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Research Article

# Techno-Functional Transformation of Mangkunegaran Royal Cuisine into Ready-to-Eat and Frozen Halal Food Products

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**Abstract** The development of halal agroindustry requires innovative approaches that integrate cultural heritage with modern food processing technologies. This study aims to explore the halal-thayyib governance and techno-functional characteristics of Mangkunegaran royal cuisine and to assess its potential for ready-to-eat (RTE) and frozen food applications. A qualitative–analytical approach combined with a techno-functional matrix evaluation was employed using primary data from field observations and expert consultations, as well as secondary data from historical manuscripts and scientific literature. The findings indicate that Mangkunegaran cuisine reflects an embedded halal-thayyib governance system, including ingredient compliance, hygienic practices, ethical consumption, and elements of religious supervision, which are broadly consistent with contemporary halal assurance principles. The techno-functional analysis suggests that low-moisture and liquid-based products may be more suitable for RTE processing, while high-moisture and complex dishes may be better aligned with frozen preservation systems. This study proposes a conceptual halal agroindustry transformation framework that integrates heritage-based culinary knowledge, techno-functional considerations, and halal governance into a unified model. The results provide preliminary insights into the potential of traditional cuisine as a resource for halal food innovation, although further experimental validation is required to confirm product feasibility and industrial applicability.

**Keywords** Halal agroindustry, halal-thayyib, royal cuisine, food processing technology, ready to eat, frozen food, cultural heritage

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## INTRODUCTION

The global halal food industry has experienced significant growth over the past decade, driven by increasing demand from Muslim consumers and rising awareness of food safety, quality, and ethical consumption. The halal concept has evolved beyond religious compliance into a broader framework encompassing hygiene, sustainability, and nutritional quality, often conceptualized as *halal-thayyib* (permissible and wholesome food) (Mausufi et al., 2023; Md Dahlal et al., 2024; Nugroho et al., 2024). This integrated concept positions halal food not only as a religious obligation but also as a comprehensive food quality system aligned with modern food science and sustainable consumption trends.

In Indonesia, the development of halal agroindustry is strategically important, given its position as the world's largest Muslim-majority country and its ambition to become a global halal hub. The implementation of the Halal Product Assurance Law (Law No. 33/2014) further strengthens the institutional framework for halal certification and standardization (Akim et al., 2019). However, despite strong regulatory support, the development of innovative halal food products remains largely dominated by conventional industrial approaches, with limited integration of cultural heritage and traditional food systems as sources of innovation.

Traditional culinary heritage represents a valuable yet underutilized resource in halal food development. Heritage-based food systems are characterized by locally sourced ingredients, embedded ethical values, and accumulated gastronomic knowledge that has evolved over generations (Kapelari et al., 2020). In particular, royal culinary traditions offer a unique form of structured food systems, where preparation methods, ingredient selection, and consumption practices are regulated by cultural norms and often aligned with religious principles. These characteristics make royal cuisine a potential model for developing culturally grounded halal food innovations.

Mangkunegaran royal cuisine in Surakarta, Indonesia, is one such example of a heritage-based halal-thayyib culinary system. Established in 1757 as part of the Mataram Islamic cultural lineage, the Mangkunegaran Palace developed a highly structured culinary tradition that integrates Javanese philosophical values with Islamic ethical principles. Food in this context serves not only as nourishment but also as a medium of spiritual expression, social hierarchy, and cultural identity. Historical records, such as Serat Memulé, document the role of food in ceremonial practices, where the use of halal ingredients, hygienic preparation, and moderation reflect principles consistent with halal-thayyib values.

In addition, Mangkunegaran cuisine has demonstrated adaptability through cultural interaction, particularly during the colonial period, resulting in hybrid culinary forms that combine local ingredients with European cooking techniques. This adaptability indicates that heritage cuisine is not static but can transform, making it relevant to contemporary food innovation. However, previous studies on Mangkunegaran cuisine have largely focused on historical narratives, cultural symbolism, and philosophical meanings (Rahayu & Prasetya, 2019; Kartika & Purnasari, 2020), with limited attention to its techno-functional characteristics and its potential translation into modern halal food products within the agroindustry sector.

From a food science perspective, the transformation of traditional cuisine into ready-to-eat (RTE) and frozen food products requires careful evaluation of physicochemical properties, microbial stability, processing compatibility, and shelf-life performance (Bharathipriya et al., 2019; Dottori et al., 2023; Jeremiah, 2019; Zhang et al., 2025). Technologies such as retort sterilization, vacuum packaging, and freezing systems have been widely applied in modern food

processing to enhance product safety and extend shelf life while maintaining sensory quality. However, the application of these technologies to heritage-based halal cuisine remains underexplored, particularly in integrating halal governance with techno-functional food processing.

