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Application of Fishbone and FMEA in Quality Control of Tempe Production at Batujajar UMKM

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Abstract

This study addresses the limited application of structured quality control tools in traditional food production, particularly within small and medium-sized enterprises (SMEs) such as tempe producers, despite their importance for product consistency and consumer satisfaction. The research aims to identify and analyze the dominant factors contributing to product defects, with a specific focus on discoloration in tempe production, using the Fishbone Diagram and Failure Mode and Effects Analysis (FMEA) as analytical frameworks. Adopting a qualitative-descriptive case study design, one tempe-producing SME in Batujajar was purposively selected. Data were collected through field observations and in-depth interviews over four months (March–June 2025) and supported by defect records from January to September 2024. Findings indicate that the primary cause of discoloration is insufficient employee training, followed by inconsistent implementation of standard operating procedures (SOPs), inadequate temperature and humidity control, poor yeast storage, and environmental conditions. FMEA results show that human error due to lack of training had the highest Risk Priority Number (RPN = 288), marking it as the most critical failure mode. The study concludes that preventive solutions such as regular training, SOP standardization, and environmental monitoring are essential for improving tempe product quality. The implications extend to

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theoretical contributions in quality management within the informal food sector and practical recommendations for SMEs and policymakers to adopt low-cost, effective quality control strategies. Future research should explore the long-term effects of such interventions on business sustainability and customer satisfaction in small-scale food enterprises.

Keywords: Quality Control; Fishbone Diagram; FMEA; Tempe Production; Small Enterprises; Human Error; Food Industry

INTRODUCTION

Indonesia is known for its rich natural and cultural resources, with one of the most prominent aspects being its diverse traditional culinary heritage. Among the various local foods, tempe stands out as a staple that is widely consumed across the country. Made from fermented soybeans, tempe is not only a dietary essential for many Indonesians but also represents the ingenuity of traditional fermentation techniques. According to Putri *et al.* (2022), tempe's accessibility and nutritional value make it a strategic commodity in supporting national food security and nutrition. Its widespread availability in both urban and rural markets makes it an ideal product for micro, small, and medium enterprises (MSMEs) to produce, especially in regions like Batujajar, where local food industries play a vital role in the community's economy (Ayu et al., 2023).

Tempe production, however, is a sensitive process that is highly influenced by several variables such as raw material quality and environmental conditions. The fermentation process depends heavily on temperature, where the optimal growth of the Rhizopus mold essential to forming tempe occurs between 26°C and 36°C. Deviations from this temperature range can result in poor fermentation outcomes. Furthermore, the quality of the soybean plays a crucial role. If the soybeans are not fresh or contaminated with foreign materials, the fermentation process may be compromised, often resulting in discoloration, texture changes, or microbial defects. According to Nugraha *et al.* (2024), improper pre-fermentation treatment or post-fermentation cooling of soybeans can lead to the Maillard reaction, which produces unwanted dark coloration and negatively impacts product quality.

One of the most significant issues faced by tempe-producing MSMEs is the lack of Standard Operating Procedures (SOPs) in production. As noted by Husrizal Syah *et al.* (2022), many small-scale tempe producers rely heavily on manual and traditional methods

without standardized protocols, resulting in inconsistent quality and an increased rate of defective products. The absence of SOPs often leads to operational inefficiencies and reduces consumer satisfaction and brand competitiveness (Ramadhani et al., 2023). Defective tempe categorized by issues such as dark spots, damaged packaging, or pest contamination not only undermines consumer trust but also affects profit margins due to increased product rejection (Mulyana et al., 2022).

