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HALAL CERTIFICATION OF CULTIVATED MEAT IN SINGAPORE: A HALAL GOVERNANCE AND REGULATORY READINESS (HGRRA) FRAMEWORK

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ABSTRACT

Cultivated meat, produced through cellular agriculture, offers potential benefits for sustainability, food security, and ethical consumption, yet it also presents complex halal-certification challenges, particularly in Muslim-minority contexts where religious authority and scientific regulation must be closely integrated. This study develops and applies the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework to assess Singapore's preparedness for the halal certification of cultivated meat. Using a qualitative doctrinal and document-based approach, the study analyses statutory provisions, the 2024 MUIS fatwa, halal-assurance manuals, food-safety guidelines, and scholarly literature published between 2019 and 2026. The HGRRA evaluates governance maturity across six domains: Legal Mandate, *Sharīʿah* Framework, Technical Expertise, Infrastructure, Stakeholder Engagement, and International Alignment, using a four-tier continuum. The findings place Singapore at Tier 3: Structured Readiness, with strengths in legal authority, doctrinal clarity, and coordinated regulatory oversight, but also with limitations in biotechnology-specific audit mechanisms, laboratory capacity, and institutionalised stakeholder-engagement structures. Advancing towards Tier 4: Managed Readiness will require the operationalisation of fatwa conditions within HalMQ, the accreditation of halal-relevant biotechnology laboratories, the enhancement of auditors' scientific competencies, and the promotion of regional harmonisation of halal-biotechnology standards. This study demonstrates the adaptability of *Sharīʿah* principles to emerging food systems and proposes a structured, *maqāṣid*-informed governance model, thereby offering halal authorities a systematic framework for navigating biotechnological innovation and supporting the development of coherent, future-oriented regulatory systems for cellular-agriculture products.

Introduction

Cultivated meat, produced through cellular agriculture, represents an emerging development in contemporary food biotechnology. In this process, animal cells are isolated and grown in controlled bioreactor environments to generate edible muscle tissue without the need for conventional animal rearing or slaughter (Ge et al., 2023; Lee J. et al., 2024; Xu et al., 2024). Advances in bioprocess engineering, including serum-free media optimisation, scaffold development, and scalable bioreactor systems, have accelerated its technical feasibility and commercial exploration (Kulus et al., 2023; Wang et al., 2023; FAO & WHO, 2023). Although cultivated meat is frequently framed as a sustainable alternative that can reduce environmental pressures and enhance supply-chain resilience (Post et al., 2020; Zhang et al., 2020; Verma & Singh, 2023), its regulatory, ethical, and religious implications remain subject to ongoing debate.

For Muslim consumers, however, cultivated meat introduces novel theological considerations. Classical Islamic dietary law (*aḥkām al-aṭʿimah*) requires that meat originate from permissible species slaughtered according to prescribed rituals (Khallāf, 1956; Al-Qaradawi, 1994). Broader jurisprudential principles such as *ṭahārah* (purity), *istiḥālah* (substantive transformation), *istiḥlāk* (dilution), and the higher objectives of the Sharīʿah (*Maqāṣid al-Sharīʿah*) also guide determinations of food permissibility (Ibn ʿĀshūr, 2022; Qaradawi, 2022; Anisa, 2024; Amrulloh & Zaman, 2024; Yusuf et al., 2023). In the context of cultivated meat, questions arise as to whether cellular proliferation outside the living animal constitutes a continuation of the original organism or a transformed substance, and whether the absence of ritual slaughter affects its legal status. Accordingly, permissibility cannot be resolved through simple analogy to conventional meat production; rather, it requires an integrated assessment combining Islamic legal reasoning, expert scientific testimony, and institutional fatwa deliberation (Hamdan et al., 2024; Kashim et al., 2024).

Singapore provides a timely case study for examining halal governance in relation to novel foods. As a Muslim-minority jurisdiction, halal certification is administered centrally by the Islamic Religious Council of Singapore (MUIS), empowered under Section 88A of the Administration of Muslim Law Act (AMLA) to regulate halal standards and certification. At the same time, Singapore was the first country to approve the commercial sale of cultivated meat under the Singapore Food Agency's Novel Food Framework (Lavars, 2020; Tay, 2020; Oi, 2020; Waltz, 2021; Singapore Food Agency, 2025). This dual regulatory architecture, in which secular food-safety approval precedes or operates independently of religious certification, raises important governance questions about inter-agency coordination and institutional capacity. In 2024, MUIS issued a pioneering fatwa outlining the *Sharīʿah* conditions for the permissibility of cultivated meat, including requirements relating to cell sourcing and production inputs, signalling doctrinal responsiveness while also exposing practical challenges in translating juristic principles into auditable certification standards (Kabalan, 2025; MUIS, 2024; Hamdan et al., 2024).

Despite growing global discourse on cultivated meat, scholarship remains fragmented across disciplinary boundaries. Scientific research primarily evaluates technological feasibility; Islamic legal scholarship examines questions of permissibility; and governance studies largely focus on conventional halal certification systems in Muslim-majority jurisdictions (Rejeb et al., 2021; Soon et al., 2023; Hadi & Dahlan, 2024;). However, limited research has systematically assessed institutional readiness for halal certification of cultivated meat within an integrated governance framework. In particular, existing studies have yet to operationalise a structured, maturity-based model that evaluates legal mandates, *Sharīʿah* governance mechanisms, technical capacity, institutional infrastructure, stakeholder coordination, and international regulatory alignment in a Muslim-minority context.

