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Halal control point (HCP) analysis in the raw material supply chain using the failure mode effect and criticality analysis (FMECA) method

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ABSTRACT

The growing demand for halal-certified food in institutional food services underscores the importance of structured risk management across the raw material supply chain. Despite regulatory requirements, many food service providers still face challenges in identifying and controlling halal-related risks, particularly in upstream processes. This study employed a cross-sectional design and applied the Failure Mode, Effects, and Criticality Analysis (FMECA) method to assess and prioritize halal risks across eight categories of raw materials. Data were collected from 30 respondents, including procurement staff, team leaders, and crew members, using structured questionnaires and interviews. Risk Priority Numbers (RPNs) were calculated based on severity, occurrence, and detection scores. The findings showed that meat and meat products had the highest RPN (94), indicating a tolerable but high-priority risk requiring strict control measures during procurement. Other categories, such as extra food, snacks, vegetables, fruits, spices, side dishes, and rice, were classified as acceptable risks but still require regular monitoring. These results highlight the effectiveness of the FMECA method in identifying critical Halal Control Points (HCPs) and supporting risk-based decision-making within halal assurance systems. Institutional food service providers are encouraged to adopt quantitative methods, such as FMECA, to enhance the effectiveness of halal risk mitigation strategies. Further studies with a broader scope and cross-industry comparisons are needed to strengthen halal integrity across diverse supply chain contexts.

1. Introduction

Halal refers to anything permissible or acceptable under Islamic law [1]. This concept applies to all aspects of life, encompassing various activities [2]. However, prior research on the Halal lifestyle has primarily focused on Halal food [3]. One likely reason is the critical role of Halal food in Islamic teachings. Consuming impure food, unlawful substances, or food prepared through unhygienic or non-compliant methods can affect a Muslim's spiritual connection with God and the validity of their prayers. In Islam, eating is not merely a physical act but carries profound religious significance for a believer's devotion and worship [4].

The Halal principle requires strict compliance within the food industry, covering every stage from sourcing and handling raw materials to delivering products to Muslim consumers. Maintaining Halal integrity demands careful oversight of the production process, including food safety, hygiene, quality control, and quality assurance [5, 6]. According to Hassan and Bojei in 2011, the Islamic concept of Halal is holistic, addressing both physical and ethical dimensions across the entire supply chain, from sourcing raw materials to handling processes [3]. Naeem et al. emphasize that the quality of Halal food depends primarily on manufacturers and suppliers [7]. However, dishonest suppliers who fail to comply with Sharia law can compromise Halal integrity, despite their critical role in providing raw materials [8].

Indonesia, home to the world's largest Muslim population (approximately 87.2%, or 209 million Muslims), leads the global Halal industry. According to the 2022 State of the Global Islamic Economy report, Indonesia is the top consumer of Halal products worldwide [9]. The Halal food industry holds significant potential in global markets, extending beyond Muslim-majority countries to secular states and

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minority Muslim populations [10]. Halal certification, issued by organizations such as SMIIC, MUIS, MUI, GSO/GCC, JAKIM, and PSQCA, is essential for building consumer trust in food products, regardless of where they are produced [11].

Law No. 33 of 2014 mandates that all products sold in Indonesia since 2019 be Halal-certified, ensuring compliance with Islamic dietary laws while enhancing quality and safety standards to boost consumer trust [12]. This legal requirement has prompted institutional food service providers to implement rigorous Halal compliance systems across their supply chains, driven by the growing demand for Halal products [13].

Three key aspects guide the supply chain to ensure products meet Halal standards expected by Muslim consumers [14]. Halal Supply Chain Management (Halal SCM) is a network management system designed to maintain Halal assurance from raw material sourcing to final delivery to consumers [15]. Halal SCM ensures strict adherence to Halal guidelines at every stage, involving coordinated handling of Halal food items by multiple stakeholders across various locations. Often, these processes occur alongside the management of non-Halal products to meet the demands of both markets while safeguarding the purity and integrity of Halal products [16, 17].

The Halal supply chain focuses not only on the final product's Halal status but also on compliance throughout the entire farm-to-fork process. This includes logistics activities such as transportation, warehousing, and terminal operations, all of which must follow Islamic principles to prevent contamination with non-Halal or impure elements. Total segregation of Halal and non-Halal products during handling, storage, and distribution is essential. Trust, traceability, and Halal certification are critical to maintaining Halal integrity [18]. Failure to control any point in the supply chain can lead to violations of Halal standards, necessitating an integrated and standardized Halal supply chain system.

