sterile conditions, contamination can still occur during transportation, distribution, or due to low-quality packaging materials (Siddiqui et al., 2022). Cross-contamination between halal and non-halal products is a significant concern in the halal food industry (Syifa' Zainal Arifin et al., 2021). Packaging plays a crucial role in maintaining quality, and packaging technologies must be adapted to the nature of cultivated meat to prevent damage such as oxidation and color changes. Siddiqui et al. (2022) highlight packaging technologies like modified atmosphere packaging (MAP), vacuum packaging, and active packaging to prevent physical, chemical, and biological contamination. Current packaging

methods follow existing food safety regulations like HACCP and GMP (FAO & WHO, 2023). Halal standards also apply to all supply chain activities, including transportation, warehousing, and retail, with logistics posing a hidden potential hazard to halal integrity due to the potential mixing of halal and non-halal products and biological, chemical, or physical hazards (Rohana Sham, Raja Zuraidah Rasi & Suhana Mohamed, 2017; Setiyawan Gunardi, 2023).

4.2. Strategies for Managing Potential Hazards at Halal Control Points (HCP) in the Halal Risk Management Plan for Cultivated meat.

The strategy for managing potential hazards in the production of cultivated meat aims to prevent halal contamination by ensuring that the production process adheres to religious guidelines and safety standards. According to Informant RCW, Interview (21 August 2022), cultivated meat companies should develop a halal system in accordance with the Malaysian Halal Management System (MHMS), 2020 based on the actual operations of cultivated meat production (Jabatan Kemajuan Islam Malaysia [JAKIM], 2020). The development of MHMS is divided into two components: (i) Internal Halal Control System (IHCS) and (ii) Halal Assurance System (HAS), which are tailored to the size of the industry, as shown in Figure 5. The industry must establish a system to identify Halal Control Points (HCP) and a halal risk management plan.

Figure 5: Requirements for halal companies according to Malaysian Halal Management System 2020.

Source: Jabatan Kemajuan Islam Malaysia (JAKIM) (2020)

4.2.1. Raw Material Control

Raw material control is essential in the production of cultivated meat to prevent contamination and ensure compliance with halal standards. According to the Malaysian Halal Management System (MHMS), the industry must develop procedures for controlling raw materials, including purchasing, receiving, and storage processes (Jabatan Kemajuan Islam Malaysia [JAKIM], 2020). This ensures that materials used in cultivated meat production are halal and in compliance with regulations (Jabatan Kemajuan Islam Malaysia [JAKIM], 2020). Companies are required to maintain a "Raw Material Master List" record for inspection during halal certification audits. Informant SNAM, Interview (25 July 2022), emphasizes the importance of verifying halal certification and supporting

documents, such as Material Safety Data Sheets, to ensure the halal status of raw materials. This applies to supplementary materials, including nutrients, amino acids, antibiotics, vitamins, and minerals.

Informant RCW, Interview (21 August 2022), suggests that raw material control should begin at the research and development (R&D) stage, allowing the industry to ensure halal compliance from the beginning of the cultivated meat production process. Early control at R&D helps identify potential hazards, such as non-slaughtered animal cell sources, non-halal growth media, and additives. This stage also helps develop strict quality monitoring and control methods. Halal executives are responsible for reviewing and examining the materials used, especially critical ones, and companies should select suppliers who can provide valid halal documentation. This aligns with MHMS 2020 guidelines for R&D products that are ready for commercialization but must meet specific halal criteria.

Cultivated meat production heavily relies on animal-derived ingredients, such as growth medium and supplementary materials. Despite efforts to replace animal sources with plant-based or synthetic alternatives, halal issues arise due to the difficulty in obtaining halal certification documents. Therefore, raw material control procedures are crucial for managing potential risks at the Halal Control Points (HCP) to prevent the use of non-halal materials.