The challenges in tempe production are also closely tied to external supply chain factors. The fluctuating price and inconsistent quality of soybeans significantly impact production outcomes. For instance, in June 2024, tempe producers in Batujajar reported receiving soybean batches mixed with pebbles and other contaminants, which disrupted production and increased defect rates. The production data from UMKM Tempe in Desa Galanggang indicated a peak in product defects during July and August, with defect rates exceeding the 3% threshold considered acceptable by the business owner, Bapak Adul. These high defect rates were attributed to poor-quality soybeans and substandard fermentation agents during the rainy season, which also heightened humidity and further complicated production. These recurring quality issues underscore the need for structured quality control mechanisms (Sari & Nugraha, 2025; Wibowo et al., 2020).

Although producers have attempted to maintain product standards using traditional knowledge and experience, these efforts are insufficient in consistently preventing defects. Key production stages such as soybean selection, washing, soaking, and inoculating with mold are highly susceptible to human error, inadequate tools, and environmental interference. Moreover, based on interviews and production data, it is evident that equipment malfunctions, lack of workforce training, and improper handling practices significantly contribute to the rate of defective products. According to Aprila *et al.* (2023), most of these issues stem from weak planning, control, supervision, and occasional negligence, all of which highlight the pressing need for structured analytical tools to identify root causes and propose actionable solutions.

To address this, the present study proposes the application of the Fishbone diagram (Ishikawa) and Failure Mode and Effect Analysis (FMEA) to systematically identify, classify, and prioritize the causes of defects in tempe production. The Fishbone diagram will be used to visually map potential causes of defects across six dimensions manpower, method, material, machine, measurement, and environment while FMEA will allow for quantitative

risk analysis by calculating the Risk Priority Number (RPN) based on severity, occurrence, and detection. Although these tools have been successfully applied in various manufacturing industries, their application in small-scale traditional food production, such as tempe, is still limited. Previous studies by Riptanti *et al.* (2023), Hanum (2022), and Fithri *et al.* (2018) have demonstrated the effectiveness of these methods in identifying and reducing process-related defects, yet there is limited literature combining both tools in the context of traditional MSME food production.

The novelty of this research lies in its integrated use of Fishbone and FMEA methods in the traditional food production sector, specifically in tempe manufacturing by an MSME in rural Indonesia. Most prior research using these tools has been conducted in large-scale or non-food industries. This study contributes by providing a methodological adaptation suitable for low-tech, resource-limited production environments. Furthermore, this research bridges the gap between theoretical quality control frameworks and their practical implementation in community-level enterprises that often lack formal training and resources. This approach is expected to empower local producers with actionable insights, ultimately improving product consistency, reducing waste, and enhancing competitiveness.

The objective of this study is to analyze and identify the root causes of tempe defects in the production process at Batujajar UMKM using the Fishbone diagram and to assess the most critical failure modes using the FMEA technique. The expected outcome is a prioritized list of problems based on their RPN scores, accompanied by practical recommendations for corrective actions. By doing so, this research aims to establish a structured, low-cost quality control system that can be replicated by similar MSMEs, thereby contributing to the sustainability of traditional food industries and supporting rural economic development.

METHODS

This research uses a qualitative descriptive approach to analyze the application of the Fishbone Diagram and Failure Mode and Effect Analysis (FMEA) in the quality control process of tempe production at Batujajar UMKM. The qualitative method is chosen because it allows a detailed examination of production-related issues through direct engagement with the production environment (Sugiyono, 2024). The study was conducted over a period of

four months, from March to June 2025, to observe the production flow comprehensively and identify patterns in the occurrence of defects.

The research design is a case study, focusing on one tempe-producing UMKM in Batujajar that consistently operates and has experienced quality issues. The target population includes production staff and management involved in quality control activities. A purposive sampling technique was applied to select five informants, including a production supervisor, quality control officer, and experienced workers, all of whom are directly involved in the tempe production and inspection process (Abdurohim, 2023; Aprila et al., 2023; Romi et al., 2022; Silalahi et al., 2022).