Therefore, there is a critical need to bridge the gap between cultural culinary heritage and modern halal agroindustry development through a systematic and interdisciplinary approach. This study addresses this gap by examining the techno-functional feasibility and halal governance of Mangkunegaran royal cuisine as a basis for developing ready-to-eat and frozen halal food products. This study seeks to integrate cultural heritage analysis, techno-functional considerations in food processing, and halal governance perspectives into a unified conceptual framework for halal agroindustry transformation. While similar elements have been discussed separately in previous studies, this research offers a combined perspective that may contribute to the understanding of heritage-based halal food innovation.

Accordingly, this study aims to: (1) explore the embedded halal-thayyib governance within Mangkunegaran royal cuisine, (2) examine the techno-functional characteristics of selected dishes in relation to their potential for ready-to-eat and frozen product development, and (3) develop a conceptual Halal Agroindustry Transformation Framework that integrates heritage-based culinary knowledge with techno-functional considerations and halal governance perspectives.

## MATERIALS AND METHODS

### Research Design

This study employed a qualitative–analytical approach, combined with a techno-functional evaluation framework, to explore the transformational potential of Mangkunegaran royal cuisine into halal agroindustry products. The study is positioned as a conceptual and exploratory feasibility assessment rather than an experimentally validated product development study. A case study design was applied, focusing on selected Mangkunegaran dishes as representative examples of heritage-based halal cuisine. This approach enables the integration of cultural analysis, food processing principles, and halal governance considerations in a structured manner (Yin, 2018).

### Data Sources and Collection

1. Primary Data

Primary data were collected through a series of field observations conducted at the Mangkunegaran culinary environment, including both traditional preparation settings and modern adaptation contexts. A total of 3 observation sessions were carried out to document processing techniques, ingredient handling, and hygiene practices. In addition, expert consultations were conducted with 3 individuals, including culinary practitioners, food technologists, and stakeholders involved in heritage food development. The selected experts had experience ranging from 5 years in culinary practice, food processing, or halal-related activities. These consultations aimed to validate traditional practices, identify processing characteristics, and assess potential adaptation into industrial systems.

2. Secondary Data

Secondary data were obtained from historical manuscripts such as *Serat Memulé* and archival documents related to royal cuisine, as well as from scientific literature on food processing, halal food systems, and preservation technologies. In addition, published studies on traditional Indonesian cuisine and halal agroindustry development were reviewed to strengthen the analytical foundation. These secondary data were used to support the techno-functional analysis and to provide scientific benchmarks for key food processing parameters, ensuring that the evaluation aligns with established principles in food science and halal system studies.

**Selection of Food Samples**

Selected dishes were determined using a purposive selection approach based on predefined criteria to ensure representativeness and analytical relevance. The selection criteria included: (1) cultural significance within Mangkunegaran culinary traditions, (2) diversity of food categories (main dishes, fermented products, and beverages), (3) variation in physicochemical properties such as moisture content and structural complexity, and (4) relevance to halal-thayyib principles.

Based on these criteria, an initial list of candidate dishes was identified from field observations and historical sources. The final selection was refined through expert consultation, resulting in four representative dishes: *Dendeng Age* (a low-moisture meat product), Brubus (a high-moisture cooked dish), Tape Ijo Legi (a fermented product), and Wedang Secang (a liquid beverage). These dishes were selected to reflect a broad range of techno-functional characteristics relevant to industrial food processing.

**Techno-Functional Evaluation Method**

A techno-functional matrix approach was applied to evaluate the feasibility of transforming traditional dishes into ready-to-eat (RTE) and frozen food products. This method integrates key food engineering parameters commonly used in food preservation and processing studies (Aguilera, 2019; Alongi & Anese, 2021; Nikbakht Nasrabadi et al., 2021), allowing for a structured assessment of product characteristics and processing suitability. The evaluation included several parameters: moisture content (qualitative estimation) to classify products into low, intermediate, or high moisture categories that influence microbial stability; water activity (aw) as an estimated range to predict microbial growth potential and shelf-life, where foods with $aw < 0.85$ are considered microbiologically stable (Tapía et al., 2020); pH characteristics to assess acidity and its role in microbial inhibition (Akkermans & Van Impe, 2018) and processing compatibility to determine suitability for industrial technologies such as retort sterilization, vacuum packaging, pasteurization, and freezing systems. In addition, shelf-life potential was estimated based on product characteristics and comparable literature, while microbial risk assessment was conducted qualitatively by considering moisture levels, handling practices, and processing conditions. Overall, the techno-functional matrix enables systematic comparison across different dishes and supports informed decision-making in selecting appropriate processing technologies for halal agroindustry development.