4.2.2. The development of Halal risk control

The development of halal risk control is a strategy for managing potential hazards at Halal Control Points (HCP) in the halal risk management plan for cultivated meat production. According to Informant RCW, Interview (21 August 2022), all cultivated meat companies must establish internal halal risk control to identify HCPs and create a halal risk management plan that effectively manages halal risks throughout the supply chain. Additionally, potential risks related to halal integrity involve unforeseen events that could contaminate products, from raw materials to consumers. These risks can occur at various supply chain stages, such as procurement, production, and logistics (Tieman, 2017).

According Malaysian Halal Management System (MHMS), there are eight (8) halal risk control procedures: research and development (R&D), products, processing, premises, workers, packaging, storage, and transportation (Jabatan Kemajuan Islam Malaysia [JAKIM], 2020). Halal risk management should be documented in the Halal Control Point Analysis Worksheet and the Halal Risk Management Plan. Potential hazards like cross-contamination with non-halal materials or the use of contaminated equipment must be assessed using a risk matrix. The Halal Control Point Analysis Worksheet evaluates the likelihood and impact of potential hazards, determining which requires strict control. Cultivated meat companies must comply with Manual Prosedur Pensijilan Halal Malaysia (MPPHM) (Domestik) 2020 and Malaysian Halal Management System (MHMS) 2020 to ensure proper halal certification.

The Halal Control Point Analysis Worksheet identifies and assesses whether the potential hazard poses a significant or high risk. The Department of Standards Malaysia (2019) established the MS 2400-1:2019, 2400-2:2019 and 2400-3:2019 standard for halal supply chain management, specifically addressing the transportation, warehousing & retailing requirements to ensure halal compliance in logistics and handling processes. The Halal risk assessment will refer to the halal risk matrix table according to the MS 2400-1:2019, 2400-2:2019 and 2400-3:2019 standard, considering two variables: the likelihood of the

hazard occurring and its impact. According to the Decision Rules Table 2, a risk matrix score of 7, 8, and 9 is identified as a Halal Control Point (HCP) that requires strict control. Hazards within this range are considered critical due to their high likelihood and profound impact on the product halal status. High-risk hazards will be set as HCPs and controlled in the Halal Risk Management Plan Table. Examples of potential hazards include cross-contamination with non-halal or the use of contaminated equipment. The risk level is evaluated based on the likelihood and consequences, as shown in Table 3, and the risk analysis results serve as the basis for determining how potential hazards should be managed based on MS 2400-1:2019, 2400-2:2019 and 2400-3:2019 standard (Department of Standards Malaysia, 2019).

Table 2: Risk matrix table to determine the potential hazards.

Likelihood	**Severity/Impact**					
	Insignificant		**Moderate**		**Critical**	
Likely	Moderate	4	Significant	7	High	9
Moderate	Low	2	Moderate	5	Significant	8
Unlikely	Low	1	Low	3	Moderate	6

Source: Department of Standards Malaysia (2019)

Table 3: Halal severity/impact to determine the potential hazards.

Halal Severity/ Impact	**Description**
Critical	The potential contaminant (non-halal materials or detrimental *(mudhorat)* substances) affects the totality of halal status of the products and/ or goods and the halal status of the products and/ or goods could not be salvaged. Release of the products and/ or goods will result in loss of trust from customers, public and authorities. May cause great impact for future business transactions.
Moderate	The potential contaminant (non-halal materials or detrimental *(mudhorat)* substances) affects the halal status of the products and/ or goods still could be salvaged. May result in delay of delivery or shipment and potential loss of future contracts, possible loss of public trust.
Insignificant	No impact on the halal status of the products and/ or goods.

Source: Department of Standards Malaysia (2019)

The likelihood scale refers to the likelihood that it will happen and is determined using qualitative levels such as likely, moderate and unlikely as a percentage of probability (Nor Azizah Jasman & Nor Hapiza Mohd Ariffin, 2024), as shown in Table 4.

The Halal Risk Management Plan, based on MHMS (2020) Section 5 General Requirements of HAS, Clause 6.2, is developed by determining the Halal Control Points (HCP) for cultivated meat, which includes: i) Halal Control Points, ii) Halal risks, iii) Control mechanisms (methods, frequency, responsible parties), iv) Corrective actions, and v) Records. Cultivated meat companies must implement all requirements outlined in

MPPHM 2020 and MHMS 2020, and according to Informant RCW (2022), the development of MHMS for these companies is also subject to their company categories. Currently, there are no specific guidelines for cultivated meat in Malaysia.