Responding to this gap, this article introduces and applies the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework, a diagnostic model designed to evaluate the degree of institutional preparedness for the halal certification of novel biotechnological products in Singapore (Suhartini et al., 2024). Specifically, this article seeks:

i. To examine the statutory, theological, and institutional regulatory structures governing the halal certification of cultivated meat in Singapore, with particular attention to coordination between MUIS and the Singapore Food Agency (SFA).

ii. To develop and apply the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework as a structured diagnostic model for evaluating institutional readiness in halal-biotechnology governance; and

iii. To formulate evidence-based policy recommendations for MUIS, the SFA, and relevant regional halal authorities in order to strengthen the governance of cultivated meat and related biotechnological innovations in alignment with the objectives of *Maqāṣid al-Sharīʿah*.

The article proceeds in five parts. The next section reviews existing scholarship on cultivated meat, *Sharīʿah* governance, and contemporary halal regulatory frameworks, thereby establishing the conceptual foundations for the HGRRA framework. The following section then outlines the doctrinal legal analysis and systematic review of statutory, fatwa, and policy documents underpinning the study. The subsequent section presents the findings derived from applying the HGRRA framework to Singapore's halal governance architecture, identifying areas of institutional strength and regulatory gaps. The discussion analyses the broader implications of these findings for halal certification authorities within and, where relevant, beyond Southeast Asia. The article concludes with policy recommendations and avenues for future research on halal governance in the context of emerging food biotechnologies.

Literature Review

Cultivated meat, also referred to as cell-based or lab-grown meat, is produced by isolating stem or progenitor cells from an animal and proliferating them in nutrient-rich media under controlled bioreactor conditions until edible muscle tissue is formed (Ge et al., 2023; Lee J. et al., 2024; Xu et al., 2024). Advances in serum-free media, scaffold engineering, and bioprocess optimisation have improved its scalability, consistency, and potential commercial viability (Kulus et al., 2023; Wang et al., 2023; Naraoka et al., 2024). While these technological developments position cultivated meat as a potential contributor to global food security and sustainability efforts, they also raise regulatory and ethical questions regarding ingredient sourcing, production oversight, and compliance with dietary standards, including halal certification (Post et al., 2020; Zhang et al., 2020; Verma & Singh, 2023; FAO & WHO, 2023).

Sharīʿah Implications of Cell Sourcing

Sharīʿah assessment of cultivated meat hinges on the permissibility of donor cells and growth media. Scholars generally agree that cells sourced from halal-slaughtered animals provide the strongest basis for permissibility, whereas cells derived from carcasses (*maytah*) or unslaughtered animals are considered impermissible (Hamdan et al., 2021; Qotadah et al., 2022; Burhanuddin et al., 2023). Opinions diverge on non-lethal biopsies: some scholars equate them with permissible derivatives such as milk or hair, while others caution that the substantive transformation of cellular tissue warrants stricter scrutiny (Halim, 2022; Hossain, 2021).

Growth media present additional challenges. Fetal bovine serum (FBS), still widely used in the industry, typically originates from non-halal sources, whereas the adoption of serum-free alternatives remains uneven (Kashim et al., 2022; 2023; Wang et al., 2023; Kim et al., 2024). These issues intersect with jurisprudential principles such as *istiḥālah* (substantive transformation) and *istiḥlāk* (dilution). Contemporary scholars emphasise laboratory verification, rather than analogy alone, when assessing whether molecular transformation renders previously impure substances permissible (Hamdan et al., 2024; Kashim et al., 2024). Such technical and legal complexities directly impact the operationalisation of halal certification procedures, highlighting the need for robust regulatory frameworks that can reconcile scientific innovation with *Sharīʿah* compliance.

Verification Challenges in Halal Assurance

Traditional halal certification primarily focuses on ingredient permissibility, slaughter compliance, and supply-chain segregation (JAKIM, 2020; Soon et al., 2023). In contrast, cultivated meat introduces additional verification requirements, including DNA authentication of donor cells, serum-origin purity checks, bioreactor contamination monitoring, and confirmation of cell-line integrity (Mohd Noor et al., 2023; Mohd Shukri et al., 2023; Naraoka et al., 2024). These verification needs surpass the technical capabilities of conventional halal auditing systems, highlighting the necessity for specialised laboratory facilities and biotechnology-trained auditors. Such challenges have direct implications for institutional

readiness, as halal certification authorities must adapt governance procedures, auditing protocols, and compliance-monitoring mechanisms to ensure both scientific rigour and *Sharīʿah* compliance (Kashim et al., 2023; 2024).