The Halal principle extends beyond compliance with Sharia law to include cleanliness, sanitation, and product safety. Consumers increasingly adopt Halal concepts as part of a healthy and safe lifestyle, demonstrating that Halal has evolved from a religious obligation into a widely accepted quality standard [19]. The main issues in processed meat products involve failures in hazard control at various production stages, such as raw material storage, cutting, and meat selection. Physical hazards primarily occur during storage, while chemical hazards arise during cutting and selection. Biological hazards are often prioritized, particularly in early to mid-production phases. Insufficient risk management and corrective actions, such as inadequate staff training or poor sanitation, can compromise the quality and safety of these products [20]. For fruits and vegetables, critical food safety risks occur during postharvest handling at the farmer level, where noncompliance with hygienic sanitation increases the likelihood of foodborne illnesses. Improper pesticide use is also a significant risk with medium-high criticality. Therefore, strict supervision, proper sanitation practices, and effective environmental controls are essential to prevent contamination and maintain product quality throughout the supply chain [21].

In institutional settings, such as company canteens, these risks are a major concern due to their impact on the safety, quality, and Halal integrity of raw materials served daily. Ensuring compliance with Halal standards and identifying points of potential non-compliance in the supply chain require a comprehensive and structured analytical approach.

This study addresses two key questions: (1) What are the primary factors that could lead to non-compliance with Halal standards in the raw material supply chain? (2) How can Failure Mode, Effect, and Criticality Analysis (FMECA) be used to identify and evaluate Halal Control Points (HCPs) in the raw material supply chain for company canteens?

One major challenge in Halal food assurance is identifying Halal Control Points (HCPs), which are stages in the supply chain with a high potential for Halal violations if proper controls are absent [22]. These include contact with haram substances, cross-contamination risks, and violations of consumer trust in Halal status [23]. Therefore, this study aims to analyze HCPs in the raw material supply chain for company canteens using the FMECA method. This approach systematically identifies, assesses, and prioritizes potential failure modes that could compromise Halal integrity and safety, providing a foundation for developing effective and targeted control strategies.

This study contributes academically by enriching the literature on Halal supply chain management through the application of FMECA to identify and evaluate HCPs, which have been underexplored in the context of company canteens. Practically, it provides guidance for institutional food service providers to enhance Halal compliance and food safety, particularly in Indonesia, the world's largest consumer of Halal products. The study's findings also support the implementation of Law No. 33 of 2014 by offering an analytical tool to ensure Halal integrity across the entire supply chain.

2. Material and method

2.1. Research stage

This study is structured in five key stages, beginning with preparation and concluding with the reporting of findings, to ensure that all processes align with established scientific standards and applicable halal regulations. This approach is expected to contribute to strengthening halal assurance systems within industrial food service operations.

2.1.1. Preparation stage

This stage involves identifying the research problem and objectives, conducting a preliminary study, reviewing relevant literature, and developing the research design and instruments (interviews, observations, and document analysis).

2.1.2. Data collection stage

Data collection is carried out through direct observation, interviews with relevant stakeholders (such as cafeteria managers, suppliers, and halal auditors), collection of supporting documents, and an additional literature review related to FMECA and HCP. A purposive sampling technique was used to select respondents directly involved in the halal supply chain. In total, thirty participants were interviewed, representing personnel from procurement, kitchen operations, and the halal compliance unit.

2.1.3. Data processing and analysis stage

This stage focuses on identifying critical points in the Halal Control Point (HCP) and conducting risk analysis using the FMECA method by assessing severity, probability of failure, and detection levels.

2.1.4. Data validation and verification stage

Validation and verification are performed through data triangulation, member checking, documentation using an audit trail, and expert discussions with halal specialists to ensure the credibility of the findings.

2.1.5. Reporting stage

This final stage includes the systematic preparation of research reports with policy recommendations, followed by the dissemination of results to relevant stakeholders and academic forums to support implementation.