Table 4: Likelihood to determine the potential hazards.

Likelihood	Description
Likely	The possibility of halal status affected expected to occur in most circumstances. Common or repeated occurrence, has happened before several times.
Moderate	The possibility of halal status affected might occur sometimes. Known to occur, happened before.
Unlikely	The possibility of halal status affected could occur in exceptional circumstances. Practically impossible.

Source: Department of Standards Malaysia (2019)

5. Conclusion

Cultivated meat products offer positive aspects such as reducing the risk of animal diseases, food resource usage, and the need for animal farming space. Cultivated meat is produced solely from animal cells and can be cultivated in large quantities with minimal resources. However, since this product is still new, detailed studies on the health effects of consuming cultivated meat on public health are still lacking.

The potential harm of cultivated meat products must be examined, including the source of animal cells, growth media, and additives. The entire product will be deemed non-halal if the animal cells are derived from a non-halal source. Furthermore, safety risks, such as the potential for cancerous cells, also need to be considered. Therefore, cultivated meat production requires strict control to ensure halal compliance and safety at every production stage.

The success of cultivated meat is seen when the product closely resembles conventional meat's form, taste, and nutrients. The production process for cultivated meat is still in its early stages, and many safety and halal factors need to be studied. Key issues for cultivated meat include halal control and safety, large-scale production, avoiding cancerous cells, and preventing diseases or contamination in the animal cells used. While technical and safety issues in cultivated meat may be resolved in the near future, halal aspects require time, research, and development because non-Muslims spearheaded the technology. Therefore, halal strategies and guidelines need to be created and aligned with cultivated meat technology.

The strategies for managing potential hazard at HCPs in the halal risk management plan for cultivated meat need to be focused on at present include company and authority commitment and responsibility, raw material control, and the development of halal risk control. It is hoped that the proposed halal strategies will assist in creating halal cultivated meat, while also facilitating authorities in inspecting the production process.

Ethics Approval and Consent to Participate

The researchers used the research ethics provided by the Research Ethics Committee of Universiti Teknologi MARA (REC UiTM). All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional research committee. Informed consent was obtained from all participants according to the Declaration of Helsinki.

Acknowledgement

Part of this article was extracted from a master's thesis submitted to Universiti Teknologi MARA, Shah Alam, Malaysia.

Funding

This study received no funding.

Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

References

Ahmad, K., Lim, J., Lee, E., Chun, H., Ali, S., Ahmad, S. S., Shaikh, S., & Choi, I. (2021). Extracellular matrix and the production of cultured meat. *MDPI*, *10*(3116), 1–14. https://doi.org/10.3390/foods10123116

Ahmad Syukran Baharuddin, Mohd Ifwat Mohd Ghazali, Mohammad Amir Wan Harun, Lukman Abdul Mutalib, Wan Abdul Fattah Wan Ismail, Sharifudin Md. Shaarani, Muhammad Syafiq Alauddin, & Mohamed Faiz Asyraf Razali. (2020). Three-Dimensional (3D) printed halal meat: Do we need a new regulatory framework? *Insla E-Proceedings*, *3*(1), 438–449. https://insla.usim.edu.my/index.php/eproceeding/article/view/49

Balasubramanian, B., Liu, W., Pushparaj, K., & Park, S. (2021). The epic of in vitro meat production—A fiction into reality. *Foods, 10*(6), 1395. https://doi.org/10.3390/foods10061395

Bhat, Z. F., Kumar, S., & Fayaz, H. (2015). In vitro meat production: Challenges and benefits over conventional meat production. *Journal of Integrative Agriculture*, *142*(2), 241–248. https://www.sciencedirect.com/science/article/pii/S209531191460887X

Bodiou, V., Moutsatsou, P., & Post, M. J. (2020). Microcarriers for upscaling cultured meat production. *Frontiers in Nutrition*, *7*(February), 1–16. https://doi.org/10.3389/fnut.2020.00010

