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DEFECT PRODUCT REDUCTION IN RICE PRODUCTION AT UD JAVA DWIPA USING SIX SIGMA METHOD

Reza Ahaddin Ramadhan
Master of Business Administration Program, Institut Teknologi Bandung
Correspondence E-mail: reza_ahaddin@sbm-itb.ac.id

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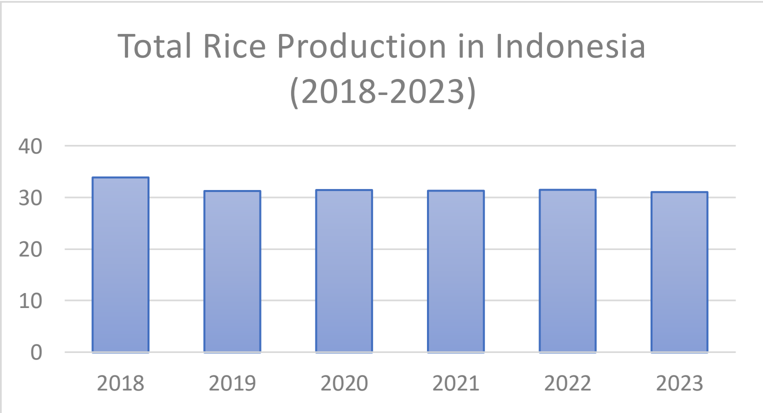
Abstract
The organic rice production process at UD Java Dwipa has faced recurring quality defects, including loosened packaging, contamination with unwanted materials, expired products, and dirty packaging. These issues have led to increased operational costs, inefficiencies, and declining customer satisfaction, raising concerns about the company's ability to consistently deliver high-quality organic rice to its customers. Given the growing competition in the organic rice market and the importance of maintaining product integrity, addressing these challenges is critical for UD Java Dwipa to sustain its market position and reputation. This research employs the Six Sigma DMAIC framework to systematically identify, analyze, and mitigate the root causes of defects. Data collection methods include Failure Mode and Effects Analysis (FMEA), Pareto analysis, and fishbone diagrams, complemented by insights from interviews and production data reviews. Key corrective actions prioritized based on frequency and impact include developing stricter Standard Operating Procedures (SOPs), providing comprehensive operator training, and implementing preventive maintenance for sealing machines. A control phase ensures sustainability through regular audits, real-time defect monitoring, and enhanced process documentation. The findings demonstrate significant reductions in defect rates and improvements in operational efficiency following the implementation of corrective measures. The process capability improved, with the Sigma Level increasing from 3.69 to 4.06, reflecting enhanced production consistency. These results highlight the effectiveness of a structured quality management approach in resolving production challenges and emphasize the importance of continuous monitoring to maintain quality standards in the competitive organic rice market.

***Keywords**: Six Sigma, DMAIC, Fishbone Analysis, FMEA, Quality Control*

1. INTRODUCTION

Rice remains a cornerstone of Indonesia's agricultural sector, integral to national food security and the primary livelihood for millions of rural residents. With an annual production range of 30 to 35 million tons between 2018 and 2023, as illustrated in Figure I.1, Indonesia ranks among the world’s leading rice producers. Despite its prominence, rice production has experienced a gradual decline since peaking at 34 million tons in 2018, stabilizing at around 31 million tons in recent years. This decrease is attributed to several factors, including climate variability, urban land conversion, and challenges in sustaining consistent quality standards.



The organic rice industry, a growing segment within Indonesia's agricultural sector, faces distinct challenges that jeopardize its potential to meet increasing consumer demand. Organic rice, often recognized for its strict cultivation practices devoid of synthetic fertilizers and pesticides, suffers from recurring quality defects. These include loosened vacuum packaging, contamination with foreign materials, and expired products—issues that compromise consumer satisfaction and tarnish brand reputations. A study by Rosa et al. (2021) highlighted defect rates in Indonesian rice milling companies, reaching as high as 8-10% of total production, far exceeding acceptable benchmarks in the food processing industry. These defects often stem from inadequacies in quality control measures, inefficient material handling, and inconsistent operating protocols.