Sharīʿah Governance and Maqāṣid al-Sharīʿah Ethical Reasoning

Sharīʿah governance frameworks emphasise the integration of juridical principles with empirical evidence. *Maqāṣid al-Sharīʿah* provides a teleological framework for evaluating new technologies in terms of preserving life, intellect, wealth, religion, and environmental well-being (Ibn ʿĀshūr, 2022; Qaradawi, 2022; Amrulloh & Zaman, 2024; Anisa, 2024). Islamic bioethics scholars argue that cultivated meat necessitates structured collaboration between jurists and scientists to assess tissue transformation, purity, and ethical implications (Syed et al., 2023; Hamdan et al., 2024). Such ethical and jurisprudential reasoning informs halal governance by guiding certification criteria, audit protocols, and institutional decision-making within bodies such as MUIS, ensuring that novel biotechnologies comply with both *Sharīʿah* principles and public-welfare objectives.

Halal Regulatory Governance and Institutional Capacity

Halal regulatory systems in Malaysia, Indonesia, and Saudi Arabia were developed primarily for slaughter-based supply chains and remain poorly aligned with the technical requirements of cellular agriculture (Rejeb et al., 2021; Wibowo & Aziz, 2024). These systems currently lack standardised procedures for verifying cell-line origin, serum composition, genetic modifications, and in vitro contamination (Rahman, 2022; Mohd Noor et al., 2023). At the international level, the absence of harmonised halal-biotechnology standards within ASEAN and the OIC–SMIIC further complicates cross-border certification due to inconsistent technical requirements and varying *Sharīʿah* interpretations (OIC–SMIIC, 2023; Verbeke et al., 2024). These regulatory gaps underscore the challenges that Singapore faces in adapting its halal-certification framework for cultivated meat and highlight the need to assess institutional readiness for governing novel biotechnologies in a Muslim-minority context.

Consumer Perceptions and Public Trust

Consumer acceptance of cultivated meat is influenced by perceptions of product naturalness, food safety, and compliance with cultural and religious norms (Bryant, 2020; Ahmad et al., 2023; Lewisch & Riefler, 2023). Among Muslim consumers, trust in halal authorities and clarity of *Sharīʿah* rulings are critical to the perceived legitimacy of halal certification and broader public confidence (Attwood et al., 2023; Ho et al., 2023). Studies in Singapore and Malaysia indicate cautious interest amid uncertainty, driven by unfamiliarity with cellular agriculture and ambiguities in religious guidance. These findings underscore the importance of transparent governance, proactive public communication, and the integration of consumer perspectives into institutional readiness and certification processes (Erwan & Ramlan, 2024; Witkowski, 2024).

Research Gap

Existing research provides valuable insights into biotechnology, Islamic jurisprudence, and consumer attitudes, but remains fragmented, thereby limiting the ability of halal authorities to develop integrated governance strategies for emerging food technologies. To date, no study has systematically benchmarked institutional readiness for the halal governance of cultivated meat across legal, *Sharīʿah*, technical, infrastructural, stakeholder, and international dimensions. This gap is particularly salient in Muslim-minority jurisdictions such as Singapore. The present study addresses this gap by developing and applying the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework to evaluate Singapore's preparedness for certifying cultivated meat as halal.

Methodology

Research Design

This study employs a qualitative doctrinal-analytical research design, a widely recognised method in Islamic legal and halal-governance studies for interpreting legal texts, fatwas, regulatory instruments, and institutional documents within their normative and operational contexts (Auda, 2021; Hasan, 2021). The doctrinal component is grounded in *uṣūl al-fiqh*, systems-based reasoning, and contemporary Islamic

bioethics. It enables the structured derivation of *Sharīʿah* principles in response to emerging biotechnological developments, such as cellular agriculture (Ibn ʿĀshūr, 2022; Qaradawi, 2022; Hamdan et al., 2024; Alias et al., 2024). This design is particularly suitable for assessing interactions between Islamic legal reasoning and regulatory structures in areas with limited empirical precedent and directly supports Objective A of this study.

Data Sources and Selection Criteria

This study relies exclusively on secondary data collected between 2019 and 2026, covering halal governance, biotechnology regulation, and Islamic jurisprudence. Five categories of documents were included:

i. Statutes and Regulatory Instruments: AMLA Section 88A; SFA Novel Food Guidelines (2019–2026); and OIC–SMIIC standards.

ii. Fatwas and Religious Rulings: MUIS Fatwa on Cultivated Meat (2024); OIC-IFA and regional fatwas.

iii. Halal Standards and Assurance Manuals: HalMQ (2023); MS1500 and JAKIM Guidelines (2020); HAS 23000 and BPJPH regulations.

iv. Peer-Reviewed Literature (2019–2026): Biotechnology research, Islamic bioethics, and halal-science scholarship.

v. Technical and Policy Reports: FAO/WHO (2023) Food Safety Aspects of Cell-Based Food.

Documents were included if they met all of the following criteria: (i) they were published between 2019 and 2026; (ii) they were issued by recognized regulatory, religious, or scientific authorities; and (iii) they demonstrated clear relevance to halal governance, cultivated meat, biotechnology, or institutional readiness. Each category was selected to address specific research objectives: statutes and fatwas inform *Sharīʿah* and legal analysis (Objective A), peer-reviewed literature and technical reports support governance indicator development (Objective B), and the synthesis of these sources informs policy recommendations (Objective C). A total of 55 documents were selected and logged in a data matrix capturing document type, issuing authority, date, and thematic relevance, thereby enabling systematic coding and subsequent ordinal scoring for the HGRRA framework.