Each parameter was qualitatively assessed using a standardized classification framework adapted from food preservation principles. Moisture content was categorized into low, intermediate, and high levels, while water activity was estimated based on typical ranges reported for similar food products. Processing compatibility was evaluated relative to common

industrial technologies, including retort sterilization, pasteurization, vacuum packaging, and freezing systems. The matrix enabled comparative analysis across different dishes by integrating intrinsic product characteristics with processing requirements, providing a structured basis for feasibility assessment.

### Feasibility Analysis for RTE and Frozen Products

Feasibility levels (high, moderate, and low) were assigned based on the alignment between techno-functional characteristics and processing requirements. Products were categorized as "high feasibility" when their intrinsic properties strongly supported processing stability, microbial safety, and compatibility with existing technologies. "Moderate feasibility" was assigned to products requiring additional process optimization or formulation adjustments, while "low feasibility" indicated significant limitations in terms of stability, microbial risk, or processing constraints.

The classification was conducted through expert-informed judgment supported by literature benchmarks rather than quantitative experimental measurement. Therefore, the feasibility assessment should be interpreted as indicative and exploratory rather than definitive. This classification is consistent with established food preservation principles, which emphasize that intrinsic product composition, such as moisture content, water activity, and structural properties, determines the most appropriate preservation method (Fellows, 2022; Sandulachi, 2012).

### Halal Governance Analysis

Halal governance was analyzed using a qualitative framework based on key principles of halal assurance systems, including ingredient compliance with halal raw materials, process hygiene and cleanliness, avoidance of cross-contamination, and the application of ethical and moderate consumption practices. This analysis not only evaluates compliance at the technical level but also considers the integration of traditional halal practices embedded in Mangkunegaran cuisine with formal certification systems. Such an approach is consistent with contemporary halal governance studies, which emphasize the importance of combining cultural practices with standardized regulatory frameworks to ensure credibility and scalability in halal food systems (Akim et al., 2019).

### Data Analysis

Data were analyzed using an integrative analytical approach that combines descriptive analysis of cultural and culinary practices, techno-functional matrix evaluation, and comparative analysis with existing food processing literature. This approach enables a comprehensive understanding of both cultural context and technological feasibility. The results were synthesized to develop a conceptual Halal Agroindustry Transformation Framework that links heritage-based culinary knowledge with modern food processing technologies and halal certification systems, providing a structured pathway for translating traditional cuisine into scalable halal agroindustry products.

Overall, this methodological approach combines qualitative analysis and techno-functional reasoning to provide a structured conceptual assessment of transformation potential. The

results are intended to generate preliminary insights and a conceptual framework, which require further experimental validation for industrial application.

## RESULT AND DISCUSSION

### Embedded Halal-Thayyib Governance in Mangkunegaran Royal Cuisine

The findings of this study reveal that Mangkunegaran royal cuisine embodies an embedded halal-thayyib governance system that has been practiced long before the formalization of contemporary halal certification frameworks. Unlike modern regulatory systems, this governance is not explicitly codified but is intrinsically embedded within cultural norms, religious values, and institutional structures of the royal court. Therefore, Mangkunegaran cuisine can be conceptualized as a form of culture-based halal governance, where compliance is maintained through ethical awareness, tradition, and internal authority. The mapping of embedded halal-thayyib governance in Mangkunegaran cuisine shown in Table 1.

**Table 1**. Mapping of Embedded Halal-Thayyib Governance in Mangkunegaran Cuisine

| Governance Aspect | Traditional Practice | Modern Halal System Equivalent | Relevance to Agroindustry |
|---|---|---|---|
| Ingredient Control | Avoidance of pork & alcohol, local sourcing | Halal-certified raw materials, supply chain verification | Ensures halal compliance in production |
| Process Hygiene | Ritual purification, clean preparation | GMP, sanitation control, HACCP | Food safety and quality assurance |
| Ethical Intention (*Niyyah*) | Cooking as spiritual act | Ethical production principles | Strengthens halal-thayyib branding |
| Moderation (*Non-Israf*) | Balanced portion, no excess | Sustainable production, waste reduction | Supports circular economy |
| Religious Supervision | Tafsir Anom, Abdus Salam | Halal certification bodies (MUI) | Institutional halal governance |
| Social Function | Sedekah and communal sharing | Social responsibility in food systems | Enhances socio-cultural value |

One of the primary components of this governance system is the strict selection of halal ingredients. Both historical documentation and field observations indicate that royal kitchens consistently avoid non-halal components such as pork and alcohol, while prioritizing locally sourced materials, including beef, poultry, spices, and plant-based ingredients. This practice aligns with fundamental halal principles of lawful sourcing and ingredient integrity. In the context of modern halal systems, this corresponds to raw material verification and halal-compliant supply chains, suggesting that traditional practices already fulfill core requirements of contemporary halal assurance systems.