UD Java Dwipa, a leading producer of organic rice in Indonesia, exemplifies the challenges faced by the industry. Specializing in premium organic rice varieties, the company has gained recognition for its high standards and sustainable practices. However, like many producers, UD Java Dwipa grapples with quality issues that jeopardize customer satisfaction and operational efficiency. Recurring defects such as loosened packaging and contamination underscore the need for comprehensive quality control improvements. This research adopts Lean Six Sigma methodology, utilizing the DMAIC (Define, Measure, Analyze, Improve, Control) framework to address the root causes of quality defects in organic rice production. By systematically identifying and resolving inefficiencies, the study aims to enhance production reliability and customer satisfaction, reinforcing the company's commitment to delivering superior organic rice.

2. THEORITICAL FOUNDATION

2.1 Six Sigma Principles

Six Sigma is a data-driven methodology designed to enhance process quality by reducing defects and minimizing variability. Introduced by Motorola in the mid-1980s, Six Sigma emphasizes improving business processes systematically to achieve near-perfect quality standards (Pyzdek & Keller, 2014). The methodology follows the DMAIC framework: Define, Measure, Analyze, Improve, and Control. This framework employs statistical tools and techniques to identify root causes of defects, optimize processes, and sustain improvements (Antony & Banuelas, 2002). Six Sigma is widely recognized for its ability to improve operational efficiency, lower production costs, and ensure consistent product quality (Montgomery, 2020).

2.1.1 Defect Per Million Opportunities

Defects Per Million Opportunities (DPMO) is a key performance metric in Six Sigma that quantifies the number of defects occurring per one million opportunities. This metric standardizes process performance evaluation across industries. The calculation formula for DPMO is:

$$DPMO = \frac{Total\ Defects}{Total\ Opportunites}\ x\ 1{,}000{,}000$$

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Sigma levels, derived from DPMO, indicate a process's performance relative to its specification limits. The formula to calculate Sigma levels is:

$$Sigma\ Level = \sigma^{-1}\left(1 - \frac{DPMO}{1{,}000{,}000}\right) + 1.5$$

where represents the inverse standard normal distribution. Table 1 illustrates the relationship between Sigma levels and DPMO values.

Sigma Level	DPMO
1σ	690,000
2σ	308,000
3σ	66,800
4σ	6,200
5σ	233
6σ	3.4

Higher Sigma levels signify superior process performance and reduced defect rates. Organizations striving for higher Sigma levels must focus on reducing variability and implementing continuous improvement initiatives (Antony, 2006).

2.1.2 Cause and Effect Diagram

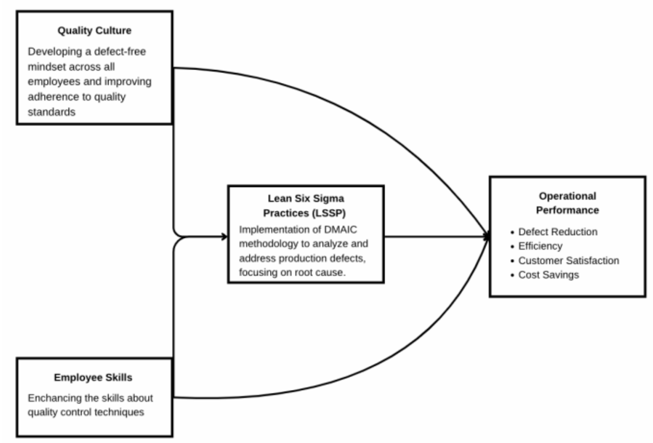
The Cause-and-Effect Diagram, also known as the Ishikawa or Fishbone Diagram, was developed by Kaoru Ishikawa in 1943. It is a visual tool used to systematically identify potential causes of defects by categorizing them into broad groups such as Man, Machine, Material, and Method. Each category represents a source of variability or inefficiency within a process (Luciana, 2016). This tool enables organizations to pinpoint root causes effectively and prioritize corrective actions. Widely adopted across industries, the Cause-and-Effect Diagram is instrumental in improving quality and reducing defects (Montgomery, 2020).

2.1.3 Pareto Analysis

The Pareto Principle, popularized by Joseph Juran, is a fundamental quality management tool based on the 80/20 rule—80% of problems often stem from 20% of causes. A Pareto Chart visually represents these causes using bar and line graphs to highlight their relative impact. This enables organizations to focus on the most critical issues affecting quality (Montgomery, 2019). In quality control, Pareto Charts identify defect frequencies, allowing companies to allocate resources efficiently to address high-impact problems (Evans & Lindsay, 2020).