2.2. Data analysis method: FMECA

FMECA is widely used in the manufacturing sector to assess risks and ensure machine availability, enabling the timely delivery of quality products that enhance customer satisfaction and strengthen company reputation. This study reviews FMECA methods, their advantages and limitations, and identifies new research opportunities, particularly in the underexplored areas of occupational health and safety [24]. Failure Mode, Effects, and Criticality Analysis (FMECA) has also been applied to evaluate quality risk levels within the food supply chain [25].

For each failure mode, actions are proposed to lower its criticality by addressing severity, frequency, or detectability. Actions targeting the root cause typically reduce the failure frequency, while improved detection methods lower detectability. Severity is more difficult to address and often requires design changes or significant investments, such as implementing backup systems. Effective actions are expected to improve risk factors by at least one level; for example, two detection measures can reduce detectability from 10 to 3 [26].

The fundamental steps in a conventional FMECA process include:

a. System Definition: Identifying internal functions and interfaces, expected performance at various levels of complexity, system constraints, and defining possible failures.
b. Functional Analysis: Illustrating operational activities, interrelationships, and dependencies among functional entities.
c. Identification of Failure Modes and Their Effects: Identifying all potential failure modes of components and interfaces, and clearly defining their impacts on immediate functions, components, and the overall system.
d. Severity Rating (S): Assessing the seriousness of the consequences or effects resulting from each failure mode.
e. Occurrence Rating (O): Evaluating the frequency or likelihood of each failure mode occurring and conducting a criticality analysis. Since system components can fail in multiple ways, this information highlights the most critical aspects of system design.
f. Detection Rating (D): Assessing the effectiveness of design controls in detecting the occurrence of failure modes.
g. Risk Priority Number (RPN): Calculated as the product of the Severity (S), Occurrence (O), and Detection (D) ratings.

The Risk Priority Number (RPN) helps identify the most critical failure modes in the supply chain. Several experts note that accurately assessing Severity (S), Occurrence (O), and Detection (D) factors is challenging, often requiring linguitic or qualitative methods, such as expert judgment or fuzzy logic, to support the evaluation [27]. Table 1, Table 2, and Table 3 provide the severity, occurrence, and detection index.

Table 1
Severity index.

Rating	Effect	Severity Effect
10	Hazardous without warning	Extremely high severity; the failure mode affects the safe operation of the system without any warning.
9	Hazardous with warning	Extremely high severity; the failure mode affects the safe operation of the system with a warning.
8	Very high	System becomes inoperable with destructive failure, though safety is not compromised.
7	High	System becomes inoperable and leads to equipment damage.
6	Moderate	System becomes inoperable with minor damage.
5	Low	System becomes inoperable but no physical damage occurs.
4	Very low	System remains operable but with significant performance degradation.
3	Minor	System remains operable with moderate performance degradation.
2	Very minor	System remains operable with minimal performance interference.
1	None	No effect on system performance.

Table 2
Occurance index.

Rating	Probability of occurrence	Failure Probability
10	Very high: failure is almost inevitable	> 1 in 2
9	Very high: failure is almost inevitable	1 in 3
8	High: repeated failures	1 in 8
7	High: repeated failures	1 in 20
6	Moderate: occasional failures	1 in 80
5	Moderate: occasional failures	1 in 400
4	Moderate: occasional failures	1 in 2000
3	Low: relatively few failures	1 in 15,000
2	Low: relatively few failures	1 in 150,000
1	Remote: failure is unlikely	< 1 in 1,500,000

Table 3
Detection index.

Rating	Detection	Likelihood of detection by design control
10	Absolute uncertainty	Design control cannot detect the potential cause/mechanism and the resulting failure mode.
9	Very remote	Very low chance that design control will detect the potential cause/mechanism and resulting failure mode.
8	Remote	Low chance that design control will detect the potential cause/mechanism and resulting failure mode.
7	Very low	Very low likelihood that design control will detect the potential cause and resulting failure mode.
6	Low	Low likelihood that design control will detect the potential cause/mechanism and resulting failure mode.
5	Moderate	Moderate likelihoodthat design control will detect the potential cause and failure mode.
4	Moderately high	Moderately high likelihood that design control will detect the potential cause and failure mode.
3	High	High likelihood that design control will detect the potential cause/mechanism and resulting failure mode.
2	Very high	Very high likelihood that design control will detect the potential cause and failure mode.
1	Almost certain	Design control is almost certain to detect the potential cause/mechanism and resulting failure mode.