In addition to ingredient control, the preparation process emphasizes cleanliness, intentionality, and ethical conduct. Ritual practices such as purification and prayer before cooking indicate that food preparation is perceived not merely as a technical process but also as a spiritual activity. This reflects the concept of *thayyib*, which encompasses hygiene, safety, and moral intention. From a food processing perspective, these practices can be interpreted as early forms of sanitation control and process integrity, which are critical components in modern food safety management systems (Fellows, 2022).

Another key dimension is the principle of moderation and avoidance of excess (*non-israf*), which is reflected in portion control, menu structuring, and food distribution practices, particularly during ceremonial events such as *khol agung*. Food is not only consumed but also distributed as *sedekah* (charity), reinforcing social equity and spiritual values. This principle is highly relevant to contemporary sustainability discourse, particularly in reducing food waste and promoting responsible consumption within halal ecosystems (FAO, 2012).

Furthermore, the presence of religious authorities within the Mangkunegaran court, such as Tafsir Anom and Abdus Salam, plays a critical role in maintaining compliance with Islamic principles. These figures serve as internal regulators, overseeing cultural and culinary practices to ensure alignment with religious teachings. This institutional arrangement closely parallels modern halal governance structures, where certification bodies such as the Indonesian Ulema Council (MUI) provide formal oversight through auditing and certification processes (Akim et al., 2019).

From a techno-governance perspective, these findings indicate that Mangkunegaran royal cuisine already has a foundational halal assurance system, albeit in an informal, culturally embedded form. When mapped against modern halal certification frameworks, key elements such as ingredient control, process hygiene, ethical consumption, and religious supervision demonstrate strong compatibility. Importantly, this embedded governance extends beyond compliance and reflects a value-based food system that integrates cultural, spiritual, and ethical dimensions. This holistic model aligns with contemporary halal ecosystem development, which emphasizes not only certification but also sustainability, traceability, and ethical production.

In contrast to previous studies that primarily focus on symbolic and historical interpretations of royal cuisine, this study highlights the operational and governance dimensions that are directly applicable to modern halal agroindustry systems. This contribution fills a critical research gap by demonstrating how traditional culinary systems can be translated into structured halal assurance frameworks. Overall, the results confirm that Mangkunegaran royal cuisine represents a viable model of culturally embedded halal governance that can be systematically adapted into modern halal certification systems, providing a strong foundation for its transformation into industrial halal food products.

**Techno-Functional Characteristics of Selected Dishes**

The techno-functional analysis of selected Mangkunegaran royal dishes reveals varying levels of suitability for transformation into modern halal food products, particularly in ready-to-eat (RTE) and frozen formats. Puro Mangkunegaran Surakarta has actualized its culinary heritage through the establishment of Pracimasana and Pracima Tuin. These signature royal restaurants are dedicated to developing and preserving the palace's authentic culinary concepts for a modern audience. These differences are primarily influenced by physicochemical properties such as moisture content, water activity (aw), pH, and compositional structure, which are critical determinants in food preservation and processing (Akkermans & Van Impe, 2018; Fellows, 2022). The techno functional characteristics of selected dishes shown in Table 2.

From a food engineering perspective, the selected dishes can be classified into four categories: low-moisture meat products, high-moisture cooked dishes, fermented products, and liquid herbal beverages. This classification is consistent with previous studies indicating that moisture content and aw are key factors in determining microbial stability and shelf-life performance (Escobedo-Avellaneda et al., 2020; López-Malo & Alzamora, 2015; Saha, 2020).