2.2 Conceptual Framework

The conceptual framework illustrates the methodologies and expected outcomes for addressing defects in organic rice production at UD Java Dwipa. The production process faces significant challenges, including defects such as loose packaging, expired products, and contamination, which disrupt operational workflows and customer satisfaction. To address these challenges, the research employs tools such as Cause-and-Effect Diagrams and Pareto Analysis within the Six Sigma DMAIC framework. This structured approach identifies the root causes of defects, prioritizes key issues, and implements targeted solutions.



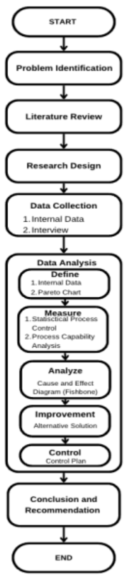
The image illustrates a conceptual framework where three independent variables—Quality Culture, Lean Six Sigma Practices (LSSP), and Employee Skills—directly influence the dependent variable, Operational Performance. This structure implies that the independent variables are hypothesized to have either simultaneous or partial effects on the dependent variable. Each arrow in the framework indicates a hypothesized direct effect of the independent variables on Operational Performance.

3. RESEARCH METHOD

3.1 Research Flow

The research flow adopts a structured methodology that begins with identifying critical issues in the organic rice production process at UD Java Dwipa, such as loose packaging, expired products, and contamination with foreign materials. Following this, a literature review explores relevant quality control frameworks, such as Lean Six Sigma (DMAIC), Cause-and-Effect Analysis, and Pareto Analysis, to establish a solid theoretical foundation.

The research design employs a descriptive quantitative approach to evaluate operational inefficiencies through internal data analysis and stakeholder interviews. The findings guide a systematic application of the DMAIC framework to identify root causes, develop solutions, and implement controls. The process concludes with actionable recommendations aimed at improving quality, efficiency, and customer satisfaction.



3.2 Research Design

This study begins by identifying defects in UD Java Dwipa's organic rice production, such as loose packaging, contamination with foreign materials, and expired products. A thorough literature review, combined with an in-depth understanding of the company's production processes, lays the foundation for data collection. Interviews with the Quality Control Manager and Production Supervisor, along with analysis of internal records like defect logs and production reports, are conducted to identify patterns of recurring defects. The Lean Six Sigma DMAIC methodology is applied to systematically analyze the defects, improve production efficiency, and establish controls to ensure long-term quality improvements. Recommendations are developed based on findings from the analysis, aiming to address root causes, reduce defect rates, and enhance operational performance in alignment with customer satisfaction and organizational goals.

3.3 Data Collection Methods

3.3.1 Internal Data Analysis

Production records, defect logs, and quality control reports are analyzed to quantify defect rates and identify patterns of inefficiency. This data forms the basis for understanding the recurring issues in UD Java Dwipa's production processes.

3.3.2 Stakeholder Interviews

Semi-structured interviews with key personnel, including the Quality Control Manager and Production Supervisor, are conducted to gather qualitative insights into operational bottlenecks and potential improvement strategies.

Table 3.1: Table of Stakeholder Interviews

No.	Participant	Participant Role
1	Quality Control Manager	Oversees quality standards, identifies defect trends, and evaluates packaging and contamination issues.
2	Production Supervisor	Manages production schedules and identifies process inefficiencies impacting product quality.

3.4 Data Analysis Methods

The data analysis follows the DMAIC methodology:

3.4.1 Define Phase

Internal production data and Pareto charts identify critical defects and their frequency.

3.4.2 Measure Phase

Tools such as Statistical Process Control (SPC) and Defects Per Million Opportunities (DPMO) metrics are applied to quantify defect trends.

3.4.3 Analyze Phase

Root cause analysis is conducted using Fishbone Diagrams and Pareto Analysis to pinpoint key contributors to defects.

3.4.4 Improve Phase

Solutions like optimized packaging techniques, enhanced raw material inspections, and SOPs are implemented to address identified issues.

3.4.5 Control Phase

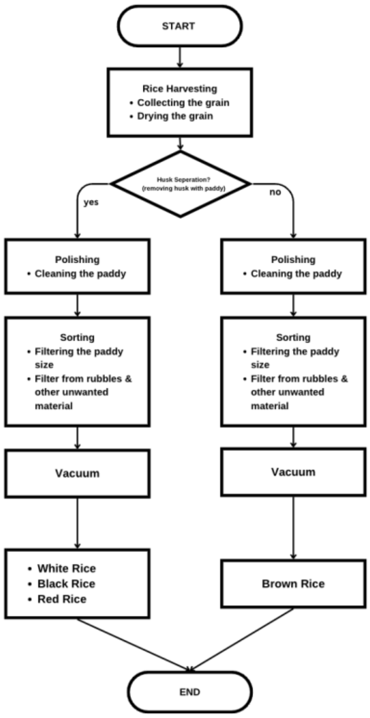
A control plan, including regular monitoring with control charts, ensures process stability and prevents defect recurrence.