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77– 101. https://doi.org/10.1191/1478088706qp063oa

Canal, W., & Bauermann, F. V. (2021). Virome characterization in commercial bovine serum batches - A potentially needed testing strategy for biological products. *Viruses 2021*, *13*(12), 1–14. https://doi.org/10.3390/v13122425

Catts, O., & Zurr, I. (2003). *Disembodied Cuisine*. Tcaproject. https://tcaproject.net/portfolio/disembodied-cuisine/

Chen, L., Guttieres, D., Koenigsberg, A., Barone, P. W., Sinskey, A. J., & Springs, S. L. (2022). Large-scale cultured meat production: Trends, challenges and promising biomanufacturing technologies. *Biomaterials*, *280*(121274), 1–13. https://doi.org/10.1016/j.biomaterials.2021.121274

Chen, X., Li, L., Chen, L., Shao, W., Chen, Y., Fan, X., Liu, Y., Tang, C., Ding, S., Xu, X., Zhou, G., & Feng, X. (2023). Tea polyphenols coated sodium alginate-gelatin 3D edible scaffold for cultured meat. *Food Research International*, *173*(P1), 113267. https://doi.org/10.1016/j.foodres.2023.113267

Chodkowska, K. A., Wódz, K., & Wojciechowski, J. (2022). Sustainable future protein foods: The challenges and the future of Cultivated Meat. *Foods*, *11*(24). https://doi.org/10.3390/foods11244008

Ching, X. L., Zainal, N. A. A. B., Luang-In, V., & Ma, N. L. (2022). Lab-based meat the future food. *Environmental Advances,* *10*(November), 100315. https://doi.org/10.1016/j.envadv.2022.100315

Department of Standards Malaysia. (2019). *MS 2400-1:2019: Halal supply chain management system - Part 1: Transportation - General requirements* (First revision). *Department of Standards Malaysia*. Department of Standards Malaysia

Dutta, S. D., Ganguly, K., Jeong, M. S., Patel, D. K., Patil, T. V., Cho, S. J., & Lim, K. T. (2022). Bioengineered lab-grown meat-like constructs through 3D bioprinting of antioxidative protein hydrolysates. *ACS Applied Materials and Interfaces*, *14*(30), 34513–34526. https://doi.org/10.1021/acsami.2c10620

Fadzila Azni Ahmad. (2019). Beyond Halal in food product : Present and future of Halalan Tayyiban. *Review of Integrative Business and Economics Research*, *7*(Supplementary Issue 2). https://doi.org/2304-1013

FAO & WHO. (2023). *Food safety aspects of cell-based food*. FAO; WHO; https://doi.org/10.4060/cc4855en

Fernandes, A. M., Teixeira, O. de S., Revillion, J. P., & Souza, Â. R. L. de. (2022). Beef as a socio-cultural identity: Rural and urban consumers' attitudes from Rio Grande do sul, Brazil, facing cultured beef. *Journal of Rural Studies*, *95*(October), 438–448. https://doi.org/10.1016/j.jrurstud.2022.09.035

Garrett, A., Avegnon, K. L. M., Delbreilh, L., Segurola, J., Delpouve, N., & Sealy, M. P. (2023). Enzymatic degradation and ageing of additively manufactured soy-based scaffolds for cell-cultured meat. *CIRP Annals*, *72*(1), 149–152. https://doi.org/10.1016/j.cirp.2023.04.020

Ianovici, I., Zagury, Y., Redenski, I., Lavon, N., & Levenberg, S. (2022). 3D-printable plant protein-enriched scaffolds for cultivated meat development. *Biomaterials*, *284*(May 2021), 121487. https://doi.org/10.1016/j.biomaterials.2022.121487

Jabatan Kemajuan Islam Malaysia (JAKIM). (2020). *Sistem pengurusan halal Malaysia* [Malaysian Halal Management System]. Jabatan Kemajuan Islam Malaysia.