**Table 2.** Techno-Functional Characteristics of Selected Dishes

| Dish | Category | Moisture Level | aw (est.) | pH | Stability | Main Risk |
|---|---|---|---|---|---|---|
| *Dendeng Age* | Dried meat | Low (Suryati & Arief, 2020) | <0.85 | ~5.5 | High | Lipid oxidation |
| *Brubus* | Cooked dish | High (Suharyanto, 2009) | >0.95 | ~6–7 | Low | Microbial growth |
| *Tape Ijo Legi* | Fermented | Medium (Yusmarini et al., 2024) | >0.90 | ~4 | Moderate | Over-fermentation |
| *Wedang Secang* | Beverage | Liquid (Rahim et al., 2023) | - | ~5 | Moderate–High | Contamination |

1. Low-Moisture Meat-Based Product: Dendeng Age

Dendeng Age demonstrates high techno-functional suitability for industrial processing due to its low moisture content and reduced water activity. The seasoned *dendeng* (jerked meat) is grilled over an open flame, basted with coconut milk, and traditionally served on bamboo skewers (Figure 1). Foods with aw below 0.85 are generally resistant to microbial growth, making them suitable for shelf-stable products (Tapía et al., 2020). This characteristic aligns with findings in dried meat processing, where dehydration and salt concentration significantly enhance product stability (Toldrá, 2022). Therefore, dendeng can be effectively adapted into RTE products using vacuum packaging, retort sterilization, or modified atmosphere packaging (MAP).

**Figure 1**. Dendeng Age (Source: Pracima Mangkunegaran, 2023)

However, lipid oxidation remains a major limitation, particularly in meat-based dried products. Oxidative deterioration can lead to rancidity and quality loss, as widely reported in meat preservation studies (Wang et al., 2023). To mitigate this, oxygen barrier packaging and antioxidant incorporation are recommended.

2. High-Moisture Cooked Product: Brubus

Brubus is an authentic Mangkunegaran appetizer that dates back to the era of K.G.P.A.A. Mangkoenagoro VII, is a traditional dish composed of minced beef seasoned with a distinctive blend of fine aromatic spices unique to the Mangkunegaran Palace in Surakarta (Figure 2). Brubus exhibits high moisture content and near-neutral pH, creating conditions favorable for microbial

growth. According to Srivastava & Sit (2025), high-moisture foods are highly perishable and require preservation technologies such as thermal processing or freezing. Similar studies on ready meals indicate that retort sterilization can achieve commercial sterility while maintaining acceptable sensory quality (Simpson et al., 2020). Alternatively, freezing is widely used to preserve the texture and flavor of high-moisture composite foods (Arriaga-Lorenzo et al., 2023). Compared to dried products, brubus requires stricter process control, including temperature regulation, rapid cooling, and hygienic packaging. Without these interventions, the product has limited shelf-life and low industrial feasibility.

**Figure 2**. Brubus (Source: Pracima Mangkunegaran, 2024)

3. Fermented Product: Tape Ijo Legi

Tape Ijo Legi presents complex techno-functional behavior due to ongoing microbial fermentation (Figure 3). Fermented foods typically exhibit lower pH, which can inhibit pathogenic microorganisms; however, uncontrolled fermentation can lead to quality deterioration (Tamang & Lama, 2022). Compared to industrial fermented foods, traditional tape lacks standardized fermentation control, making it less stable for large-scale production. Studies on fermented rice products suggest that controlled fermentation and pasteurization can improve consistency and shelf life (Tamang et al., 2020). Freezing may be applied as a preservation strategy; however, it can negatively affect texture due to ice crystal formation. Therefore, optimizing freezing rates and packaging is necessary to maintain product quality.

**Figure 3**. Tape Ijo Ice (Source: Pracima Mangkunegaran, 2023)

4. Liquid Herbal Beverage: Wedang Secang

Wedang Secang demonstrates high industrial adaptability due to its liquid form and relatively simple processing requirements (Figure 4). Liquid foods are generally easier to process using

pasteurization or ultra-high temperature (UHT) methods, which effectively extend shelf life (Polak et al., 2024). This is consistent with studies on functional beverages, which show that thermal processing and aseptic packaging are commonly used to maintain microbial safety and product stability (Matos et al., 2024). Challenges include sedimentation, flavor consistency, and microbial contamination. These can be addressed through filtration, homogenization, and controlled thermal processing. Compared to solid foods, liquid herbal beverages offer higher scalability and lower technological barriers.

**Figure 4**. Wedang Secang (Source: kompas, 2023)

The findings confirm that product feasibility is strongly influenced by intrinsic food properties, particularly moisture content and water activity. Processing compatibility for RTE or frozen product is shown in Table 3. This supports previous research stating that preservation strategies must be tailored to product characteristics rather than applied uniformly (Rahman, 2007; Fellows, 2009). Compared to existing studies that focus on industrial food products, this study demonstrates that heritage-based cuisine can be systematically analyzed using techno-functional parameters, providing a scientific basis for its transformation into halal agroindustry products.