4. RESULTS AND DISCUSSION

4.1 Define Phase

4.1.1 Process Flow

The production process of Beras Rassena begins with rice harvesting, where grains are collected and dried to achieve optimal moisture levels, preserving quality. Following this, the grains undergo husk separation to decide whether the husk is removed, leading to two paths: polished rice (white, black, or red rice) or unpolished rice (brown rice). Both paths involve cleaning the paddy during the polishing stage to remove dirt and impurities. The grains are then sorted, filtered by size, and cleared of unwanted materials to ensure uniformity and purity. Next, the rice undergoes a vacuum process, which eliminates any remaining contaminants, maintaining the high hygiene standards of Rassena rice. Finally, the processed grains are divided into their respective final products: white, black, or red rice for the polished path, and brown rice for the unpolished path. The process ends with careful packaging and distribution, ensuring that Rassena rice retains its quality and meets consumer expectations. This streamlined and meticulous process underscores Rassena's commitment to delivering high-quality rice for a variety of preferences. Rassena production process flow illustrated in figure below



4.1.2 Defect Analysis

UD Java Dwipa maintains a maximum defect rate threshold of 2% across its total production. However, key quality issues persist, including loosened packaging, contamination with rubble or unwanted materials, expired products, and dirty packaging.

4.1.1.1 Loosened Packaging

Loosened packaging arises primarily from inadequate machine calibration, operator errors, and inconsistencies in sealing procedures. This defect compromises the vacuum seals, impacting product freshness and customer satisfaction.

4.1.1.2 Mixed with Rubbles or Other Unwanted Materials

This defect stems from inadequate filtering and cleaning processes, allowing foreign materials to remain during production. These contaminants pose risks to product quality and consumer health.

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4.1.1.3 Expired Products

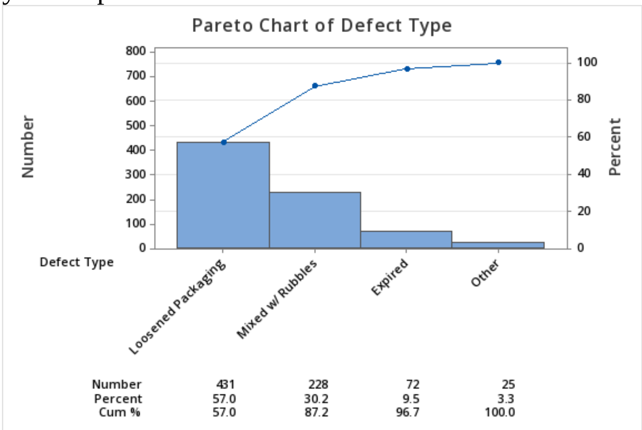
Improper inventory management and insufficient stock rotation practices contribute to expired products, undermining customer trust and financial performance.

4.1.1.4 Dirty Packaging and Other Defects

Dirty packaging, caused by poor handling and storage practices, diminishes the product's appeal and reflects negatively on quality assurance processes.

4.1.2 Pareto Analysis

A Pareto Chart was utilized to determine the most significant defect types in production. Loosened packaging emerged as the most frequent defect, accounting for 57% of the total defects, followed by mixed rubble (30.2%). These two issues together represent 87.2% of all defects, emphasizing their criticality for improvement.



4.2 Measure Phase

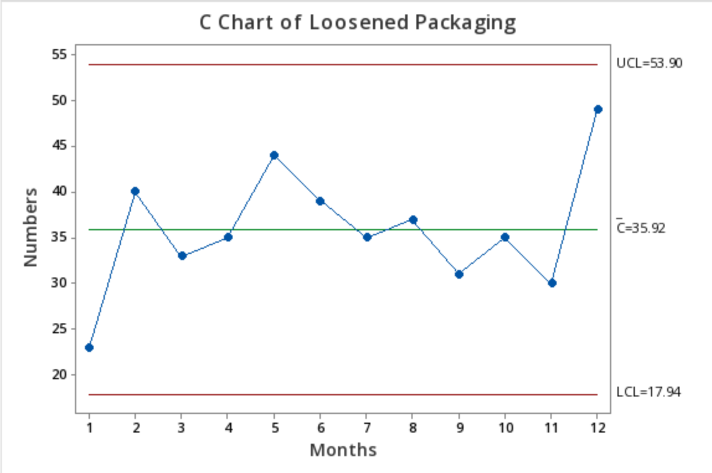
4.2.1 Statistical Process Contro

Statistical Process Control (SPC) was applied to historical defect data, producing c-charts for loosened packaging and mixed rubble defects. The c-charts revealed variations in defect counts over 12 months. Notably, loosened packaging exhibited a spike in Month 12, while mixed rubble showed a consistent upward trend in the second half of the year.