Analytical Framework: The HGRRA Model

Analysis was guided by the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework, which evaluates institutional maturity across six domains:

i. Legal Mandate: Presence and clarity of statutory authority for halal certification.

ii. Sharīʿah Framework: Availability and robustness of jurisprudential guidelines for emerging technologies.

iii. Technical Expertise: Competence of auditors, regulators, and scientists in halal-biotechnology assessment.

iv. Infrastructure: Accredited laboratory facilities, documentation systems, and operational resources supporting certification.

v. Stakeholder Engagement: Processes for consultation with industry, religious authorities, and consumers.

vi. International Alignment: Consistency with regional and global halal-biotechnology standards.

Each domain was assessed using a four-tier readiness continuum — Ad Hoc, Emerging, Structured, and Managed — adapted from regulatory governance and organizational capacity maturity models (Post et al., 2020; FAO & WHO, 2023). Indicators were derived from doctrinal reasoning and document analysis, then mapped to the continuum to enable structured comparison across domains. “Ad Hoc” reflects reactive or informal processes, “Emerging” indicates developing but inconsistent systems, “Structured” signifies

formalized procedures with moderate implementation, and "Managed" represents fully operational, audited, and continuously improved governance. This approach allows for the benchmarking of institutional readiness and the identification of priority areas for capacity development.

Coding Reliability and Scoring Procedure

Coding was conducted using a single-coder system to maintain interpretive consistency, as doctrinal and regulatory analysis requires specialised knowledge of halal law and biotechnology. To enhance reliability, 20% of documents were independently reviewed by subject-matter experts familiar with halal regulation and Islamic legal methodology. Any coding discrepancies were discussed and reconciled until consensus was achieved.

Each indicator was assigned a score from 1 (Ad Hoc) to 4 (Managed) using HGRRA criteria. The Legal Mandate domain achieved Tier 4 through MUIS's explicit statutory authority under AMLA Section 88A and formalised coordination with the SFA. Technical Expertise was assessed at Tier 3, reflecting competent auditors and scientists but revealing a lack of specialised biotechnology training for non-graduate enforcement officers. Infrastructure was also placed at Tier 3, with strong HalMQ systems and accredited laboratories but no specific cultivated meat certification schemes. Stakeholder Engagement was rated at Tier 3 through transparent consultation, despite challenges in media representation. International Alignment achieved Tier 2, showing active participation but limited harmonisation with global standards. This structured scoring ensures a transparent and replicable evaluation of governance readiness.

Ethical Considerations

This study relied exclusively on publicly accessible documents and did not involve human participants; therefore, formal ethics approval was not required. Nonetheless, the analysis adhered to ethical principles grounded in both Islamic scholarship and academic research standards. Specifically, *ḥifẓ al-ʿaql* (integrity of knowledge) and *ḥifẓ al-dīn* (respect for religious authority) guided the interpretation of fatwa texts and institutional documents, ensuring faithful and contextually accurate representation (Ibn ʿĀshūr, 2022; Qaradawi, 2022). Additionally, all sources were cited transparently, and document coding and scoring were conducted systematically to maintain academic rigour and integrity.

Limitations

While this study employed a rigorous document-based methodology, it does not incorporate empirical validation through interviews, laboratory observations, or operational audits of halal certification processes. Additionally, reliance on a single-coder system introduces potential interpretive bias, and the geographic focus on Singapore may limit the generalisability of the findings to other Muslim-minority contexts. The temporal scope (2019–2026) may also omit emerging developments. Future studies could employ mixed-methods designs, including empirical validation, and conduct cross-jurisdictional benchmarking to enhance the robustness, external validity, and generalisability of findings, particularly for operationalising the HGRRA framework in diverse regulatory settings.

Results and Findings

Overview

Singapore's readiness to certify cultivated meat as halal is assessed as Tier 3: Structured Readiness. Application of the Halal Governance and Regulatory Readiness Assessment (HGRRA) framework reveals a governance landscape characterised by robust legal foundations, proactive theological guidance, and well-coordinated institutional mechanisms, whilee simultaneously exposing critical developmental needs in operational infrastructure, stakeholder engagement, and international harmonisation of halal-biotechnology standards.

The analysis draws upon 55 documents, including statutes, fatwas, halal standards, scholarly literatures, and policy reports published between 2019 and 2026, establishing a comprehensive evidence base for assessing readiness across six domains: Legal Mandate, *Sharīʿah* Framework, Technical Expertise, Infrastructure, Stakeholder Engagement, and International Alignment. A brief summary of these domains is provided in Annex A.

Thematic Relevance Criteria

The thematic relevance rating assesses how directly and significantly each document or framework element relates to the core objectives of the HGRRA framework for halal governance of cultivated meat and emerging food technologies.