**Table 3.** Processing Compatibility for RTE and Frozen Products

| Dish | RTE Feasibility | Frozen Feasibility | Recommended Technology |
|---|---|---|---|
| Dendeng Age | High | High | Vacuum, MAP, retort |
| Brubus | Low–Moderate | High | Retort / blast freezing |
| Tape Ijo Legi | Low | Moderate | Controlled fermentation |
| Wedang Secang | High | Low | Pasteurization / UHT |

**Feasibility of RTE and Frozen Product Development**

The transformation of Mangkunegaran royal cuisine into ready-to-eat (RTE) and frozen food products demonstrates significant potential for integration into modern halal agroindustry systems. However, this feasibility is strongly determined by the compatibility between intrinsic food characteristics and appropriate preservation technologies, particularly in terms of microbial safety, physicochemical stability, sensory retention, and halal compliance (Fellows, 2022).

1. Feasibility of Ready-to-Eat (RTE) Products

RTE food systems require strict thermal processing and packaging control to achieve commercial sterility while maintaining product quality. Technologies such as retort sterilization and aseptic processing are widely used in the production of industrial ready meals and beverages

(Simpson et al., 2020). Low-moisture products such as *Dendeng Age* are highly feasible for RTE applications due to their reduced water activity, which limits microbial growth. This is consistent with studies on dried meat products, which show that low aw significantly enhances shelf stability (Toldrá, 2022). Furthermore, vacuum packaging and modified atmosphere packaging (MAP) can minimize oxidative deterioration and extend shelf life (Helmi et al., 2021; Zhang et al., 2025).

Similarly, liquid herbal beverages such as *Wedang Secang* are well-suited to RTE systems. Previous studies on functional beverages indicate that pasteurization and UHT processing effectively ensure microbial safety while preserving bioactive compounds (Matos et al., 2024). This positions Wedang Secang as a promising halal functional beverage with high scalability. In contrast, high-moisture dishes such as *Brubus* present significant challenges. Retort processing may ensure safety but often leads to undesirable changes in texture, flavor, and phase stability, particularly in emulsion-based foods containing coconut milk. Similar findings have been reported in thermal processing of composite foods, where protein denaturation and fat separation reduce sensory quality (Fellows, 2022). Fermented products such as *Tape Ijo Legi* demonstrate the lowest compatibility with RTE systems. Continuous microbial activity during storage may lead to overfermentation and deterioration of quality. Studies on fermented foods recommend stabilization through pasteurization or fermentation control to ensure product consistency (Reli et al., 2017).

2. Feasibility of Frozen Food Products

Compared to thermal processing, freezing technology offers better preservation of sensory and structural quality, particularly for high-moisture foods (Hu et al., 2022). Rapid freezing techniques such as blast freezing minimize ice crystal formation, thereby preserving cellular integrity and texture. High-moisture dishes such as *Brubus* are better suited to frozen applications, as freezing reduces microbial activity without requiring major formulation changes. This aligns with findings that frozen ready meals maintain higher sensory acceptance compared to thermally sterilized products (Montero et al., 2021, 2024).

For *Tape Ijo Legi*, freezing can effectively slow down fermentation and extend shelf life. However, improper freezing conditions may lead to texture degradation and syneresis due to ice crystal damage. Therefore, optimization of freezing rate and packaging is essential (Dottori et al., 2023). Liquid products such as *Wedang Secang* are less suitable for frozen systems due to phase separation and reduced consumer convenience. Instead, ambient-stable RTE systems are more appropriate for beverage products. The comparative feasibility of selected dishes shown in Table 4.

**Table 4**. Comparative Feasibility of RTE vs Frozen Processing

| Product | RTE Feasibility | Frozen Feasibility | Main Limitation | Recommended Strategy |
|---|---|---|---|---|
| Dendeng Age | High | High | Oxidation | Vacuum / MAP |
| Brubus | Low–Moderate | High | Texture degradation | Freezing + reformulation |
| Tape Ijo Legi | Low | Moderate | Fermentation instability | Controlled fermentation |

| Product | RTE Feasibility | Frozen Feasibility | Main Limitation | Recommended Strategy |
|---|---|---|---|---|
| Wedang Secang | High | Low | Phase stability | Pasteurization/UHT |

3. Halal Compliance in Industrial Processing

Beyond technological feasibility, halal compliance is a critical determinant in product development. Modern halal agroindustry requires structured halal assurance systems, including traceability, contamination control, and certification (Akim et al., 2019). Although Mangkunegaran cuisine inherently follows halal-thayyib principles, industrial transformation requires formalization into systems such as the Halal Product Assurance System (SJPH). Critical control points include raw material sourcing, processing equipment, additives, and packaging materials. This transition reflects a shift from cultural halal assurance to standardized halal governance, which is essential for scalability and market acceptance.