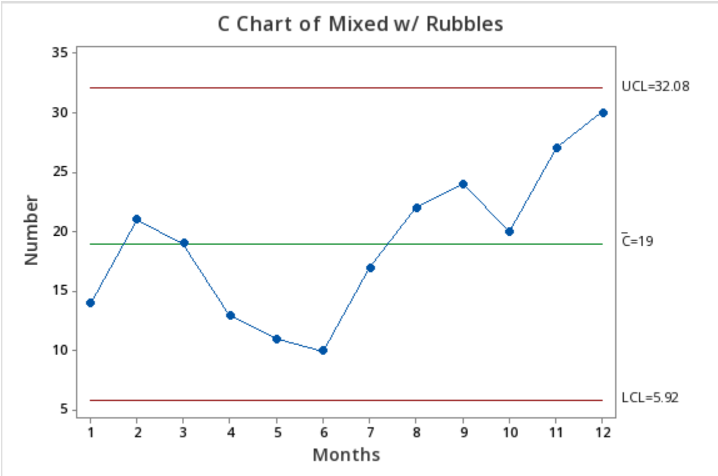
Months	Total Production (pcs)	Defect Type of Beras Rassena (White, Black, Brown, Red)				Total Defects (pcs)	% Defect
		Loosened Package	Mixed w/ Rubbles	Expired	Dirty Package		
1	1101	23	14	5	6	48	4,4%
2	1115	40	21	3	3	67	6,0%
3	1080	33	19	1	9	62	5,7%
4	1127	35	13	2	8	58	5,1%
5	1092	44	11	0	8	63	5,8%
6	1127	39	10	2	4	55	4,9%
7	1108	35	17	1	8	61	5,5%
8	1142	37	22	0	0	59	5,2%
9	1073	31	24	0	9	64	6,0%
10	1110	35	20	1	0	56	5,0%
11	1043	30	27	2	9	68	6,5%
12	1168	49	30	8	8	95	8,1%
Total	13286	431	228	25	72	756	5,7%

The table above presents UD Java Dwipa's defect data collected over a 12-month period. To analyze the stability of the defect proportions in Beras Rassena production, a c-chart was applied. All charts, including the one below, were generated using Minitab software.

4.2.1.1 C Chart for Loosened Packaging



4.2.1.2 C Chart for Mixed Rubbles

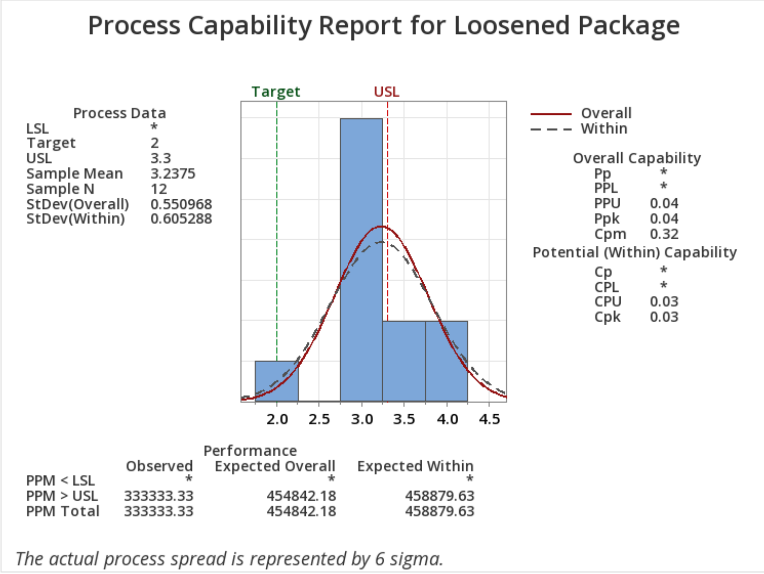


4.2.2 Process Capability Analysis

A binomial capability analysis was conducted to evaluate the production process against the company's 2% defect threshold. The analysis revealed that the process for both defect types failed to meet quality standards.