Table 1. Thematic Relevance Criteria and Tier Readiness Scale for Halal Governance

Relevance Level	Explanatory
High Relevance	Documents and frameworks that are: • Directly regulatory or authoritative with binding legal or religious authority • Immediately applicable to current halal certification processes • Foundational to halal governance structures and decision-making • Critical for compliance with established halal standards and requirements • Issued by recognised halal authorities (MUIS, JAKIM, OIC-SMIIC, government agencies)
Medium Relevance	Documents and frameworks that are: • Supportive but not directly regulatory in nature • Relevant to implementation but not foundational to governance • Informative for decision-making but not legally binding • Technical or academic in nature, providing context and expertise • Related to operational aspects rather than core governance
Low Relevance	Documents and frameworks that are: • Indirectly related to the core framework objectives • Regional cooperation initiatives that may influence but don't directly govern • Future-oriented rather than immediately applicable • Broad policy alignment rather than specific operational requirements

Tier Readiness Scale

i. Tier 1: Conceptual stage requiring substantial development

ii. Tier 2: Partially developed requiring significant enhancement

iii. Tier 3: Well-developed with minor gaps requiring attention

iv. Tier 4: Fully developed and immediately implementable

Systematic Coding Categories:

i. Regulatory Foundation, Certification Framework, Competency Framework

ii. Religious Guidance, Academic Research, Technical Guidelines

iii. Risk Assessment, Policy Reports, Operational Capacity

iv. Standards Collaboration, Technology Adaptation, Regional Harmonisation

Legal Mandate

Singapore's halal governance operates under a clear statutory foundation. Section 88A of the Administration of Muslim Law Act (AMLA) empowers MUIS with exclusive authority to regulate halal certification, including standard-setting, enforcement, and accreditation. This legal basis satisfies key HGRRA indicators by ensuring clear jurisdictional control and enforceability, consistent with international halal-governance best practices. Complementing this, the Singapore Food Agency (SFA) regulates novel foods, including cultivated meat, under the Sale of Food Act and the Novel Food Regulatory Framework (SFA, 2024; 2025). The dual-regulatory model integrates religious assurance (MUIS) with scientific oversight (SFA), reflecting international frameworks recommended by FAO & WHO (2023) for novel food governance.

Joint-review mechanisms between MUIS and SFA demonstrate regulatory coherence and effective coordination, thereby strengthening compliance pathways for biotechnology-based foods. These mechanisms include coordinated risk assessment, shared review of documentation, and formal inter-agency communication channels.

Sharīʿah Framework

The MUIS Fatwa on Cultivated Meat (2024) marks a significant theological milestone, situating Singapore among the first jurisdictions to issue a structured *Sharīʿah* position on cellular agriculture. The fatwa declares cultivated meat permissible subject to the following conditions:

i. Donor cells must be sourced from halal-slaughtered animals.

ii. Growth media must be free from *najis* or *ḥarām* components.

iii. Production systems must ensure *ṭahārah* and avoid cross-contamination.

These conditions align with contemporary jurisprudential discourse on transformation (*istiḥālah*), dilution (*istiḥlāk*), and purity, and reflect the higher objectives of *Maqāṣid al-Sharīʿah* (Ibn ʿĀshūr, 2022; Anisa, 2024; Hamdan et al., 2024). Scholars also emphasise the need for technological verification of inputs, particularly serum sources such as FBS (Kashim et al., 2022; 2023).

Technical Expertise

Technical readiness represents one of the strongest domains in Singapore's halal governance for cultivated meat. Most MUIS auditors are graduates in food science and technology and are trained in traditional food-manufacturing audit processes, and biotechnology-focused training modules have also been operationalised. However, enforcement officers who conduct the post-certification process are not graduates in food science and technology. As a result, Singapore possesses the underlying scientific capacity and halal-specific technical expertise needed to strengthen operational readiness in this domain, although gaps in technical expertise may remain at the enforcement level.

Infrastructure

The HalMQ System provides a comprehensive framework for ensuring halal compliance by identifying and controlling critical operational points at which halal integrity could be compromised. This system establishes Halal Assurance Points (HAPs) at the procurement, receiving, storage, preparation, and serving stages, where specific halal threats are systematically managed through structured control measures. The framework requires detailed process-flow charts, monitoring protocols with defined responsibilities, zero-tolerance limits for violations, and robust corrective procedures. Through systematic product tracking and continuous oversight, HalMQ enables businesses to maintain certification standards while proactively addressing compliance issues.

Singapore's halal-certification process operates through multiple tailored schemes: Eating Establishment (EE) for restaurants, Food Preparation Area (FPA) for commercial kitchens, Product (PRO) or Whole Plant (WP) for manufacturers, Poultry Abattoir (PA) for slaughterhouses, Endorsement (EN) for imports, Storage Facility (SF) for warehouses, and Food Verification & Ritual Cleansing (FVRC) for specialised requirements. Each scheme provides detailed guidelines to support businesses through the preparation, application, processing, certification, post-certification inspection, and renewal phases. However, no specific certification scheme currently exists for cultivated meat, and this represents a regulatory gap requiring attention as the technology advances.

Singapore's scientific infrastructure supports halal verification through globally recognised A*STAR, university, and private laboratory facilities. MUIS maintains comprehensive lists of SAC-SINGLAS-accredited laboratories specifically for halal certification, accredited under ISO/IEC 17025 standards. According to clause 3.8 of the MUIS Halal Certification Conditions, laboratory analysis reports may be required to confirm that products, raw materials, additives, and processing aids meet halal requirements, with businesses able to access accredited laboratory lists and selection guidelines through the MUIS website.