Data were collected through observations, semi-structured interviews, and document analysis related to production records and defect logs. The instruments were developed based on prior research and validated through expert review. The collected data were analyzed using the Fishbone Diagram to identify potential root causes of product defects and FMEA to assess the severity, occurrence, and detectability of each failure mode using Risk Priority Numbers (RPN). The analysis was guided by Miles and Huberman's (2023) interactive model, which includes data condensation, data display, and conclusion drawing, ensuring the reliability and depth of the findings.

RESULTS

This research, conducted over a four-month period from January to September 2024, aims to analyze quality control problems in tempeh production at a Batujajar-based UMKM using the Fishbone (Ishikawa) diagram and FMEA methods. The main focus is to reduce defective products that negatively impact customer satisfaction and business sustainability. Data collected through observation and interviews shows the total production volume and the number of defective products recorded from January to September 2024, which forms the baseline for this analysis. During this period, a total of 27,400 tempeh units were produced, and 737 units were identified as defective, yielding an average defect rate of 3%. The types of defects observed include discoloration (blackening), damaged packaging, and contamination from animals.

The monthly breakdown reveals significant fluctuations in the rate of defective products. As shown in Table 1, the defect rate was relatively stable from January to May (ranging between 1.1%–2.2%), but a dramatic increase was observed in July (3.8%) and

peaked in August at 7.6%. This sudden spike may correlate with environmental factors such as extreme temperatures and high humidity during the dry season. These findings suggest that seasonal variations significantly impact the fermentation process of tempeh, which is highly sensitive to its surrounding climate. The months with the highest defects also coincide with those that had the least temperature control measures in place.

Table 1. Defective Product Data (January–September 2024)

Month	Production (pcs)	Blackened (pcs)	Damaged Packaging (pcs)	Animal Damage (pcs)	Total Defects	Defect Rate (%)
January	3,100	50	10	2	62	2.00%
February	2,900	40	20	0	65	2.20%
March	3,100	18	15	1	37	1.10%
April	3,000	30	25	2	57	1.90%
May	3,100	25	30	1	60	2.00%
June	3,000	20	12	0	32	1.00%
July	3,100	100	19	1	120	3.80%
August	3,100	200	32	0	237	7.60%
September	3,000	50	27	2	67	2.10%
Total	**27,400**	**533**	**190**	**9**	**737**	**-**
Average	**3,044**	**59.2**	**21.1**	**1.0**	**81.9**	**3.00%**

To further clarify the trend of defective products, a visual chart was developed (see Figure 1). The graph demonstrates a sharp rise in product defects during July and August, confirming the impact of climatic conditions and internal process inconsistencies on product quality. This visual representation emphasizes the urgency of corrective actions during peak environmental stress periods, and also signals a potential lack of control in the production environment.