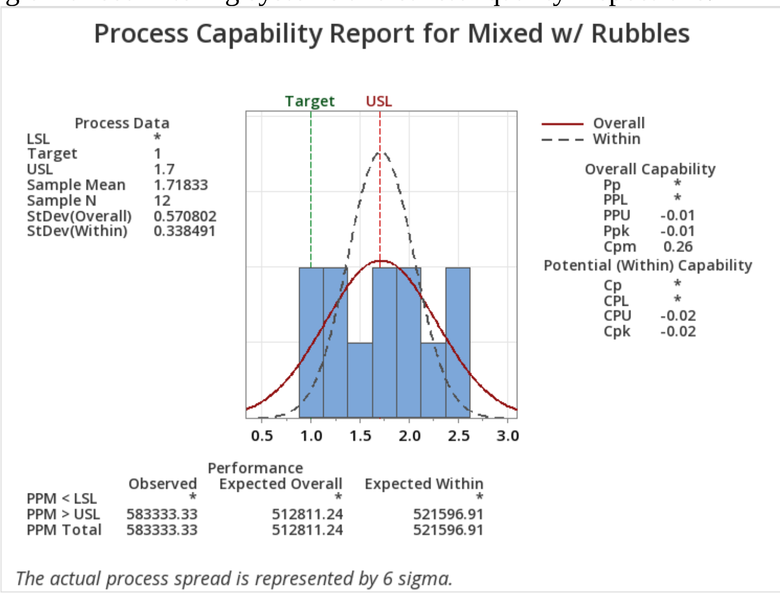
4.2.2.1 Process Capability for Loosened Packaging

The process capability indices, including Ppk and Cpk values of 0.04 and 0.03 respectively, were significantly below the acceptable benchmark of 1.33. The calculated DPMO for loosened packaging was 333,333.33, corresponding to a sigma level of 3.69. This indicates a pressing need for improvements in sealing machine calibration and operator training.



4.2.2.2 Process Capability for Mixed Rubbles

For mixed rubble defects, the process capability indices (Ppk: -0.01, Cpk: -0.02) also fell well below acceptable standards. The DPMO was calculated as 583,333.33, indicating a severe quality issue requiring enhanced filtering systems and stricter quality inspections.



4.2.3 DPMO Target Analysis

The current DPMO for UD Java Dwipa's overall production is 14,226, with a sigma level of 3.69. A target DPMO of 278 was proposed to achieve a sigma level of 4.06, necessitating immediate corrective actions such as upgraded equipment, refined SOPs, and consistent quality monitoring.

Current UD Java Dwipa DPMO

Defects:	756
Units:	13.286
Opportunities per Unit:	4

DPMO:	14.226
Sigma Level:	3,69

Target UD Java Dwipa DPMO

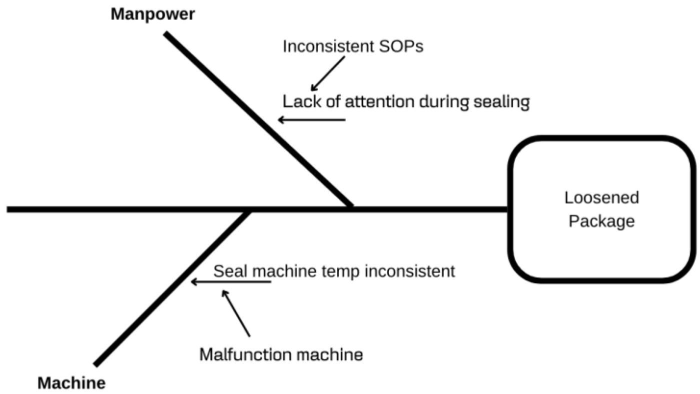
Defects:	278
Units:	13.286
Opportunities per Unit:	4