Effective halal verification of cultivated meat requires specialized testing capabilities, including:

i. Species-specific DNA authentication;

ii. Serum-origin purity verification;

iii. Detection of *najis* contaminants;

iv. Biomolecular traceability.

Stakeholder Engagement

Singapore exemplifies a strong model of public-sector consultation through MUIS's cultivated meat fatwa development, which involved comprehensive dialogue with scientists, scholars, regulators, and halal auditors, thereby demonstrating adaptive-governance best practices (Ho et al., 2023; Attwood et al., 2023). Despite being the first country to approve cultured meat for consumption, public awareness remains limited, with younger demographics showing greater familiarity than older participants, who primarily learn about this technology through interpersonal communication and news sources rather than official channels (Ho et al., 2023).

Research by Ho et al., (2023) revealed significant misconceptions amongst Muslim participants, with many confusing cultured meats with plant-based alternatives or "fake meat". These misunderstandings highlight critical gaps in scientific communication, particularly concerning health-related risk perceptions centred on perceived artificiality and uncertainty about long-term effects. Interestingly, although religious considerations dominated Muslim participants' decision-making processes, their risk-benefit assessments largely mirrored those of non-Muslims, focusing on environmental benefits, food security, and health safety rather than religion-specific concerns (Ho et al., 2023).

Singapore's approach to religious guidance is exemplified through the Fatwa Lab initiative, launched by MUIS's Office of the Mufti and showcased at the symposium on 23 June 2025 at Fairmont Singapore. This innovative framework demonstrates adaptive governance through the systematic integration of diverse expertise in addressing contemporary Islamic jurisprudential challenges. The cultivated meat fatwa development, led by researchers including Zahratur Rofiqah Binte Mochamad Sandisi, Nurul Hikmah Binte Jumahat, Zubair Bin Mohd Redza, and Syazaa Binte Mohamed Nizam under Fatwa Committee mentorship, exemplifies Singapore's multidisciplinary methodology, which brings together food-technology experts, Islamic scholars, and industry stakeholders.

This collaborative approach ensures that religious guidance remains rooted in Islamic tradition while engaging in intellectually rigorous dialogue with modern technological advances. The inaugural Fatwa Lab Symposium highlighted the breadth of current fatwa explorations, showcasing how diverse expertise informs Singapore's collective response to complex social, ethical, and religious challenges through critical reflection and forward-thinking inquiry.

Media representation significantly influences public perceptions, with terminology choices such as "lab-grown meat" versus "clean meat" affecting acceptance levels (Bryant, 2020). Consequently, neutral media representation becomes crucial for effective scientific communication, helping to address misconceptions and facilitate informed understanding of emerging food technologies (Ho et al., 2023).

These findings underscore the importance of comprehensive public-education strategies that complement regulatory approval processes and religious guidance, particularly where religious and cultural considerations intersect with technological innovation (Ho et al., 2023). Singapore's framework demonstrates how the Office of the Mufti has evolved its fatwa discourse to meet the needs of contemporary society, reflecting a commitment to evidence-based religious decision-making that meaningfully engages with modern food technology while maintaining Islamic principles and values in a dynamic and diverse society.

International Alignment

Singapore actively participates in global halal forums, particularly OIC–SMIIC technical committees and aligns its food safety regulation with Codex Alimentarius standards (FAO & WHO, 2023). Recognition of selected foreign halal certification bodies under the FHCB framework further supports cross-border compliance. However, ASEAN and OIC have not yet established standards for cultivated meat. This absence of international harmonisation increases certification uncertainty and limits mutual recognition of halal approvals, as highlighted in industry and scholarly analyses (Wortley, 2022; Verbeke et al., 2024; Abdul Halim et al., 2020).

Summary of Domain Scores

Table 2. Summary of Domain Scores

HGRRA Framework Domain	Tier	Category	Key Strengths	Key Gaps
Legal Mandate	4	Managed	Codified Authority; MUIS–SFA Coherence	No significant gaps
Sharīʿah Framework	4	Managed	Clear Fatwa; *Maqāṣid* Alignment	No significant gaps
Technical Expertise	3	Structured	Competent Auditors, Regulators, and Scientists in Halal-Biotechnology Assessment	No specialised continuous professional development in biotechnology and Islamic bioethics for enforcement officers (non-graduates of food science and technology)
Infrastructure	3	Structured	Strong HalMQ system and availability of SAC-SINGLAS accredited laboratories	No specific certification scheme for cultivated meat
Stakeholder Engagement	3	Strcutured	Transparent consultation and discussion with food technology experts, Islamic scholars, and industry stakeholders	No neutral and unbiased media representation of cultured meat would be important for the scientific communication of cultured meat to the public, which would help to eliminate the public's misperceptions.
International Alignment	2	Emerging	Global active participation	No harmonization of global halal standards and halal certification of cellular agricultural standards

Discussion of Key Patterns

The findings highlight a dual nature in Singapore's halal governance landscape. On one hand, the system exhibits exceptional institutional maturity, characterised by highly centralised regulatory authority under MUIS, legally coherent statutory frameworks, theologically proactive fatwa development, and sophisticated technical expertise among auditors and regulators. On the other hand, operational infrastructure, institutionalised stakeholder engagement, and the international harmonisation of halal-biotechnology standards are still developing. The MUIS–SFA partnership exemplifies an innovative governance framework in which scientific and religious regulators operate in tandem, reflecting a practical application of *Maqāṣid al-Sharīʿah*, particularly in preserving life, intellect, and religion.

