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Priority Analysis Of Defect Risk In Crab (Portunus Pelagicus) Processing Using The Failure Mode And Effect Analysis (Fmea) Method In The Crab Industry Of Maros Regency

Muhammad Yusri Yunus[1], M. Yusuf[2] , Nursanti[3], Janny Jovita Pakanan[4] , Nur Islah Sugianto[5]

[1,2,3,4,5]Fakultas Sains dan Teknologi, Program Studi Teknik Industri, Universitas Wira Bakti.

Corresponding Author : yusrilintas1905@gmail.com

Abstract

The swimming crab (Portunus pelagicus) is a highly perishable fishery commodity with high economic value. In the home industry in Maros Regency, quality constraints in the form of defects in swimming crab meat products are still frequently found and have an impact on economic losses. This study aims to identify the types of defects, measure the level of risk of failure in the swimming crab processing process, determine improvement priorities, and formulate recommendations for appropriate quality management strategies. The research approach used is descriptive quantitative with the Failure Mode and Effect Analysis (FMEA) method and root cause analysis using the Fishbone Diagram. Primary data were obtained through direct observation and assessment of the Severity (S), Occurrence (O), and Detection (D) parameters by five expert respondents. During the period of January–June 2026, the total defects recorded were 62.90 kg with a defect rate of 1.86% of the total meat produced. Quantitatively, "stale" defects were the most dominant failure with a contribution of 51.03%. However, the FMEA analysis results show differences in risk priorities, where the "loss of aroma" defect occupies the top priority for improvement with the highest Risk Priority Number (RPN) value of 538.14 due to its characteristics being the most difficult to detect (D = 9.60). The next risk priorities are contamination (RPN = 462.34), staleness (RPN = 291.84), and softness (RPN = 129.60). This study confirms that quality control priorities cannot be determined solely based on the frequency of occurrence, but must be based on comprehensive risks. The improvement strategy is recommended through a parallel

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approach: systemic prevention for loss of aroma defects and rapid corrective action in the form of tightening cold chain discipline to suppress stale defects.

Keywords: Defect, Fishbone Diagram, FMEA, Portunus pelagicus, RPN

INTRODUCTION

The swimming crab (Portunus pelagicus) is a fishery commodity with high economic value and plays a crucial role in the seafood trade and processing industry in Indonesia. Demand for swimming crab products, particularly in the form of frozen meat, pasteurized meat, and other processed products, drives the industry to maintain production continuity while ensuring consistent product quality. However, swimming crab is a food ingredient that is susceptible to quality degradation due to its perishable characteristics and sensitivity to changes in handling conditions, particularly temperature, time, cleanliness, and raw material quality. Quality control is becoming increasingly important because the quality of fishery products not only determines consumer acceptance but is also related to food safety, production efficiency, supply chain sustainability, and the competitiveness of the fishery processing industry (Hassoun et al., 2022; Ghaly et al., 2023; El Sheikha & Hu, 2023).

Various defects can occur in crab processing, including spoilage, loss of aroma, contamination, changes in texture, and other quality deviations that can cause the product to fail specifications and result in rejection. These problems can lead to economic losses due to wasted raw materials, increased production costs, yield loss, and decreased operational efficiency. Furthermore, defects in fishery products are often influenced by a combination of interacting factors, such as raw material quality, working methods, equipment condition, operator competence, temperature control, sanitation, and inspection systems (Dutta et al., 2022; Kour et al., 2023; Nirmal et al., 2023).

The crab processing industry in Maros Regency faces the need to more systematically control potential process failures so that the source of defects can be identified before they significantly impact product quality. Although various studies have addressed quality control and defect identification in the food and fisheries industry, most studies still focus on measuring the number of defects or identifying their causes descriptively. Meanwhile, studies that simultaneously prioritize potential failures based on severity, occurrence, and detectability in the crab processing process are still limited. This gap highlights the importance of an approach that can measurably link defect types, failure impacts, causal factors, and risk priority levels.

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Failure Mode and Effect AnalysisFMEA is a relevant method to meet these needs because it can identify potential failure modes, analyze their impacts, identify causes, and determine risk priority through the Risk Priority Number (RPN) value based on a combination of severity, occurrence, and detection parameters (Liu et al., 2019; Mandal & Maiti, 2021; Zhang et al., 2022). The application of FMEA in this study is expected to provide a more structured approach to determining the types of defects and potential process failures that need to be prioritized in efforts to improve the quality of crab products.

Therefore, this study aims to analyze defects in the processing of swimming crab (Portunus pelagicus) in the swimming crab industry in Maros Regency using the FMEA method, identify potential failures and their impacts, determine risk priorities based on RPN values, and formulate recommendations for improvements that can be implemented by the industry. Theoretically, this study is expected to enrich the application of the FMEA approach in the context of quality control in the fishery industry, especially swimming crab processing. Practically, the results of the study are expected to be the basis for decision-making for the industry in prioritizing preventive and corrective actions so that the number of defects, production waste, and potential quality losses can be minimized.