Jeong, D., Seo, J. W., Lee, H. G., Jung, W. K., Park, Y. H., & Bae, H. (2022). Efficient myogenic/adipogenic transdifferentiation of bovine fibroblasts in a 3D bioprinting system for steak-type cultured meat production. *Advanced Science*, *9*(31), 1–16. https://doi.org/10.1002/advs.202202877

Kolkmann, A. M., Post, M. J., Rutjens, M. A. M., van Essen, A. L. M., & Moutsatsou, P. (2020). Serum-free media for the growth of primary bovine myoblasts. *Cytotechnology*, *72*(1), 111–120. https://doi.org/10.1007/s10616-019-00361-y

Kumar, P., Sharma, N., Sharma, S., & Mehta, N. (2021). *In-vitro meat : a promising solution for sustainability of meat sector*. *63*(4), 693–724. https://doi.org/10.5187/jast.2021.e85

Lee, D. Y., Lee, S. Y., Yun, S. H., Jeong, J. W., Kim, J. H., Kim, H. W., Choi, J. S., Kim, G.-D., Joo, S. T., Choi, I., & Hur, S. J. (2022). Review of the current research on fetal bovine serum

and the development of cultured meat. *Food Science of Animal Resources*, *42*(5), 775–799. https://doi.org/10.5851/kosfa.2022.e46

Lee, M., Park, S., Choi, B., Kim, J., Choi, W., Jeong, I., Han, D., Koh, W. G., & Hong, J. (2022). Tailoring a gelatin/agar matrix for the synergistic effect with cells to produce high-quality cultured meat. *ACS Applied Materials and Interfaces*, *14*(33), 38235–38245. https://doi.org/10.1021/acsami.2c10988

Leung, A. K. y., Chong, M., Fernandez, T. M., & Ng, S. T. (2023). Higher well-being individuals are more receptive to cultivated meat: An investigation of their reasoning for consuming cultivated meat. *Appetite*, *184*(November 2022), 106496. https://doi.org/10.1016/j.appet.2023.106496

Levi, S., Yen, F.-C., Baruch, L., & Machluf, M. (2022). Scaffolding technologies for the engineering of cultured meat: Towards a safe, sustainable, and scalable production. *Trends in Food Science & Technology*, *126*(May), 13–25. https://doi.org/10.1016/j.tifs.2022.05.011

Li, L., Chen, L., Chen, X., Chen, Y., Ding, S., Fan, X., Liu, Y., Xu, X., Zhou, G., Zhu, B., Ullah, N., & Feng, X. (2022). Chitosan-sodium alginate-collagen/gelatin three-dimensional edible scaffolds for building a structured model for cell cultured meat. *International Journal of Biological Macromolecules*, *209*(PA), 668–679. https://doi.org/10.1016/j.ijbiomac.2022.04.052

Liu, Y., Wang, R., Ding, S., Deng, L., Zhang, Y., Li, J., Shi, Z., Wu, Z., Liang, K., Yan, X., Liu, W., & Du, Y. (2022). Engineered meatballs via scalable skeletal muscle cell expansion and modular micro-tissue assembly using porous gelatin micro-carriers. *Biomaterials*, *287*(June), 121615. https://doi.org/10.1016/j.biomaterials.2022.121615

Mancini, M. C., & Antonioli, F. (2022). Italian consumers standing at the crossroads of alternative protein sources: Cultivated meat, insect-based and novel plant-based foods. *Meat Science*, *193*(March), 108942. https://doi.org/10.1016/j.meatsci.2022.108942

Messmer, T., Klevernic, I., Furquim, C., Ovchinnikova, E., Dogan, A., Cruz, H., Post, M. J., & Flack, J. E. (2022). A serum-free media formulation for cultured meat production supports bovine satellite cell differentiation in the absence of serum starvation. *Nature Food*, *3*(1), 74–85. https://doi.org/10.1038/s43016-021-00419-1

Mian N Riaz, & Fariha Arshad. (2018). Clean meat, opportunities, challenges and its halal status. *Scientific Conference WHS 2018 Clean*, 97–100. https://doi.org/ISBN 978-605-68962-0-0 (eBook)

Misnu Bin Haji Taha, D. H. (2021). *Fatwa hukum penggunaan plasma darah dalam makanan - Sarawak Government Gazette 1938*. Jabatan Mufti Negeri Sarawak.