Compared with other jurisdictions, Singapore's progress is notable. Malaysia and Indonesia possess more mature halal infrastructures but slower regulatory responsiveness, while Saudi Arabia maintains theological authority yet exhibits limited operational flexibility (JAKIM, 2020; BPJPH, 2022; Attwood et al., 2023). Singapore's Tier 3: Structured Readiness positions it as a regional reference point for integrating halal and biotechnology governance.

Advancing to Tier 4: Managed Readiness requires actions mapped to HGRRA domains:

i. *Sharīʿah* Framework / Infrastructure: Formalising the MUIS Fatwa (2024) conditions into laboratory audit checklists within HalMQ.

ii. Technical Expertise / Infrastructure: Establishing a halal certification scheme for cultivated meat.

iii. Technical Expertise: Specialised continuous professional development in biotechnology and Islamic bioethics for auditors at the enforcement level.

iv. Stakeholder Engagement: Institutionalising multi-stakeholder consultation forums to maintain public trust and policy responsiveness.

v. International Alignment: Strengthening regional cooperation through ASEAN–OIC harmonisation of halal biotechnology standards.

These measures collectively address technical, procedural, regulatory, and ethical gaps, thereby guiding Singapore toward full operational maturity in halal-biotechnology governance.

Conclusion of Findings

The HGRRA assessment indicates that Singapore's halal governance system exhibits strong statutory authority, clear *Sharīʿah* guidance, and well-coordinated institutional structures, collectively supporting a Tier 3: Structured Readiness classification.

Key constraints are observed in:

i. Infrastructure: no development of halal certification scheme for cultivated meat.

ii. Stakeholder Engagement: no neutral media representation eliminates public misconceptions about cultured meat.

iii. International Alignment: no harmonization and cross-border standardisation.

The HGRRA model proves effective in diagnosing these domain-level strengths and weaknesses. It provides a systematic basis for benchmarking institutional maturity and identifying targeted reforms, thereby guiding Singapore towards a fully integrated halal-biotechnology governance system. These findings also offer a reference point for policymakers, halal authorities, and researchers in similar Muslim-minority jurisdictions seeking to harmonise the religious, technical, and regulatory dimensions of novel food governance.

Discussion

Integrating Sharīʿah Governance with Biotechnology Regulation

The findings illustrate that Singapore has developed a highly coherent regulatory environment in which doctrinal reasoning, statutory authority, and scientific oversight operate in complementary domains. The MUIS Fatwa (2024) exemplifies proactive *ijtihād* applied to technological innovation, aligning classical jurisprudential principles such as *istiḥālah, istiḥlāk, ṭahārah,* and *Maqāṣid al-Sharīʿah* with empirically verifiable processes.

This constitutes an emerging model of *Sharīʿah*-informed technocracy, in which ethical-religious objectives are operationalised in a manner compatible with laboratory-based validation and risk governance. As for instance, joint MUIS–SFA review mechanisms and audit criteria derived from the fatwa operationalise *Sharīʿah* principles in practice, thereby demonstrating alignment between doctrinal reasoning and technical verification.

In terms of the HGRRA framework, this integration reflects strong Legal Mandate (statutory authority), *Sharīʿah* Framework (Fatwa application), and Technical Expertise / Infrastructure (laboratory verification), illustrating a novel governance approach for Muslim-minority contexts.

Governance Readiness, Institutional Learning and System Adaptation

Singapore's Tier 3 readiness reflects well-defined legal authority (Legal Mandate), structured *Sharīʿah* guidance (*Sharīʿah* Framework) and competent halal-specific expertise (Technical Expertise). However, its transition to full operational readiness requires deeper technical integration. The absence of a halal-certification scheme for cultivated meat (Infrastructure) highlights a gap between doctrinal permissibility and enforceable audit mechanisms (Technical Expertise / Infrastructure).

This gap aligns with broader observations that halal systems originally designed for slaughter-based supply chains are not yet optimised for cellular agriculture. Singapore's compact regulatory ecosystem, exemplified by MUIS–SFA joint-review mechanisms and iterative updates to HalMQ audits, positions it for institutional learning and agile adaptation. Such adaptability could accelerate the operationalisation of fatwa conditions, biotechnology verification, and auditor training, thereby facilitating progression toward Tier 4: Managed Readiness.

Maqāṣid al-Sharīʿah as a Framework for Technology Governance

The HGRRA model illustrates how *Maqāṣid al-Sharīʿah* can guide policy development beyond binary permissibility judgments, providing a structured ethical lens for evaluating cultivated meat. Cultivated meat intersects with the higher objectives of Islamic law:

i. *Ḥifẓ al-nafs* (preservation of life): contributes to food security and mitigates zoonotic risk, aligning with technical verification and infrastructure requirements.

ii. *Ḥifẓ al-dīn* (preservation of religion): ensures halal standards govern emerging food systems, thereby reinforcing *Sharīʿah* Framework maturity.

iii. *Ḥifẓ al-ʿaql* (preservation of intellect): integrates scientific reasoning into religious decision-making, thereby strengthening Technical Expertise and Stakeholder Engagement.

iv. *Ḥifẓ al-māl* (preservation of wealth): promotes efficient regulatory systems that reduce duplication and enhance Legal Mandate and Infrastructure domains.

v. *Ḥifẓ al-biʾah* (preservation of the environment): reduces land and water use through cellular agriculture, thereby supporting International Alignment and sustainability ethics.