METHODS

This study uses a quantitative descriptive approach to analyze and prioritize defects in the processing of swimming crab (Portunus pelagicus) in one of the swimming crab industries located in Maros Regency. This approach was chosen because the study not only aims to identify the types of defects that occur, but also to measure the risk level of each potential failure based on the severity of the impact, frequency of occurrence, and the ability to detect the failure. The analysis was conducted using the Failure Mode and Effect Analysis (FMEA) method, which is a systematic method for identifying potential failures, analyzing their impact on the process or product, identifying the causes of failure, and determining the priority of corrective actions based on the level of risk (McDermott et al., 2009; Carlson, 2012; Liu, 2016). The research was conducted at a crab processing industry in Maros Regency, with the object of research being the processing and defects of crab products produced during the observation period. The research data consisted of primary and secondary data. Primary data were obtained through direct observation of the processing stages, semi-structured interviews, and risk assessment using the FMEA instrument. Secondary data were obtained from relevant company documents, including production data, defect or reject records, standard operating procedures (SOPs), and

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available quality control documents. The use of both types of data was intended to obtain a more comprehensive picture of the actual conditions of the processing process and the types of failures that occurred during production activities.

The research subjects were selected using a purposive sampling technique, taking into account the respondents' direct involvement, knowledge, experience, and competence in the crab processing process and product quality control. Respondents consisted of production supervisors, Quality Control (QC) personnel, operators directly involved in the processing process, and experts or practitioners with relevant experience and competence in the field of fishery product processing and quality management. The selection of respondents was carried out because the FMEA assessment requires information from parties who understand operational conditions, potential failures, the impact of failures, and the effectiveness of controls that have been implemented in the crab processing process.

Data collection was conducted through observation, interviews, documentation, and the completion of the FMEA assessment instrument. Observations were conducted by directly observing the stages of the crab processing process to identify points in the process that could potentially cause failure. Interviews were conducted with selected respondents to obtain information regarding experiences with defects, causal factors, impacts on product quality, and control measures that have been implemented. Documentation was used to obtain historical production and defect data recorded in company documents. Next, the FMEA instrument was used to assess each potential failure mode based on three main parameters: Severity (S), Occurrence (O), and Detection (D).

Data analysis was conducted in stages. The first stage was to identify and map the stages of the crab processing process based on observations and available process documents. The second stage was to identify failure modes, or potential forms of failure, at each stage of the process, including their impact on product quality and potential causes. The third stage was to assess each failure mode based on three FMEA parameters.

The Severity value is used to indicate the severity of the impact caused if a failure occurs, Occurrence is used to indicate the level of possibility or frequency of failure, while Detection is used to indicate the ability of the control system to detect failure before the product reaches the next stage or the consumer. Each parameter is assessed using a scale of 1–10 based on the assessment criteria that have been established in the

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research instrument. The Risk Priority Number (RPN) value is then calculated by multiplying the Severity, Occurrence, and Detection values using the equation:

$$RPN = S \times O \times D$$

The RPN value is used to determine the risk priority of each failure mode. The higher the RPN value, the higher the priority level of the failure for corrective action. The scores for each parameter are first aggregated using the average respondent assessment score, then used in the RPN calculation. Next, all failure modes are ranked based on the RPN value to determine the potential failures that are the highest priority in quality control of the crab processing process.

To deepen the analysis of the failure mode with the highest RPN value, a root cause analysis was performed using a Fishbone Diagram. This analysis is used to group causal factors into categories of people, methods, machines or equipment, materials, measurements, and the environment. The results of the Fishbone analysis are used to explain the relationship between causal factors and priority failure modes and serve as a basis for formulating more targeted recommendations for corrective actions.

The reliability of the research findings was strengthened through triangulation of sources and techniques. Source triangulation was conducted by comparing information obtained from supervisors, QC personnel, operators, and experts or practitioners, while technical triangulation was conducted by comparing the results of observations, interviews, documentation, and FMEA assessments. The use of various sources and data collection techniques was carried out to increase the consistency and credibility of the failure mode identification results and reduce the possibility of bias originating from a single data source. With these procedures, the research is expected to produce a measurable defect mapping and risk prioritization and provide an objective basis for developing quality improvement strategies in the crab processing industry in Maros Regency.

RESULT

Identification and Distribution of Crab Defects

This study analyzed production and defect data at a crab processing industry in Maros Regency during the period January–June 2026. Based on production data, the amount of raw material (RM) processed reached 13,875 kg and produced 3,384.15 kg of meat. Of this amount, the net meat obtained was 3,181.10 kg with a total defect of 62.90

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kg. Based on the comparison between total defects and meat produced, the defect rate was 1.86%.

