

PENINGKATAN KUALITAS DAN PENGENDALIAN CACAT DALAM KEMASAN INDUSTRI MAKANAN DENGAN PENDEKATAN DMAIC

QUALITY IMPROVEMENT AND DEFECT CONTROL IN FOOD PACKAGING INDUSTRY WITH DMAIC APPROACH

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ABSTRAK

Kualitas kemasan produk makanan yang rendah dapat berdampak negatif terhadap kepuasan pelanggan dan kinerja perusahaan. Penelitian ini bertujuan untuk meningkatkan kualitas kemasan produk Kacang Atom Shanghai dengan menggunakan metode Six Sigma melalui pendekatan DMAIC, yang terdiri dari tahapan Define, Measure, Analyze, Improve, dan Control. Penelitian ini mengidentifikasi dua faktor utama yang kritis terhadap kualitas, yaitu berat produk yang tidak sesuai dan kualitas penyegelan yang buruk, yang secara keseluruhan menyumbang 84,3% dari total cacat. Sebelum dilakukan perbaikan, beberapa hari menunjukkan data yang berada di luar batas kendali, dengan jumlah cacat sebanyak 814 unit dari 6.480 unit yang diperiksa. Perbaikan dilakukan menggunakan metode FMEA, termasuk standarisasi produk, pemasangan sensor, dan peningkatan pengawasan operator. Setelah perbaikan, jumlah cacat menurun menjadi 299 unit, dan seluruh titik data berada dalam batas kendali. Nilai RPN juga menurun secara signifikan, dengan D1 turun dari 336 menjadi 175 dan D2 dari 294 menjadi 100. Uji T berpasangan menunjukkan bahwa perbaikan yang dilakukan signifikan secara statistik dengan nilai P sebesar 0,001. Hal ini menunjukkan bahwa pendekatan DMAIC efektif dalam mengurangi cacat dan mendukung pengendalian proses yang berkelanjutan. Untuk penelitian selanjutnya, mengevaluasi efektivitas pendekatan Six Sigma pada berbagai jenis kemasan seperti kemasan metalisasi, dus karton, dan kaleng dapat berkontribusi dalam pengembangan proses pengemasan yang lebih efisien dan berorientasi pasar.

ABSTRACT

Low product packaging quality in food products can negatively impact customer satisfaction and company performance. This research aims to improve the packaging quality of Shanghai Atom Peanut products using the Six Sigma method with the DMAIC approach, consisting of Define, Measure, Analyze, Improve, and Control phases. The research identified two main critical to quality factors: nonconforming product weight and poor sealing quality, which together contributed 84.3 % of total defects. Before improvement, several days showed out-of-control data, with 814 defective units out of 6480 inspected. Improvements were implemented using the FMEA method, including product standardization, sensor installation, and enhanced operator supervision. After improvement, defects were reduced to 299 units, and all data points were within control limits. The RPN decreased significantly, with D1 dropping from 336 to 175 and D2 from 294 to 100. A paired T-test confirmed the improvements were statistically significant with a P-Value of 0.001. This shows that the DMAIC approach effectively reduces defects and supports sustainable process control. For future research, evaluating the effectiveness of the Six Sigma approach across various packaging types, such as metallised packaging, carton boxes, and cans, may contribute to the development of a more efficient and market-orientated packaging process.

I. INTRODUCTION

Nowadays, in the manufacturing industry, particularly within the food sector, the quality of products and packaging significantly affects both consumer safety and satisfaction. Moreover, packaging aesthetics play a crucial role as a marketing medium that can boost product sales. Packaging quality directly influences the distribution process; any defect or damage during production renders the product unsuitable for delivery to consumers. Therefore, maintaining packaging quality is essential to ensuring successful product marketing [1]. According to Djoko A.W. et al. (2020) in their book on quality control, quality fundamentally refers to the fulfillment of customer expectations, whereby customers consistently demand high-

quality products and satisfactory service. The Six Sigma guideline for quality establishes standardized rules to deliver zero-defect products, applicable across both large- and small-scale industries [1] Quality assurance is a critical endeavor aimed at fostering customer confidence that the products they receive conform to their specific requirements [2]. Quality improvement is supported by effective quality control practices, including the reduction of waste [3]. The company experiences high packaging rejection rates, leading to financial loss, inefficiency, and lower customer satisfaction. Strengthening quality control is essential to reduce defects and maintain operations. The Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) method offers a proven, effective approach to improving quality and business performance [4]. DMAIC is a