By grounding governance in these objectives, Singapore operationalises a *maqāṣid*-driven halal regulatory model, positioning itself as a reference point for Muslim-minority jurisdictions seeking to integrate ethical-religious reasoning with biotechnology regulation. Examples include the MUIS–SFA joint-review mechanism, HalMQ audit protocols, and the consideration of sustainable production metrics within regulatory oversight.

Strategic Policy Implications

The HGRRA assessment highlights several strategic priorities for advancing Singapore's halal-biotechnology governance:

i. Develop biotechnology-specific modules within HalMQ (Infrastructure / Technical Expertise) to operationalise fatwa conditions and ensure laboratory-verifiable compliance.

ii. Establish halal-accredited testing laboratories (Technical Expertise / Infrastructure) to enable rigorous verification of cell-line purity, serum origin, and contamination control.

iii. Institutionalise multi-stakeholder consultation (Stakeholder Engagement) to maintain transparency, public trust, and adaptive governance for emerging food technologies.

iv. Advance regional cooperation on halal-biotechnology standards (International Alignment) to facilitate cross-border harmonisation and mutual recognition, thereby addressing current gaps in ASEAN and OIC frameworks.

Prioritisation of these initiatives should consider operational feasibility, resource allocation, and regulatory sequencing, thereby ensuring that doctrinal permissibility is effectively translated into enforceable and credible governance outcomes. Collectively, these strategies strengthen Singapore's position as a regional reference model for integrating *Sharīʿah* principles with cutting-edge food biotechnology.

Advancing Toward Tier 4: Managed Readiness

Achieving Tier 4: Managed Readiness requires Singapore's halal governance system to transition from structured foundations to a fully integrated biotechnology-based assurance framework. This stage focuses on consolidating existing reforms rather than introducing new initiatives. The priority is to operationalise legal and *Sharīʿah* clarity into enforceable operational mechanisms supported by halal-accredited laboratory capability, specialised audit competencies, and sustained multi-stakeholder engagement.

Key readiness domains can be aligned with targeted actions:

Table 3. Strategic Priorities for Advancing Toward Tier 4: Managed Readiness

HGRRA Domain	Strategic Priority (High-Level)
Legal Mandate	Integrate statutory authority with enforceable audit protocols.
Sharīʿah Framework	Embed fatwa conditions into laboratory SOPs within HalMQ.
Technical Expertise	Establish halal-accredited biotech laboratories and train auditors in cell-based meat verification.
Infrastructure	Incorporate lab and bioreactor verification modules into HalMQ.
Stakeholder Engagement	Institutionalize continuous advisory councils and multi-stakeholder forums.
International Alignment	Coordinate ASEAN–OIC standards for cultivated meat to support cross-border recognition.

Together, these measures create the technical depth, regulatory coherence, and international coordination necessary for a mature halal-biotechnology governance system, thereby enabling Singapore to serve as a regional reference model.

Collectively, these strategic priorities illustrate Singapore's organisational trajectory from a structured system towards a mature, fully integrated halal-biotechnology governance model. These priorities do not introduce new findings; rather, they synthesise domain-level implications into a forward-looking roadmap. By aligning legal authority, *Shari'ah* guidance, technical capability, infrastructure, stakeholder engagement, and international standards, this roadmap supports regulatory certainty, doctrinal integrity, and international interoperability, ensuring that Singapore remains responsive as cultivated meat technologies continue to advance.

Conclusion

Cultivated meat challenges halal governance systems to integrate *Sharīʿah* principles with biotechnology-based verification. Applying the HGRRA framework, this study finds that Singapore has achieved Tier 3: Structured Readiness, characterised by strong legal authority (Legal Mandate), clear theological guidance (*Sharīʿah* Framework), and accredited laboratories (Infrastructure), yet constrained by limitations in qualified technical expertise at the enforcement level (Technical Expertise), coordinated regulatory oversight (Stakeholder Engagement) and minimal regional collaboration (International Alignment). The study contributes a *maqāṣid*-informed, maturity-based HGRRA model that enables halal authorities to systematically evaluate institutional capabilities and align doctrinal reasoning with scientific assurance. Demonstrating the applicability of the HGRRA framework in a Muslim-minority context broadens the conceptual base of halal governance and provides a framework adaptable to other jurisdictions engaging with cellular agriculture and novel food technologies.

Future research should incorporate empirical audits, multi-jurisdictional comparisons, and industry engagement to refine readiness indicators and validate operational gaps. Policymakers may prioritise biotechnology-specific standards, laboratory development, and enhanced scientific training for auditors. These measures will help ensure that halal governance remains robust, responsive, and technologically informed, thereby supporting Singapore's progression toward Tier 4: Managed Readiness and a fully integrated halal-biotechnology governance system.

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