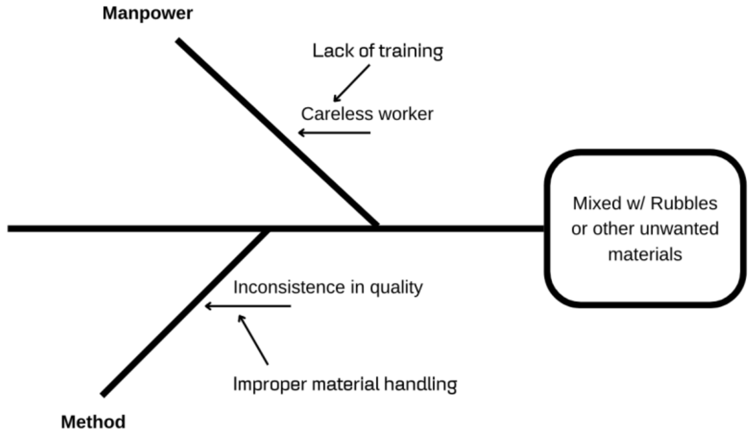
DPMO:	5.231
Sigma Level:	4,06

4.3 Analyze Phase

4.3.1 Cause and Effect Diagram

The fishbone diagram for Loosened Packaging revealed two primary root causes: inconsistent SOPs and malfunctioning machines. Similarly, for Mixed with Rubbles or Unwanted Materials, the root causes were identified as careless workers and improper material handling methods.





These figures illustrate the root causes of both defects, categorizing them into four main factors: Manpower, Machine, Material, and Method.

Root Cause Classification

The classification of root causes, based on their frequency and impact, prioritizes the following:

1. **Inconsistent SOPs** for Loosened Packaging (Manpower).
2. **Improper Material Handling** for Mixed with Rubbles (Method).

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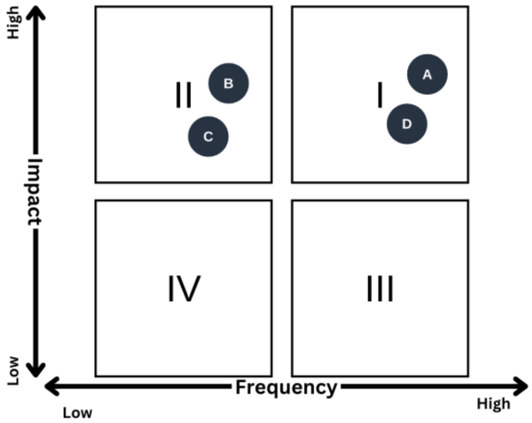
Defect	Factor	Root Cause	Letter
Loosened Package	Manpower	Inconsistence SOPs	A
	Machine	Malfunction Machine	B
Mixed w/ Rubbles or Unwanted Materials	Manpower	Careless Worker	C
	Method	Improper Material Handling	D



The table presents the root causes and their associated factors, with a focus on those categorized as high-frequency, high-impact in Quadrant 1.

4.4 Improve

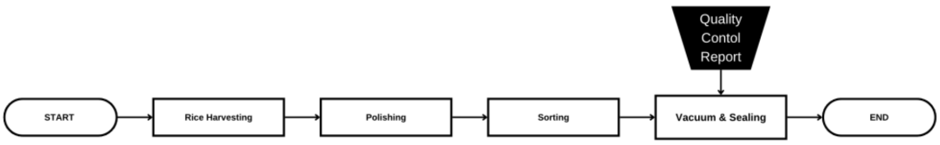
The "Improve" phase focuses on resolving the prioritized root causes to address the critical defects and enhance production processes.

4.4.1 Proposed Improvements

For Loosened Packaging:

Root Cause: Inconsistent SOPs

- Solution: Revise and standardize the Standard Operating Procedures (SOPs) for sealing processes. This includes detailed instructions for machine settings, sealing parameters, and operator training.
- Implementation: Provide operator training and monitor compliance through routine audits.

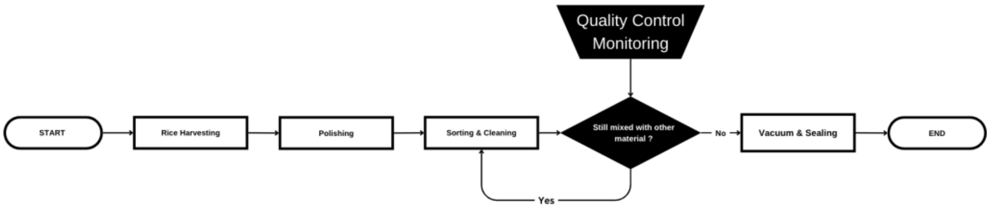


This figure outlines the revised production flow, highlighting process checkpoints to ensure proper sealing practices. UD Java Dwipa will implementing new quality control report that will be presented below

Name			Total Item Checked				
Date			Total Defect Items				
Hours	Total Packages Checked	Packages Accepted	Defect Type			Notes	Action
			Loose Sealing	Unsealed Package	Irregular Sealed		

For Mixed with Rubbles or Unwanted Materials:
Root Cause: Improper Material Handling

- Solution: Introduce updated material handling SOPs focusing on thorough inspections and consistent usage of cleaning equipment like de-stoners.
- Implementation: Train staff on contamination prevention practices and install regular quality checkpoints.