Table 1. Summary of Crab Production and Defects January–June 2026

Parameter	Amount
Raw materials (RM)	13,875 kg
Meat	3,384.15 kg
Meat net	3,181.10 kg
Total defects	62.90 kg
Defect in meat	1.86%

The types of defects found during processing include staleness, loss of aroma, contamination, and softness. The distribution of each type of defect is shown in Table 2.

Table 2. Distribution of Types of Crab Defects

No.	Defect Type	Amount (kg)	Percentage (%)	Ranking
1	Stale	32.10	51.03	1
2	Lost scent	15.60	24.80	2
3	Contamination	8.00	12.72	3
4	Soft	7.20	11.45	4
Total		**62.90**	**100.00**	

The results showed that stale defects were the most dominant type of failure, contributing 32.10 kg or 51.03% of the total defects. Furthermore, loss of aroma contributed 24.80%, contamination 12.72%, and softness 11.45%. Thus, stale and loss of aroma defects cumulatively contributed 75.83% of the total identified defects. These findings indicate that quality issues in the crab processing process are not only related to the number of defects, but also include changes in sensory quality characteristics and product conditions that have the potential to affect consumer acceptance.

Failure Mode and Effect Analysis (FMEA) Assessment Results

An FMEA analysis was performed on four failure modes: stale, off-flavor, contaminated, and soft. Each failure mode was assessed based on three main parameters: Severity (S), Occurrence (O), and Detection (D). Each parameter was scored

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on a 1–10 scale, and the average score from five respondents was used to determine the RPN.

Table 3. Average Values of Severity, Occurrence, and Detection

No.	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)
1	Stale	9.60	8.00	3.80
2	Lost scent	7.80	7.20	9.60
3	Contamination	9.60	5.60	8.60
4	Soft	7.20	5.00	3.60

Based on Table 3, the stale failure mode has the highest Occurrence value, namely 8.00. This value indicates that this failure occurs most frequently and is consistent with actual data showing that stale is the type of defect with the largest number. The highest Severity values are found for stale and contamination, each at 9.60. Meanwhile, the highest Detection value is found for loss of aroma at 9.60, followed by contamination at 8.60.

Risk Priority Number Value Analysis

The results of the calculation of RPN values and risk ratings are presented in Table 4.

Table 4. Results of RPN Calculation and Failure Mode Priority

Ranking	Failure Mode	S	O	D	RPN
1	Lost scent	7.80	7.20	9.60	538.14
2	Contamination	9.60	5.60	8.60	462.34
3	Stale	9.60	8.00	3.80	291.84
4	Soft	7.20	5.00	3.60	129.60

The analysis results showed that the odor loss failure mode had the highest RPN value of 538.14 and was the top priority for repair. Furthermore, contamination had an RPN value of 462.34, staleness 291.84, and softness 129.60. These results indicate a difference between prioritization based on the actual frequency of defects and priority based on FMEA risk values.

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Table 5. Comparison of Priorities Based on Frequency and RPN

Basis of Assessment	Rank 1	Rank 2	Rank 3	Rank 4
Number of defects	Stale	Lost scent	Contamination	Soft
RPN Value	Lost scent	Contamination	Stale	Soft

This difference is one of the research's key findings. Staleness was the most frequently found defect quantitatively, but loss of aroma had the highest risk based on the combined S, O, and D values.

DISCUSSION

Failure Mode and Effect Analysis (FMEA) Assessment

The FMEA results showed that odor loss was the failure mode with the highest RPN value, at 538.14. This value is the result of a combination of Severity (7.80), Occurrence (7.20), and Detection (9.60). A high Detection value indicates that the failure is relatively difficult to detect through the existing control system.

Although aroma loss is lower in quantity than spoilage, this failure has a low detection rate. Therefore, changes in aroma characteristics can occur without being immediately identified by the quality control system. In the context of quality control, this condition indicates the need to improve sensory inspection systems and control process parameters that could potentially affect product aroma characteristics. Monitoring of raw material conditions, lead times, storage conditions, and temperature stability needs to be strengthened because these factors have the potential to affect product quality characteristics.

Contamination ranked second with an RPN of 462.34. A Severity score of 9.60 indicates that the impact of this failure is considered very serious. Although the frequency of contamination is lower than that of spoilage and off-flavor, the risk remains high due to the combination of severity and low detectability. Therefore, contamination control needs to be implemented preventively through strengthening hygiene and sanitation, monitoring material handling practices, controlling potential cross-contamination, and increasing the effectiveness of inspections at critical process points.