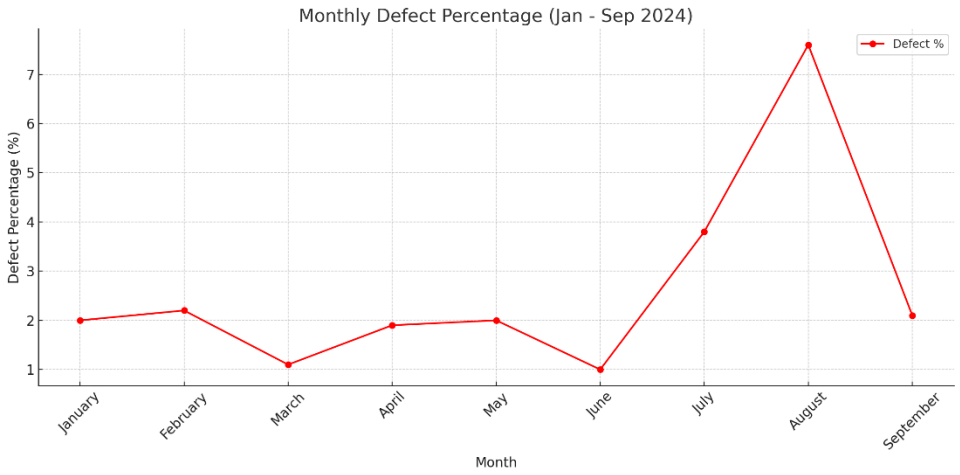


Figure 1. Monthly Defect Rate in Tempeh Production

To investigate the root causes of these defects, the research employed a Fishbone (Ishikawa) Diagram, identifying five major categories: Man, Method, Machine, Material, and Environment. Under the "Man" category, lack of consistent training led to human error, such as incorrect ragi (starter) dosing, affecting fermentation quality. The "Method" category revealed the absence of standardized operating procedures (SOPs), resulting in process inconsistencies. For the "Machine" category, it was found that fermentation rooms lacked temperature and humidity control equipment, causing unstable environmental conditions. Poor handling and low-quality ragi were classified under "Material," while high ambient temperature and humidity, especially during the dry season, were categorized under "Environment."

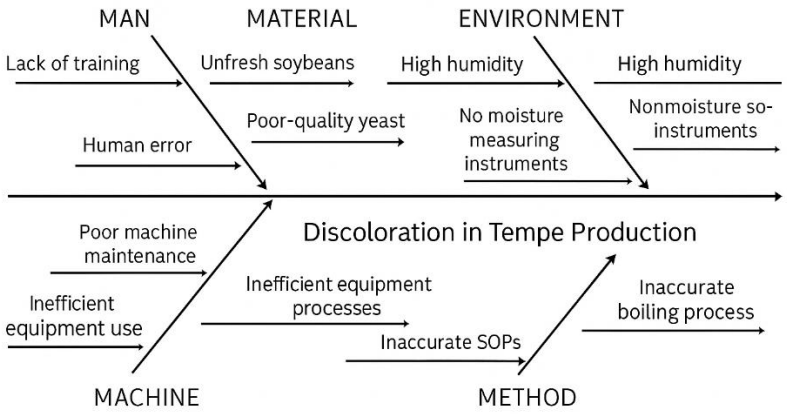


Figure 2. Fishbone Diagram – Root Causes of Defects in Tempeh Production

After identifying the root causes, a Failure Mode and Effect Analysis (FMEA) was performed to assess the severity, frequency, and detection difficulty of each issue. The resulting Risk Priority Number (RPN) helped determine which problems should be addressed first. The highest RPN (288) was assigned to the lack of work training, which not only increased the likelihood of fermentation defects but also had high severity and low detectability. This was followed by poor environmental control (RPN: 270) and low-quality or poorly stored ragi (RPN: 270), both of which also contributed significantly to product defects.

Table 2. FMEA Table of Potential Causes of Tempeh Defects

Factor	Potential Problem	Effect	S	O	D	RPN	Prevention Strategy
Man	Lack of work training	Incorrect ragi dosage, fermentation failure	8	6	6	288	Conduct regular training and establish clear SOPs
Method	SOP is not written or inconsistent	Product inconsistency, discoloration defects	7	7	5	245	Create written SOPs and ensure consistent application
Machine	No temperature/humidity monitoring tools	Fermentation failure, spoilage	9	5	6	270	Install thermometers and hygrometers in fermentation rooms
Material	Poor ragi storage or quality	Fermentation failure, black discoloration	9	6	5	270	Store ragi in cool, dry places; procure only high-quality culture
Environment	High temperature & humidity during dry season	Rapid spoilage, discoloration, contamination	8	7	4	224	Improve ventilation, install cooling systems or climate control in fermentation rooms

Based on table 2 the findings of the FMEA analysis provide clear direction for improvement efforts. Training programs should be prioritized to increase worker skill and reduce human error. Standardized SOPs must be developed, documented, and reinforced through regular evaluations. Environmental monitoring tools, such as thermometers and hygrometers, are essential investments to ensure that the fermentation environment remains within optimal limits. Raw material handling procedures, including proper ragi storage and procurement standards, should also be revised. Lastly, controlling the fermentation environment through better ventilation or even simple cooling systems could drastically reduce defect rates during the dry season.