Mohammad Naqib Hamdan. (2018). *Analisis hukum taghyir khalqillah dalam fatwa perubatan badan fatwa terpilih* [Master's thesis, Universiti Malaya]. *http://studentsrepo.um.edu.my/11397/*

Mohammad Naqib Hamdan, Post, Mohd Anuar Ramli, & Amin Rukaini Mustafa. (2017). Cultured meat in Islamic perspective. *Journal of Religion and Health*, *57*(6), 2193–2206. https://doi.org/10.1007/s10943-017-0403-3

Mohammad Naqib Hamdan, & Mohd Anuar Ramli. (2016). Daging kultur menurut perspektif Islam: Analisis terhadap penggunaan ESCs sebagai sumber sel stem Cultured meat in Islamic perspective: An analysis to the use of ESCs as source of stem cell. *Global Journal Al-Thaqafah*, *6*(2), 129–141. https://doi.org/10.7187/gjat11920160602

Mohammad Naqib Hamdan, Mohd Anuar Ramli, & Azman Ab Rahman. (2019). Penggunaan sel stem dalam pengkulturan daging: Analisis menurut perspektif hukum Islam The use of stem cells in cultured meat: Analysis according to Islamic

law perspective. *Journal of Fatwa Management and Research*, *18*(October), 8–24. https://doi.org/10.33102/jfatwa.vol18no1.2

Mohammad Naqib Hamdan, Mohd Anuar Ramli, Nek Mohd Farid Zaman Huri, Nur Najwa Hanani Abd Rahman, & Akmaliza Abdullah. (2021). Will Muslim consumers replace livestock slaughter with cultured meat in the market? *Trends in Food Science and Technology*, *109*(June 2020), 729–732. https://doi.org/10.1016/j.tifs.2021.01.034

Mohammad Naqib Hamdan, Post, M., Mohd Anuar Ramli, Mohd Khairy Kamarudin, Mohd Farhan Md Ariffin, & Nek Mohd Farid Zaman Huri. (2021). Cultured meat: Islamic and other religious perspectives. *UMRAN - International Journal of Islamic and Civilizational Studies*, *8*(2), 11–19. https://doi.org/10.11113/umran2021.8n2.475

Mohammad Shahadat Hossain. (2019). Consumption of stem cell meat: An Islamic perspective. *IIUM Law Journal*, *27*(1), 233–257. https://doi.org/10.31436/iiumlj.v27i1.384

Mohd Farhan Md Ariffin, Nurul Syahadah Mohd Riza, Mohammad Fahmi Abdul Hamid, Fareed Awae, & Badlihisham Mohd Nasir. (2021). Halal food crime in Malaysia: An analysis on illegal ceat Cartel issues. *Journal of Contemporary Issues in Business and Government*, *27*(02), 1408–1412. https://doi.org/10.47750/cibg.2021.27.02.152

Mohd Izhar Ariff Mohd Kashim, Alia Aryssa Abdul Haris, Nur Asmadayana Hasim, Sahilah Abd Mutalib, & Nurina Anuar. (2022). Species-specific Deoxyribonucleic Acid (DNA) identification of bovine in cultured meat serum for halal status. *Foods*, *11*(20), 3235. https://doi.org/10.3390/foods11203235

Mohd Izhar Ariff Mohd Kashim, Alia Aryssa Abdul Haris, Sahilah Abd. Mutalib, Nurina Anuar, & Safiyyah Shahimi. (2023). Scientific and islamic perspectives in relation to the Halal status of cultured meat. *Saudi Journal of Biological Sciences*, *30*(1), 103501. https://doi.org/10.1016/j.sjbs.2022.103501

Mohd Kashim, M. I. A., Hasim, N. A., Othaman, R., Yahaya, M. Z., Khalid, R., Samsudin, M. A., & Mat Zin, D. M. (2017). Plasma darah dalam makanan daripada perspektif Islam dan sains. *Sains Malaysiana*, *46*(10), 1779–1787. https://doi.org/10.17576/jsm-2017-4610-15