This figure maps the updated material handling process to reduce contamination risks. UD Java Dwipa will implementing new quality control report that will be presented below.

Name						
Date						
Hours	Total Batches Checked	Batches Accepted	Defect Type		Notes	Action
			Contaminations (gravel, rubbles)	Bad Cleaning		

4.4.2 Proposed Quality Control SOPs

Proposed SOP for Quality Control in UD Java Dwipa

Process Stage	Objective	Detailed Steps	Responsible Team	Documentation
Incoming Raw Material Inspection	Ensure raw materials meet quality standards and are free of contaminants.	1. Inspect incoming rice batches for foreign materials (e.g., rubble, stones). 2. Use sieves and visual checks to remove large contaminants. 3. Record results in the Raw Material Inspection Log.	Farmer Division, Quality Control Team	Raw Material Inspection Log
Cleaning and Sorting	Remove impurities and contaminants from raw rice.	1. Pass rice through mechanical de-stoners and sieving machines. 2. Perform visual inspection post-cleaning to identify residual impurities. 3. Record outcomes in Cleaning Inspection Log.	Production Team, Quality Control Team	Cleaning Inspection Log
Packaging Process	Ensure consistent and secure packaging for product freshness.	1. Calibrate sealing machines daily (set temperature and pressure). 2. Perform hourly checks on sealed packages for loosened seals or incomplete seals. 3. Record defective units in Packaging Quality Report.	Packaging Operators	Packaging Quality Report

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Final Product Inspection	Confirm finished products meet quality standards.	1. Randomly sample products from each batch. 2. Inspect for defects such as loosened seals, contamination, or dirty packaging using a checklist. 3. Rework or reject defective products.	Quality Control Team	Final Product Inspection Checklist
Documentation and Reporting	Track quality performance and identify recurring issues.	1. Consolidate all inspection logs (raw materials, cleaning, packaging, final inspection). 2. Analyze defect trends and identify root causes. 3. Present findings in weekly quality control meetings.	Quality Control Manager	Weekly Quality Control Report
Training and Monitoring	Ensure all personnel comply with quality control standards.	1. Conduct training sessions on SOP adherence for operators and staff. 2. Monitor compliance through periodic audits. 3. Document non-compliance and corrective actions.	Quality Control Manager	Training Attendance Sheets, Audit Records

4.5 Control Phase

1. Managing Process Improvements
   Focus: Evaluate stability and consistency in the production process using control charts and Defects per Million Opportunities (DPMO) calculations.
   Metric: The DPMO target is set at 278, representing a 4.06 sigma level, as shown in figure below

Defects:	278
Units:	13.286
Opportunities per Unit:	4

DPMO:	5.231
Sigma Level:	4,06

2. Documenting the Implementation
   Introduce comprehensive documentation to record key metrics such as defect frequencies, machine calibration logs, and worker compliance with SOPs.
3. Continuous Feedback and Improvement
   Establish regular meetings to assess corrective actions and track progress toward quality goals. Develop a feedback mechanism for workers to report issues encountered during production, enabling iterative improvements.
4. Conducting Regular Training and Audits
   Train new workers and conduct refresher courses to maintain quality standards. Perform quarterly audits of production and material handling processes to ensure compliance with updated SOPs.

5. CONCLUSION

The rice production process at UD Java Dwipa faces critical challenges stemming from inadequate cleaning procedures, inconsistent operator training, and the absence of standardized contamination control methods. These deficiencies have resulted in contamination issues, such as the presence of rubble and gravel in the final product, significantly affecting product quality and safety. The lack of clear and documented Standard Operating Procedures (SOPs) is the primary factor contributing to these issues, leading to variability in cleaning, sorting, and packaging processes. To address these challenges, UD Java Dwipa must prioritize the implementation of comprehensive SOPs at each stage of production, focusing on contamination prevention and process standardization. Regular operator training, investment in advanced cleaning equipment, and consistent quality checkpoints are essential measures to enhance process reliability. Establishing a robust monitoring and reporting system will ensure the effectiveness of these interventions, reducing contamination risks and ensuring high-quality rice products that meet both safety standards and customer expectations.

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