3. Results and discussions

3.1. Key factors causing non-compliance with halal standards

An in-depth interview with the canteen leader, along with other key stakeholders in the raw material supply chain, provided strategic insights into potential halal non-compliance. Interviewees included procurement and storage staff as well as food suppliers. Using a semi-structured format, the interviews aimed to gather open and detailed information reflecting real field conditions.

The main goal was to gain a deeper understanding of underlying risk factors that may have been overlooked but significantly affect halal compliance from procurement to serving. These findings formed the basis for risk identification and analysis using the FMECA method to strengthen the canteen's halal assurance system. The key factors identified are as follows.

3.1.1. Absence of Halal certification from suppliers

The lack of halal certification from suppliers is a major factor contributing to non-compliance with halal standards. Without official certification from authorized bodies such as MUI or BPJPH, the halal status of raw materials cannot be verified. Therefore, a thorough evaluation of all suppliers is necessary to ensure they hold valid and active halal certificates.

3.1.2. Cross-contamination

Cross-contamination can occur when halal materials come into direct or indirect contact with haram or impure substances due to shared equipment, storage, or processing areas. This poses a significant risk to the halal assurance system and must be strictly controlled.

3.1.3. Lack of employee knowledge and training

Insufficient understanding of halal principles among employees increases the risk of errors in handling raw materials. Inadequate training leads to low awareness of the importance of maintaining halal integrity throughout the supply chain.

3.1.4. Lack of raw material traceability

Incomplete information on the origin, composition, and production process of raw materials makes it difficult to verify their halal status. An ineffective traceability system hinders the company’s ability to ensure compliance with Islamic law and Indonesian halal standards.

3.1.5. Use of additives with unclear halal status

Additives such as emulsifiers, preservatives, flavorings, and colorants may come from animal, plant, or synthetic sources. Without clear information and halal certification, these ingredients can become critical points affecting the overall halal status of food served in the canteen.

3.2. Priority improvements for key factors causing non-compliance with Halal standards

3.2.1. Absence of Halal certification from suppliers

The company must implement a purchasing policy requiring all raw materials to be sourced from halal-certified suppliers. Regular verification of certificate authenticity through the official websites of LPPOM MUI or BPJPH is essential. Supplier contracts should mandate valid halal certification, and non-compliant suppliers must be replaced with certified ones.

3.2.2. Cross-contamination

To prevent cross-contamination, the company must strictly segregate storage, processing areas, and equipment for halal and non-halal materials. Cleaning procedures adhering to Islamic principles must be applied before and after using shared equipment. Kitchen and logistics staff require training on cross-contamination risks and prevention, with regular inspections to ensure compliance.

3.2.3. Lack of employee knowledge and training

The company should conduct regular training on halal principles, Halal Control Points (HCP), and proper food handling in accordance with Islamic law. Providing halal operational guidelines to all canteen staff is essential. Involving employees in internal halal audits fosters understanding and responsibility for maintaining compliance throughout operations.

3.2.4. Lack of raw material traceability

The company should implement a documentation system, either digital or manual, to record raw material origins, including supplier name, batch number, and receipt date. All incoming materials must bear clear halal labels and producer information. Regular traceability audits are essential to assess the company's ability to track raw material sources in cases of halal non-compliance.

3.2.5. Use of additives with unclear halal status

The company must ensure that all additives, such as flavorings, colorants, emulsifiers, and preservatives, are sourced from halal-certified producers. Additives with unclear names or codes should not be used until their halal status is verified. A verified list of halal additives should guide purchasing and production, with active communication with LPPOM MUI or BPJPH to clarify doubtful additives.

3.3. Identification of failure impacts in canteen raw materials

This study employs Failure Modes, Effects, and Criticality Analysis (FMECA) to identify critical Halal Control Points (HCPs) in the company's canteen raw material supply chain. Halal compliance depends on all stages—from procurement to serving—requiring thorough risk evaluation to prevent contamination.

FMECA assesses failure modes based on severity, occurrence, and detection to calculate Risk Priority Numbers (RPNs) for prioritizing control points. The study covers common canteen ingredients, including meat, vegetables, rice, spices, fruits, and snacks. The results aim to enhance halal assurance systems and guide management in ensuring the halal integrity of food served. Table 4 shows the identified risks, failure modes, and their impacts.