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structured approach designed to identify and eliminate root causes of defects while minimizing variability in production processes [5]. According to Saputra & Mahbubah (2021) in Bahauddin & Latif (2022), Six Sigma is a continuous improvement method where each production process is closely monitored [6]. The structured application of DMAIC entails sequential improvement steps to achieve targeted outcomes [7]. The Define phase identifies common defect types and their root causes. The Measure phase collects data on defect frequency and impact. The Analyze phase employs fishbone diagrams (man, material, machine, method, environment) to determine root causes. The Improve phase uses FMEA to develop corrective actions, prioritizing risk through RPN (Risk Priority Number) to address the most critical quality issues [8]. FMEA (Failure Mode and Effects Analysis) is utilized to analyze failures and design preventative measures, helping to prioritize actions, enhance workplace safety, and improve customer satisfaction [9]. The Control phase ensures sustained quality by standardizing procedures and monitoring improvements, prioritized by the highest RPN (Risk Priority Number) values [10]. Effective quality control requires stricter supervision regarding cleanliness, raw materials, and operator comfort [11].

Several researchers have examined defect reduction in food packaging using Six Sigma and DMAIC approaches, validating their effectiveness. For instance, Tri Widyawati and Sumartik identified five types of packaging defects, with body leaks being the most common at 53.3%. However, their research focused primarily on the Improve phase, with limited discussion on the Control phase, which is crucial for long-term sustainability [12]. Similarly, research by Sumiati, Isna Nugraha, and Dwi Sukma Donoriyanto did not include the Control phase, and the Improve phase was limited to providing recommendations without any follow-up validation [13]. Another research by Hery Hamid Azwir, Dimas Rangga Arya G., and Hirawati Qomar demonstrated significant defect reduction at PT. PP2. However, it lacked detailed evaluation on long-term process control and the sustainability of implemented improvements [14].

This research applies all phases of the Six Sigma DMAIC method to improve Kacang Atom packaging quality, emphasizing long-term control through standardization, supervision, and sensor monitoring. CTQ (Critical of Quality) analysis identifies are : the product mass weight not being in accordance (D1) with a 45% defect and the packaging seal quality not being in accordance (D2) as the main defects, which cumulatively contribute 85% of the total defects. Paired t-test results confirm significant improvement. The research aims to identify root causes, reduce defects, and establish sustainable quality control to enhance efficiency and lower operational costs.

II. LITERATURE REVIEW

A. Quality Control

According to Djoko Adi Walujo, Titiek Koesdijati, and Yitno Utomo, quality is essentially the fulfillment of consumer desires; customers always want high-quality products and satisfactory service.

According to Sofjan Assauri, quality control is the activity of ensuring that quality policies (standards) are reflected in the final results, or in other words, the

effort to maintain the quality of the products produced in accordance with the product specifications established based on management policies. Here are some statements on quality control from experts. Joseph M. Juran defines quality as “accuracy and suitability in use,” Deming as “conformity with customer requirements,” and Philip Crosby defines it as “customer satisfaction.” According to Crosby, quality control includes the definition of quality as conformance rather than luxury, the core of the quality system is prevention, standard performance is the concept of Zero-Defect, and quality measurement in the form of costs [15].

Quality control activities are a very broad and complex field of work because all variables that influence quality must be considered. Generally, quality control approaches can be divided into three categories, as follows: Raw material quality control, which includes coconut raw materials that do not meet certain specifications, such as broken coconuts, rotten coconuts, and coconuts that have sprouted; quality control during the production process, which aims to reduce errors that occur outside the company's control, such as machines and dough; and final product quality control: At this stage, leaky packaging and high micron levels are checked because they do not meet specifications [16].

B. Issues Causing Packaging Defects

There are 5 types of defects in the packaging of the Shanghai atom peanut product, which serve as the research variables in this study. These products are manufactured using the Masema machine. The identified defects include: non-conforming product weight, improper sealing quality, missing expiration date, overlapping packaging, side striping on packaging surface.

C. The Six Sigma Approach

The Six Sigma method with the DMAIC approach is commonly employed to minimize the defect rate in product packaging, as it has been proven effective in reducing defects and enhancing overall quality across various industrial sectors. DMAIC is a structured methodology designed to identify and eliminate the root causes of defects while minimizing process variability in manufacturing operations [5]. The application of the DMAIC approach represents a systematic strategy for addressing quality-related issues. The Define phase facilitates a clear understanding of the problem, such as identifying the most common types of defects and the factors contributing to their occurrence. The Measure phase involves the collection of data to assess the frequency and impact of the problem. Subsequently, the Analyze phase enables the identification of the root causes of quality issues, including production errors or equipment failures. The Improve phase focuses on implementing recommended solutions to reduce the number of rejected packaging units. Finally, the Control phase establishes measures to ensure that the

improvements are sustained over time and that packaging quality remains consistent.