4. Industrial Scalability and Market Potential

From an agroindustrial perspective, heritage-based products offer strong differentiation through cultural value and storytelling, thereby enhancing their competitiveness in modern markets. Previous studies have shown that traditional foods can be successfully commercialized when integrated with appropriate processing technologies and effective branding strategies (Lee et al., 2021; Mardatillah et al., 2019). In this context, products such as dried meat (*Dendeng Age*) have potential in the protein snack market, herbal beverages like *Wedang Secang* align with the functional beverage sector, and frozen traditional meals such as *Brubus* fit well within the growing convenience food segment, all of which demonstrate strong alignment with current halal food trends.

However, despite these opportunities, scalability remains a critical challenge in the industrial transformation of heritage-based foods. Key issues include standardizing processes to ensure consistent product quality, establishing reliable, traceable supply chains, and integrating cold chain logistics systems, particularly for frozen products (Table 5). Addressing these challenges is essential to ensure that heritage-based halal products can be produced efficiently, distributed widely, and meet both regulatory and consumer expectations in modern halal markets.

**Table 5**. Processing–Technology Compatibility

| Parameter | RTE Processing | Frozen Processing |
|---|---|---|
| Shelf-life | Long (ambient) | Medium–long (cold chain) |
| Sensory retention | Moderate | High |
| Processing intensity | High (thermal) | Low–moderate |
| Infrastructure need | Moderate | High (cold chain) |
| Product diversity | Limited | High |

The findings demonstrate that feasibility is not universal but product-specific, depending on intrinsic food properties and processing compatibility. This supports previous research emphasizing the importance of tailored preservation strategies rather than uniform approaches (Sandulachi, 2012). More importantly, this study introduces a novel perspective by integrating heritage-based culinary systems with techno-functional and halal processing frameworks, providing a scientific basis for translating traditional cuisine into scalable halal agroindustry products.

**Halal Agroindustry Transformation Framework**

The findings of this study culminate in the development of a Halal Agroindustry Transformation Framework, which integrates cultural heritage, techno-functional food processing, and halal governance into a unified model for scalable halal food innovation. This framework extends previous studies that primarily focus on halal supply chains or certification systems (Akim et al., 2019; Bonne & Verbeke, 2008) by introducing a heritage-driven transformation approach that positions traditional culinary systems as the starting point for industrial innovation. Unlike conventional food product development models that emphasize formulation and process optimization (Fellows, 2022), this framework begins with culturally embedded food systems, thereby integrating ethical, spiritual, and socio-cultural values into technological development.

1. Conceptual Foundation of the Framework

The proposed framework is built upon three interconnected pillars. The comprehensive halal agroindustry transformation framework is illustrated in the Figure 5 below:

(1) Heritage-Based Culinary Knowledge

This pillar emphasizes the role of traditional cuisine as a repository of embedded halal-thayyib values, including ethical sourcing, cleanliness, and moderation. This aligns with the concept of traditional food systems as carriers of cultural identity and sustainability values (Espluga-Trenc et al., 2021; Maulid & Ciptandi, 2023; Pugra et al., 2025).

(2) Techno Functional Food Processing

This pillar translates traditional dishes into industrial products by analyzing physicochemical properties, processing compatibility, and preservation strategies. Similar approaches have been used in food engineering to adapt traditional foods into commercial products through process standardization and shelf-life optimization (Prabawa et al., 2022; Rusdan & Najwa, 2025; Surono, 2016; Yan et al., 2022).

(3) Halal Governance and Certification

This pillar formalizes traditional halal practices into structured systems, including traceability, documentation, and certification. This reflects modern halal governance models that emphasize institutional verification and compliance systems (Akim et al., 2019; Osman, 2023).

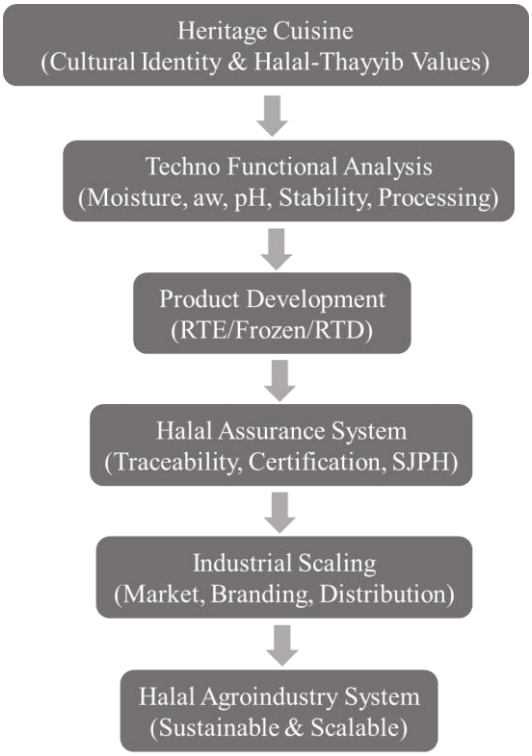


**Figure 5**. Halal Agroindustry Transformation Framework

2. Translational Pathway: From Royal Table to Industry

The structured transition from traditional culinary heritage to a modern industrial model is detailed in Table 6, which outlines the five essential stages of the translational pathway.