In conclusion, the integration of Fishbone and FMEA tools in this study successfully identified and prioritized key factors affecting the quality of tempeh production. The use of both qualitative and quantitative data provides a strong foundation for decision-making and practical interventions. Implementing the recommended solutions has the potential to reduce product defects significantly and enhance overall production efficiency, sustainability, and product reliability at Batujajar UMKM.

DISCUSSION

The findings of this study highlight that among the various causes of product defects in tempe production at UMKM Batujajar, the human factor plays the most critical role. Based on the FMEA analysis, the issue of insufficient employee training received the highest Risk Priority Number (RPN) of 288, signifying its high impact on the final product quality. Improper knowledge and skills among workers lead to errors such as incorrect measurements of yeast, resulting in poor fermentation and color inconsistencies in the tempe. These issues not only decrease the visual appeal and shelf life of the product but also reduce its market competitiveness. Furthermore, the lack of standardized procedures exacerbates these errors, leading to irregularities in the production process. The consistent appearance of these defects in the monthly production data from January to September 2024, especially during the months with higher temperatures, reinforces the conclusion that human error, compounded by environmental factors, is the most pressing challenge in maintaining consistent product quality.

Using the Fishbone Diagram, this study successfully categorized root causes into five major dimensions*: Man, Method, Machine, Material, and Environment*. Each category revealed specific issues that contribute to product defects. For example, under the "Method" category, the absence of clear, written SOPs causes inconsistencies in fermentation practices among different workers. Similarly, the "Machine" factor identified the lack of temperature and humidity monitoring tools, such as thermometers and hygrometers, which prevents timely intervention during unfavorable environmental conditions. The "Material" category highlighted how careless storage or low-quality yeast (ragi) directly affects the fermentation process, producing dark-colored or spoiled tempe. The "Environment" factor, especially high temperatures and humidity during summer, contributes to the accelerated spoilage of products. The integration of these insights using both Fishbone and FMEA allows for a

structured prioritization of the root causes, offering a clear pathway for implementing preventive actions (Li, 2024).

These findings are in strong alignment with previous research in the field of traditional food production, particularly among small and micro enterprises (SMEs). A study by Santosa & Palupi (2024) on tofu production within similar UMKM settings found that insufficient worker training and the absence of operational standards were major contributors to product quality issues. Likewise, research by Romadhoni and Dahdah (2024) emphasized the critical role of environmental control during the fermentation of traditional foods. In both studies, as in the current research, the combination of internal process weaknesses and external environmental challenges proved to be the dominant sources of product inconsistency. The recurring identification of these two factors across different food-based UMKM in Indonesia suggests a broader systemic problem related to limited access to training, infrastructure, and quality control tools within the sector (Pratama et al., 2022).

While these consistencies reinforce the credibility of the current study's findings, the novelty of this research lies in its comprehensive and integrative approach (Yentifa et al., 2023). Unlike prior studies that may have focused solely on qualitative analysis or descriptive surveys, this research applies a hybrid model combining Fishbone and FMEA methodologies, supported by real-world production data over a nine-month period (Novianti & Rochmoeljati, 2023). This data-driven approach provides stronger empirical grounding and allows for objective prioritization of improvement actions. Moreover, the detailed calculation of severity (S), occurrence (O), and detection (D) scores offers granular insights into the nature of each issue. This structured analytical framework not only enhances the robustness of the findings but also contributes a practical model that can be replicated by other small-scale food producers facing similar challenges (Nursyamsi & Momon, 2022).

The practical implications of this study are highly significant, particularly for small-scale enterprises seeking to improve product quality with limited resources. The recommendations such as implementing regular training sessions, drafting and socializing written SOPs, installing basic monitoring equipment, and ensuring high-quality raw material storage are feasible even for low-budget operations. These measures, if implemented, are likely to reduce the defect rate, which averaged around 3% during the observation period, with a peak of 7.6% in August. From a broader economic perspective, improving product

quality enhances customer trust, reduces wastage, and increases profitability elements that are crucial for the sustainability of UMKM. Theoretically, the study contributes to the literature on quality management in traditional food industries by demonstrating the effective adaptation of industrial engineering tools such as FMEA and Fishbone to micro-enterprise contexts.