III. METHOD

This research applies a quantitative, experimental approach to implement improvements in the packaging process of Kacang Atom Shanghai. Through data analysis, it seeks to pinpoint important quality variables and create improvement plans. The research employs continuous monitoring, operator training, sensor installation, and standardized measurements using the Six Sigma DMAIC framework. The impact of these changes is empirically assessed by comparing the RPN values from FMEA pre- and post-improvement adoption using a paired t-test. The premise that Six Sigma implementation significantly lowers failure rates is tested using the deductive technique. Through observations, interviews, and documentation, primary data were gathered. The following are the DMAIC stages:

A. Research Flow Chart

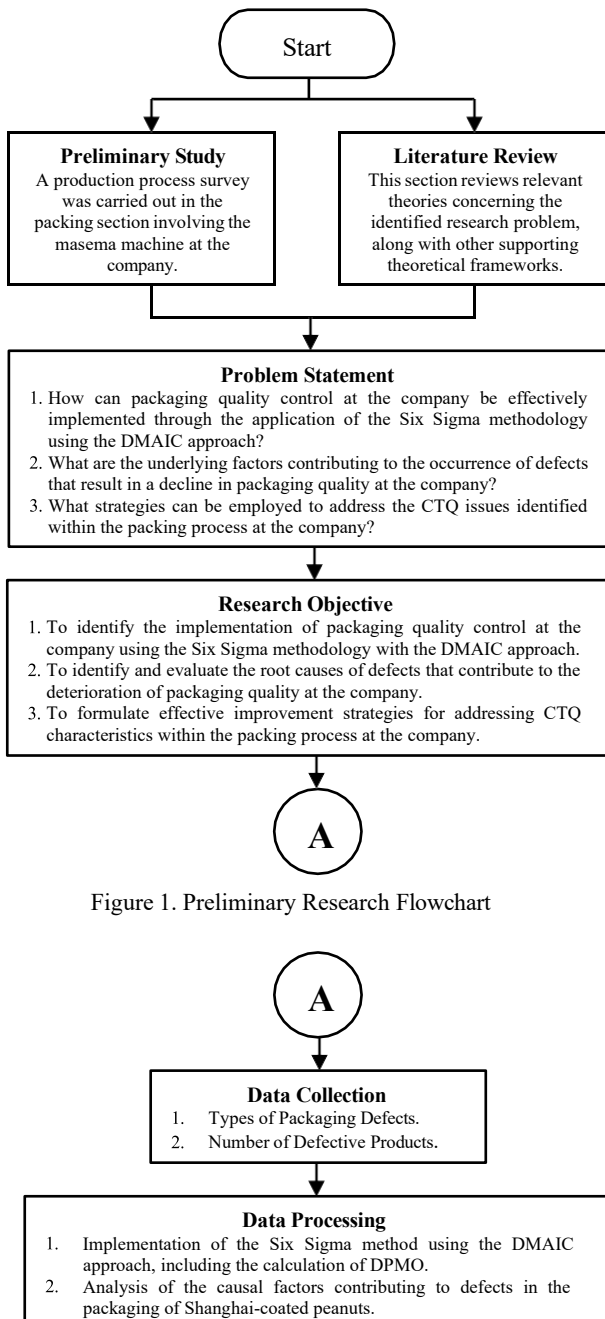


Figure 1. Preliminary Research Flowchart

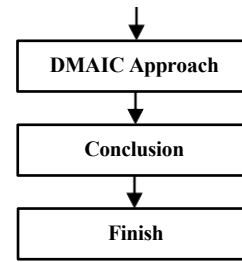


Figure 2. Flowchart of Research Steps in Data Analysis

B. Research Variables

Research variables are the objects of study or the focal points of a research investigation. The variables selected must align with the research problems and objectives to be achieved. Research variables are generally categorized into two types:

1. Independent Variable

An independent variable is one that influences or causes changes in another variable, specifically the dependent variable (also referred to as variable X). In this study, the independent variable in the packing process using the Masema machine is the number of packaging defects.

2. Dependent Variable

A dependent variable is one that changes as a result of the influence of the independent variable. It is the variable being measured or affected (also referred to as variable Y). In this study, the dependent variable is the change in CTQ characteristics.