Moritz, J., Tuomisto, H. L., & Ryynänen, T. (2022). The transformative innovation potential of cellular agriculture: Political and policy stakeholders' perceptions of cultured meat in Germany. *Journal of Rural Studies*, *89*, 54–65. https://doi.org/10.1016/j.jrurstud.2021.11.018

Majlis Ugama Islam Singapura (MUIS). (2024). *Fatwa on cultivated meat*. MUIS: Majlis Ugama Islam Singapura. https://www.muis.gov.sg/Media/Media-Releases/2024/2/3-Feb-24-Fatwa-on-Cultivated-Meat

Nor Azizah Jasman, & Nor Hapiza Mohd Ariffin. (2024). Risk factors analysis in halal supply chain management system. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *46*(2), 213–226. https://doi.org/10.37934/araset.46.2.213226

Orzechowski, A. (2015). Artificial meat? Feasible approach based on the experience from cell culture studies. *Journal of Integrative Agriculture*, *14*(2), 217–221. https://doi.org/10.1016/S2095-3119(14)60882-0

Park, S., Jung, S., Choi, M., Lee, M., Choi, B., Koh, W.-G., Lee, S., & Hong, J. (2021). Gelatin MAGIC powder as nutrient-delivering 3D spacer for growing cell sheets into cost-effective cultured meat. *Biomaterials*, *278*(June), 121155. https://doi.org/10.1016/j.biomaterials.2021.121155

Pejabat Mufti Wilayah Persekutuan. (2021). *Irsyad al-fatwa siri ke-595-daging kultur (cultured meat) menurut perspektif syarak*. Pejabat Mufti Wilayah Persekutuan. https://muftiwp.gov.my/en/artikel/irsyad-fatwa/irsyad-fatwa-umum-cat/4887-

irsyad-al-fatwa-siri-ke-595-daging-kultur-cultured-meat-menurut-perspektif-syarak

Post, M. J. (2012). Cultured meat from stem cells: Challenges and prospects. *Meat Science*, *92*(3), 297–301. https://doi.org/10.1016/j.meatsci.2012.04.008

Post, M. J. (2014). An alternative animal protein source: cultured beef. *Annals of the New York Academy of Sciences*, *1328*(1), 29–33. https://doi.org/10.1111/nyas.12569

Qotadah, H. A., Al Anshory, A. C., Achmad, A. D., & Syarifah, M. (2022). Cultured meat for Indonesian muslim communities: A review of maslahah and prospect. *Al-Istinbath : Jurnal Hukum Islam*, *7*(2), 337. https://doi.org/10.29240/jhi.v7i2.5476

Ramani, S., Ko, D., Kim, B., Cho, C., Kim, W., Jo, C., Lee, C. K., Kang, J., Hur, S., & Park, S. (2021). Technical requirements for cultured meat production: A review. *Journal of Animal Science and Technology, 63*(4), 681–692. https://doi.org/10.5187/jast.2021.e45

Reza Adnan, M. R. A., Mohd Fadzil, S. D. N., Baharuddin, A. S., & Wan Harun, M. A. (2021). Cultured meat as halalan toyyiban food: A maqasid review in the preservation of life. *Food Research*, *5*(5), 174–178. https://doi.org/10.26656/FR.2017.5(5).161

Rodríguez Escobar, M. I., Cadena, E., Nhu, T. T., Cooreman-Algoed, M., De Smet, S., & Dewulf, J. (2021). Analysis of the cultured meat production system in function of its environmental footprint: Current status, gaps and recommendations. *Foods*, *10*(12), 2941. https://doi.org/10.3390/foods10122941

Rohana Sham, Raja Zuraidah Rasi, N. A., & Suhana Mohamed. (2017). Halal logistics implementation in Malaysia: A practical view. *IOP Conference Series: Materials Science and Engineering, 226*(1), 012040. *https://doi.org/10.1088/1757-899X/226/1/012040*