3.4. SOD calculation and Risk Priority Number (RPN) results

After identifying the impacts of failure, the study proceeds with calculating the SOD and RPN using the FMECA method. The analysis focuses on commonly used raw materials in the canteen, such as meat and its products, vegetables, rice, spices, fruits, extra food, side dishes, and snacks. The calculation results are presented as follows.

For each category, three key parameters are evaluated: Severity (S) — the level of impact severity; Occurrence (O) — the likelihood of failure occurring; and Detection (D) — the ability to detect such failure. The assessments are conducted by 30 respondents representing key personnel involved in the raw material supply chain and food handling operations, including members of the halal assurance team, the procurement division, hygiene supervisors, and kitchen staff.

Each respondent provides scores for the S, O, and D parameters on a discrete scale from 1 to 10, where higher scores indicate higher criticality (e.g., S = 10 means an extremely severe impact). These scores are assigned by referring to the detailed definitions and criteria outlined in Table 1, Table 2, and Table 3, which describe the scoring scales for Severity, Occurrence, and Detection. The final values for S, O, and D are obtained by calculating the average (mean) of the scores from all 30 respondents, resulting in decimal values (e.g., 5.4, 4.3, etc.).

The RPN serves as a risk indicator for each type of raw material. A higher RPN value indicates a greater severity and likelihood of halal non-compliance, thus requiring more intensive control and possibly designation as a Halal Control Point (HCP). The complete results of S, O, D averages and RPN values for all raw material categories are presented in Table 4 and Table 5.

Table 4
Identified risks, failure modes, and impacts follows.

Raw materials	Risk identification	Failure mode	Effect of failure mode
Meat and Snacks	Procurement	The product does not have a halal certificate or an official halal label.	Raw materials may not be halal, Muslim consumers lack halal assurance, and trust is compromised
Rice and Fruits	Storage	Mixing of halal and non-halal ingredients, or cross-contamination.	Potential contamination causing halal ingredients to become non-halal, damaging halal status
Vegetables	Washing	Using water or equipment contaminated with impurities or non-halal substances.	The material remains impure, not pure according to Sharia, and cannot be consumed under halal standards
Spices and Extra Food	Processing	Using cooking utensils previously used for non-halal ingredients without cleaning.	Cross-contamination causes halal ingredients to become haram, violating the Halal Assurance System (HAS) procedures.
Side Dishes	Serving	Served together with or in containers previously used for non-halal food.	Consumers consume food indirectly exposed to haram substances, compromising the final halal status.

Table 5
SOD calculation and Risk Priority Number (RPN) results.

Raw materials	Stage	Critical value			RPN	Description
		S	O	D		
Meat & Meat Products	Procurement	5.4	4.3	4.1	94	Tolerable
Vegetables	Washing	3.7	3.3	2.6	32	Accaptable
Rice	Storage	1.8	1.6	1	4	Acceptable
Spices	Processing	3.1	2.5	2.2	17	Accaptable
Fruits	Storage	3.8	3.2	2.4	29	Accaptable
Extrafood	Processing	4.4	3.5	2.6	40	Accaptable
Side Dishes	Serving	3.0	2.6	2.2	17	Accaptable
Snack	Procurement	4.6	3.3	2.5	38	Accaptable

Table 6
RPN.

No	Raw material	RPN	Category	Description
1	Meat & Meat Products	94	Tolerable	Special supervision is needed in the purchasing and processing stages.
2	Vegetables	32	Accaptable	Routine control is sufficient, especially during washing and storage.
3	Rice	4	Accaptable	Minimal risk, verification of halal labels is adequate.
4	Spices	17	Accaptable	Halal certification from suppliers must be checked.
5	Fruits	29	Accaptable	Low potential for contamination; basic controls are sufficient.
6	Extrafood	40	Accaptable	Attention is needed for additives and packaging.
7	Side Dishes	17	Accaptable	Low risk, but routine control remains necessary.
8	Snack	38	Accaptable	Additives and processing equipment should be inspected.

If the Risk Priority Number (RPN) is low, the risk of halal noncompliance is also low, indicating that Severity (S), Occurrence (O), and Detection (D) levels are well-controlled. Raw materials or processes with low RPN values have acceptable risks, requiring only routine control without additional supervision.

Conversely, a high RPN value indicates a greater risk of halal noncompliance, with high S, O, and D values: severe failure impact, frequent likelihood of failure, and low detectability, making timely identification difficult. Thus, raw materials or processes with high RPN values require stricter supervision and are often designated as Halal Control Points (HCPs) needing special attention.