**Table 6.** The framework proposes a structured transformation pathway

| Stage | Description | Literature Alignment |
|---|---|---|
| Heritage Identification | Selection of culturally significant foods | Traditional food studies (Nurjayanti, 2022; Rusdan & Najwa, 2025) |
| Techno functional Mapping | Physicochemical analysis | Food engineering (Nikbakht Nasrabadi et al., 2021) |
| Product Standardization | Recipe & process optimization | Industrial food processing (Chemat et al., 2017) |
| Halal Integration | Certification & traceability | Halal governance (Akim et al., 2019) |
| Industrial Scaling | Market & distribution | Agroindustry systems (Nurhasah et al., 2018) |

3. Integration of Halal-Thayyib and Sustainability

A key novelty of this framework lies in integrating halal-thayyib principles with sustainability concepts. Traditional Mangkunegaran cuisine inherently reflects practices such as local sourcing, balanced consumption, and minimal waste, which are closely aligned with the principles of sustainable food systems and circular economy models (FAO, 2012). These characteristics demonstrate that halal-thayyib values extend beyond religious compliance to

encompass environmental and social responsibility. This finding is consistent with recent studies indicating that halal systems are increasingly associated with ethical and sustainable production practices (Lever & Miele, 2012).

This confirms that product–technology alignment is critical, as also emphasized in food preservation research (Saha, 2020). This framework contributes significantly to the halal ecosystem by bridging three critical dimensions: cultural heritage, food technology, and halal governance, which have often been treated separately in previous studies. By integrating these elements into a unified model, the framework highlights a strong novelty in positioning heritage-based cuisine as a viable foundation for modern halal agroindustry development. Furthermore, it supports the advancement of halal value chain systems, enables heritage-based product differentiation, and enhances the global competitiveness of halal food products by combining cultural authenticity with technological and regulatory compliance.

The novelty of this study lies in its ability to integrate heritage cuisine, food engineering, and halal systems into a cohesive and operational framework for halal agroindustry development. Unlike previous studies that tend to focus either on descriptive cultural perspectives or solely on certification and regulatory aspects, this research advances a more comprehensive approach by combining cultural values, techno-functional analysis, and structured halal governance. In addition, this study introduces a heritage-driven halal innovation model in which traditional culinary practices are not only preserved but also systematically transformed into scalable industrial products. Therefore, this research contributes an integrated techno-cultural halal model that bridges tradition and modernity, offering both theoretical advancement and practical applicability in the development of sustainable halal food systems.

The proposed framework offers practical implications by providing actionable pathways for multiple stakeholders within the halal ecosystem. For the food industry, it serves as a guide for developing innovative heritage-based halal products with strong market potential. For government institutions, it supports integrating cultural resources into halal policy and industry development strategies. For researchers, it provides a foundation for further experimental and techno-functional studies in halal food innovation. Meanwhile, for cultural institutions, the framework opens opportunities to preserve and commercialize culinary heritage in ways that remain authentic while being economically viable.

## CONCLUSION

This study provides a conceptual exploration of Mangkunegaran royal cuisine as a culturally embedded halal-thayyib food system that aligns with modern halal agroindustry principles. The findings suggest that integrating ethical sourcing, hygienic practices, and value-based consumption into traditional culinary systems may be compatible with contemporary halal assurance frameworks. From a techno-functional perspective, the study indicates that transforming heritage cuisine into industrial products requires a product-specific approach, in which intrinsic food characteristics, such as moisture content and structural properties, influence the selection of appropriate processing technologies, including thermal processing for ready-to-eat products and freezing for high-moisture foods. This study proposes a preliminary Halal Agroindustry Transformation Framework that integrates cultural heritage, techno-functional considerations, and halal governance into a conceptual model for halal food innovation; however, the framework remains exploratory in nature and should be interpreted as an initial analytical model. Therefore, further research is required to validate the proposed

framework through experimental product development, shelf-life evaluation, and techno-economic analysis to assess its practical feasibility and industrial applicability.

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