Staleness was the most dominant type of defect, accounting for 32.10 kg or 51.03% of the total defects. The Occurrence value of 8.00 was also the highest among all failure modes. This indicates that staleness was the most frequent failure during the observation period. The high frequency of staleness indicates a need to strengthen control over factors that can affect the freshness of ingredients and products. However,

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the RPN for staleness, at 291.84, was below that for odor loss and contamination. This was primarily due to the lower Detection value of 3.80. Thus, failures in the form of staleness were relatively easier to detect than odor loss and contamination.

These results demonstrate that frequency analysis and risk analysis offer different perspectives. If prioritization were determined solely based on the number of occurrences, staleness would be the top priority. However, when severity and detectability were taken into account, odor loss emerged as the highest risk. Nevertheless, the high incidence of stale defects indicates that ease of detection has not been matched by adequate corrective action in the field, so the only solution is to tighten operational oversight.

Failure modeSoft texture has the lowest RPN value of 129.60, which is influenced by Occurrence of 5.00 and Detection of 3.60. Soft texture remains related to product quality conformity and needs to be controlled through processing consistency, material condition control, and product quality inspection.

Priority Failure Mode Root Cause Analysis

Based on the results of the FMEA analysis, the loss of aroma failure mode has the highest RPN value so it is determined as the main focus of the root cause analysis using a Fishbone Diagram with six cause categories:



Figure 1. Fishbone Diagram Failure Mode Loss of Aroma

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Integrative Improvement Strategy and Solution Recommendations

Considering the gap between the actual defect volume (where staleness dominates) and the priority risk values based on FMEA (where loss of aroma is the highest), the crab processing industry is advised to implement two parallel improvement strategy approaches:

1. Systemic Preventive Repair Strategy (Odor & Contamination Removal):
   - Enhanced Detection Capability: strengthening the aroma sensory inspection system at each process stage and training the QC team with sharper panel standards.
   - Strengthening Hygiene & Sanitation: eliminating potential cross-contamination by enforcing mandatory container sterilization and hand sanitization of workers before touching meat products.

2. Operational Quick Wins Strategy (Stale & Soft Defects):
   - Cold Chain Discipline: Ensure the availability of abundant ice cubes on the peeling table and limit the waiting time for raw materials to a maximum of 15 minutes without refrigeration.
   - Raw Material Sorting: Tightening material inspections when receiving crabs from fishermen to eliminate raw materials whose initial quality has decreased.

This multidimensional approach aligns with Hasibuan et al.'s (2024) study, which identified defects in crab products using FMEA. The main difference lies in the object; Hasibuan et al.'s (2024) focused on canned packaging defects, while this study extends the application of FMEA to analyze the quality risks of product characteristics based on sensory and biological characteristics.

CONCLUSION

This study shows that the processing of swimming crab (Portunus pelagicus) in the swimming crab industry in Maros Regency still faces several types of defects, namely stale, loss of aroma, contamination, and soft, with a total defect of 62.90 kg during the period January–June 2026. Stale defects are the most dominant failure quantitatively with a total of 32.10 kg or 51.03% of the total defects, while the results of the Failure Mode and Effect Analysis (FMEA) analysis show that loss of aroma is the failure mode with the highest Risk Priority Number (RPN) value of 538.14, followed by contamination of 462.34, stale of 291.84, and soft of 129.60.

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These results provide insight that quality control priorities cannot be determined solely based on defect frequency, as failures that are more difficult to detect and have serious consequences can have a higher risk level. Fishbone analysis shows that the main causes of odor loss defects are related to human factors, methods, materials, machines, measurements, and the environment.

However, this study is still limited to the analysis of one home industry, a relatively short observation period (six months), and the assessment of FMEA parameters involving only five internal respondents. This limited number of respondents has the potential to trigger a high degree of subjective bias in determining Severity, Occurrence, and Detection scores. Therefore, further research is recommended to expand the expert panel to at least 10–15 respondents by involving elements of food technology academics or external food safety auditors for stronger validation. Combining the FMEA method with Root Cause Analysis (RCA), Fault Tree Analysis (FTA), or the Fuzzy FMEA approach is also highly recommended to produce a more comprehensive, objective, and robust risk analysis.

The crab industry in Maros Regency is advised to prioritize controlling odor loss and contamination defects by strengthening the implementation of standard operating procedures (SOPs), controlling temperature and processing time, and improving quality monitoring. Furthermore, quick wins management of the high number of stale defects must be carried out in parallel by strictly monitoring the adequacy of ice on the production floor. For further research, it is recommended to conduct a comprehensive (end-to-end) defect risk analysis at all stages of the crab processing process, from raw material receipt, steaming, peeling, pasteurization, to final storage, and involve more comparison industries and a longer observation period to obtain a more comprehensive picture of quality characteristics

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