According to Table 6, meat and meat products have the highest RPN value (94), indicating a moderate risk level. This suggests a higher potential for halal failure, particularly during purchasing (e.g., lack of valid halal certification), unsanitary storage, or use of non-sterile equipment, necessitating intensive supervision. Other categories, such as vegetables (32), fruits (29), snacks (38), and miscellaneous food items (40), have low RPN values but still require regular controls to prevent cross-contamination or use of uncertified additives. Rice, with the lowest RPN (4), poses minimal risk but still requires halal-certified suppliers. Overall, halal assurance efforts should prioritize meat products, while other categories can be managed through routine, verified standard operating procedures (SOPs).

This evaluation aligns with Failure Mode and Effect Analysis (FMECA), a systematic method for identifying and ranking potential failure points based on severity, frequency, and detectability. The RPN is calculated by multiplying these factors, with higher scores indicating greater risks requiring stricter controls [28]. In halal supply chains, meat products carry higher risks due to complex processing and potential contamination, necessitating stringent certification and hygiene protocols [29].

Research applying FMECA to halal poultry slaughtering has identified high-RPN risk areas, recommending preventive measures like careful supplier selection, comprehensive staff training, and thorough equipment sterilization to ensure compliance [29]. Similarly, blockchain technology, combined with FMECA, has been proposed to improve traceability and risk mitigation in halal meat supply chains [30].

FMECA-based halal risk analysis confirms that meat and meat products have the highest RPN values due to complex processing and contamination risks, requiring strict supervision, valid certification, and high hygiene standards. In contrast, low-RPN materials like rice and vegetables need only routine SOP-based controls. These findings align with prior research emphasizing the importance of identifying critical halal risk points and implementing corrective actions, such as supplier vetting, staff training, and equipment sterilization, to maintain halal integrity throughout the supply chain.

4. Conclusions

Based on in-depth interviews with the canteen manager and key stakeholders within the raw material supply chain, five primary factors contributing to non-compliance with halal standards were identified. These include the absence of halal certification from suppliers, risks of cross-contamination, insufficient employee knowledge and training regarding halal principles, inadequate traceability systems, and the use of additives with unclear halal status. These factors served as the foundation for risk assessment and the identification of Halal Control Points (HCPs) aimed at strengthening the halal assurance system within the company’s canteen operations.

The application of Failure Mode, Effects, and Criticality Analysis (FMECA) was employed to evaluate the risk level of each raw material by assessing three key parameters: Severity (S), Occurrence (O), and Detection (D). The calculation of Risk Priority Number (RPN) revealed that meat and meat products recorded the highest RPN value of 94, classified as tolerable, indicating the need for strict monitoring, particularly during procurement. Other raw materials presented lower RPN values and were classified as acceptable, including extra food (40), snacks (38), vegetables (32), fruits (29), spices (17), side dishes (17), and rice (4). Although these values represent relatively low risk, they still require standardized operational control at each processing stage.

The application of the FMECA method in halal risk analysis indicates that raw materials such as meat and meat products have the highest RPN values, reflecting a greater risk of halal non-compliance. This is due to complex processing procedures and potential cross-contamination, requiring strict supervision, valid halal certification, and high hygiene standards. On the other hand, raw materials with low RPN values, such as rice or vegetables, generally only require routine control based on standard operating procedures (SOP). These findings are consistent with existing theories and previous research emphasizing the importance of identifying critical halal risk points and implementing corrective actions such as supplier selection, staff training, and equipment sterilization to maintain halal integrity throughout the supply chain.

Overall, the RPN values provide a strategic basis for prioritizing control measures and corrective actions in the halal assurance system. Raw materials with higher RPNs should be designated as critical control points due to their significant potential to compromise halal integrity. Conversely, ingredients with lower RPNs must continue to be managed under documented and verified standard operating procedures. Accordingly, the FMECA approach offers a systematic and preventive framework to identify, assess, and mitigate halal non-compliance risks across the canteen's supply chain.

Declaration statement

Akhmad Sadeli: Conceptualization, Methodology, Writing - Review & Editing, Supervision, Formal Analysis. **Khafizh Rosyidi**: Supervision, Project Administration, and Validation.

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