In terms of theoretical implications, this research affirms the relevance of structured problem-solving models in small business environments. Often, tools like Fishbone and FMEA are associated with large-scale industrial settings due to their origin in manufacturing quality assurance. However, this study shows that, when properly adapted, these tools can be powerful in diagnosing issues even in low-tech environments such as UMKM tempe production. By quantifying risks and organizing problems based on categories, the study presents a clear model that can inform both academic researchers and business practitioners. Additionally, the study supports the idea that traditional industries benefit not only from technical upgrades but also from organizational improvements such as standardized procedures and workforce development.

Despite these valuable insights, this study is not without limitations. First, the research was conducted within a single UMKM located in Batujajar, West Java, which limits the generalizability of the results. While the problems identified may be common across similar enterprises, the specific environmental and organizational conditions may differ in other regions. Second, the data on temperature and humidity were gathered through interviews and observations rather than using automated monitoring systems, which could introduce bias or inaccuracies. Additionally, while the Fishbone and FMEA tools offer strong diagnostic capabilities, they rely on subjective scoring for severity, occurrence, and detection, which may vary between evaluators. Moreover, external factors such as supply chain disruptions, inflation in raw material prices, and consumer behavior patterns were not addressed in this study, though they can also influence product quality and production efficiency.

To address these limitations, future research could expand the scope by involving multiple UMKM across different regions and food categories to enhance external validity. Incorporating real-time environmental data through IoT-based sensors could increase the precision of environmental impact assessments. Further studies might also explore the long-term impact of the suggested preventive measures through longitudinal analysis, offering

insights into their sustainability and effectiveness. Finally, future work could include customer satisfaction surveys to link production quality improvements with market performance, thus integrating internal process improvement with external customer-oriented outcomes.

CONCLUSION

This study aimed to analyze the causes of defective color in tempe production at a small-scale enterprise (UMKM) in Batujajar by utilizing Fishbone Diagram and Failure Mode and Effects Analysis (FMEA). The analysis revealed that the most dominant factor contributing to product defects was the lack of worker training (Man factor), which received the highest Risk Priority Number (RPN) of 288. This deficiency leads to improper ragi dosing and inconsistencies in the fermentation process, resulting in discoloration and a higher rate of spoilage. Other significant issues include the absence of standardized operating procedures (Method), inadequate environmental monitoring tools (Machine), careless storage and poor quality of yeast (Material), and unfavorable ambient temperature and humidity (Environment). The integration of Fishbone and FMEA tools enabled a structured diagnosis of root causes and the prioritization of actionable solutions, such as routine training, SOP implementation, and environmental control.

While the findings are robust and offer actionable insights, this research is subject to certain limitations. The study was conducted at a single production unit, potentially limiting the generalizability of the results to other small-scale food producers with different environmental or operational conditions. The assessment of environmental impacts relied on observational data rather than continuous monitoring, which may affect accuracy. Moreover, the FMEA scoring process, while systematic, is inherently subjective and may vary based on evaluator perspectives. These constraints should be taken into account when interpreting the findings.

Future research should consider expanding the sample across multiple UMKM in different geographic areas to increase generalizability. Additionally, incorporating digital monitoring tools for temperature and humidity would enhance the accuracy of environmental assessments. Further studies could also adopt a longitudinal approach to measure the long-term effectiveness of the implemented preventive actions. Finally, connecting quality improvements with consumer satisfaction metrics could provide a more

holistic understanding of how production processes affect market outcomes. Through these refinements, future investigations can build upon the foundation established in this study to further support the advancement of quality control in traditional food industries.

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