Rubio, N. R., Xiang, N., & Kaplan, D. L. (2020). Plant-based and cell-based approaches to meat production. *Nature Communications*, *11*(1), 1–12. https://doi.org/10.1038/s41467-020-20061-y

Schaefer, G. O., & Savulescu, J. (2014). The ethics of producing In Vitro Meat. *Journal of Applied Philosophy*, *31*(2), 188–202. https://doi.org/10.1111/japp.12056

Setiyawan Gunardi. (2023). The Role of Shari'ah Principles in Guaranteeing Halal Logistics: A Review. *Halalpshere*, *3*(1), 40–46. https://doi.org/10.31436/hs.v3i1.36

Siddiqui, S. A., Bahmid, N. A., Karim, I., Mehany, T., Gvozdenko, A. A., Blinov, A. V., Nagdalian, A. A., Arsyad, M., & Lorenzo, J. M. (2022). Cultured meat: Processing, packaging, shelf life, and consumer acceptance. *LWT*, *172*(July), 114192. https://doi.org/10.1016/j.lwt.2022.114192

Syifa' Zainal Arifin, Anis Najiha Ahmad, Yumi Zuhanis Has-Yun Hashim, Nur Hanie Mohd Latif, Haruna Babatunde Jaiyeoba, Nurhusna Samsudin, & Mohd Said, N. (2021). Positioning HalalanToyyiban in halal food system: Production, processing, consumption, marketing, logistic and waste management. *Halalpshere*, *1*(2), 17–40. https://doi.org/10.31436/hs.v1i2.30

The Star. (2021, April 22). Brunei seizes over 4,000kg of dubious meat. *The Star*. https://www.thestar.com.my/aseanplus/aseanplus-news/2021/04/22/brunei-seizes-over-4000kg-of-dubious-meat

Tieman, M. (2017). Halal risk management: Combining robustness and resilience. *Journal of Islamic Marketing*, *8*(3), 461–475. https://doi.org/10.1108/JIMA-06-2015-0041

Xiang, N., Yuen, J. S. K., Stout, A. J., Rubio, N. R., Chen, Y., & Kaplan, D. L. (2022). 3D porous scaffolds from wheat glutenin for cultured meat applications. *Biomaterials*, *285*(May 2021), 121543. https://doi.org/10.1016/j.biomaterials.2022.121543

Ye, Y., Zhou, J., Guan, X., & Sun, X. (2022). Commercialization of cultured meat products: Current status, challenges, and strategic prospects. *Future Foods*, *6*(August 2022), 100177. https://doi.org/10.1016/j.fufo.2022.100177

Zagury, Y., Ianovici, I., Landau, S., Lavon, N., & Levenberg, S. (2022). Engineered marble-like bovine fat tissue for cultured meat. *Communications Biology*, *5*(1), 1–12. https://doi.org/10.1038/s42003-022-03852-5

Zhang, C., Guan, X., Yu, S., Zhou, J., & Chen, J. (2022). Production of meat alternatives using live cells, cultures and plant proteins. *Current Opinion in Food Science*, *43*(2022), 43–52. https://doi.org/10.1016/j.cofs.2021.11.002

Zheng, Y. Y., Chen, Y., Zhu, H. Z., Li, C. B., Song, W. J., Ding, S. J., & Zhou, G. H. (2022). Production of cultured meat by culturing porcine smooth muscle cells in vitro with food grade peanut wire-drawing protein scaffold. *Food Research International*, *159*(June), 111561. https://doi.org/10.1016/j.foodres.2022.111561

Zheng, Y. Y., Shi, Y. F., Zhu, H. Z., Ding, S. J., & Zhou, G. H. (2022). Quality evaluation of cultured meat with plant protein scaffold. *Food Research International*, *161*(August), 111818. https://doi.org/10.1016/j.foodres.2022.111818

Zuhaib Bhat, & Sunil Kumar. (2021). 3D printing: Development of animal products and special foods. *Trends in Food Science and Technology*, *118*(October), 87–105. https://doi.org/10.1016/j.tifs.2021.09.020