C. Population and Sample

The following outlines the population and sample of the research:

1. Population

The population of this research consists of packaging defect data collected from the production process in the packing section using the Masema machine for the Kacang Atom Shanghai Gangsar Super Pack product at the company. The data were gathered over a period of 15 days, comprising a total of 6,480 units.

2. Sample

The sample in this research consists of the Kacang Atom Shanghai Gangsar Super Pack. The sampling technique was conducted during each observation, with the sample size varying depending on the total production output. The total number of samples was calculated using the following formula:

$$\begin{aligned}
 N &= \text{Number of Inspections} / \text{Total Product Population} \\
 &= 6,480 / 15 \\
 &= 432
 \end{aligned}$$

Thus, the number of samples taken for inspection is 432.

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D. Data Collection Method

The data collected in this study is primary data, which was obtained directly by the researcher. The data collection methods employed are as follows:

1. Interview

Conducted with relevant personnel involved in the packing process to gain insights into production flow, types of defects, and potential causes of quality issues.

2. Documentation

Involves collecting records and documents related to production reports, defect data, and quality control procedures in the packaging section.

3. Observation

Direct observation of the packaging process, particularly on the Masema machine, to monitor activities, identify defects, and validate findings from interviews and documentation.

E. Data Processing Method

The following presents the data processing steps using the Six Sigma methodology with the DMAIC (Define, Measure, Analyze, Improve, Control) approach:

1. Define Phase

Initial observations identified packaging defects and determined CTQ factors based on customer requirements, prioritizing those with the greatest impact on the overall defect rate. This stage focused on identifying the most critical defects contributing to production failure.

In this phase, the proportion of defects that contribute most significantly to production failures is identified, as follows:

- a. Identifying packaging defects in the product.
- b. Determining the CTQ factors.

2. Measure Phase

This phase involves analysis using the p-chart (attribute control chart). In the Measure stage, data variation for variables and attributes is measured by creating control charts and determining the sigma level using DPMO (Defect Per Million Opportunities) [17]. The following formulas are used to calculate the control limits for a p-chart:

- a. Calculating control limits and control map p.

Here is the formula for calculating control limits for control maps, as follows:

- 1) Calculating the Central Line (CL):

$$CL = \bar{p} = \frac{\sum np}{\sum p} \quad (1)$$

Description:

CL = \bar{p} = Average proportion of defective units

$\sum np$ = Total number of defective units

$\sum p$ = Total number of inspected units

n = \sum total products / sample size taken in the inspection

n = Total sample size collected during the inspection

- 2) Calculating the Upper Control Limit (UCL):

$$UCL = \bar{p} + 3 \cdot \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \quad (2)$$

Description:

UCL = Upper control limit

\bar{p} = Average proportion of defective units

- 3) Calculating the Lower Control Limit (LCL):

$$LCL = \bar{p} - 3 \cdot \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \quad (3)$$

Description:

LCL = Lower control limit

\bar{p} = Average proportion of defective units

- b. Calculating DPO and DPMO

The following formulas are used to calculate DPO and DPMO (Ayu et al., 2023):

$$DPO = \frac{\sum \text{Number of Defects Found}}{\sum \text{Units Inspected} \times \text{CTQ}} \quad (4)$$

$$DPMO = DPO \times 1.000.000$$

Description:

DPO = *Defects Per Opportunity*

DPMO = *Defects Per Million Opportunities*

- c. Level Sigma

The primary objective of Six Sigma is to focus on the process and reduce variation. Through the Six Sigma approach, it is expected that the process can achieve a “zero defect” condition, or 3.4 defects per million opportunities (DPMO). Table 2.1 presents a comparison of different sigma levels based on corresponding DPMO values [18].

3. Analyze Phase

Utilizing a fishbone diagram, this step analyzed the root causes of significant packaging defects, focusing on Man, Material, Machine, Method, and Environment. Additionally, it identified the primary sources of weight and sealing discrepancies [19].

4. Improve Phase

The Improve stage applies FMEA, which is used to evaluate failures and identify the one with the greatest impact caused by the masema machine defect issues. This leads to improvement recommendations. Mathematically, the Risk Priority Number (RPN) is determined by the values of Severity (S), Occurrence (O), and Detection (D).

$$RPN = S \times O \times D \quad (6)$$

Description:

RPN = *Risk Priority Number*

S = *Severity*

O = *Occurrence*

D = *Detection*

5. Control Phase

The Control stage is the final phase in the Six Sigma methodology using the DMAIC approach. It involves implementing controls in each activity to

achieve optimal results by minimizing time, issues, and unnecessary costs.

IV. RESULT AND DISCUSSION

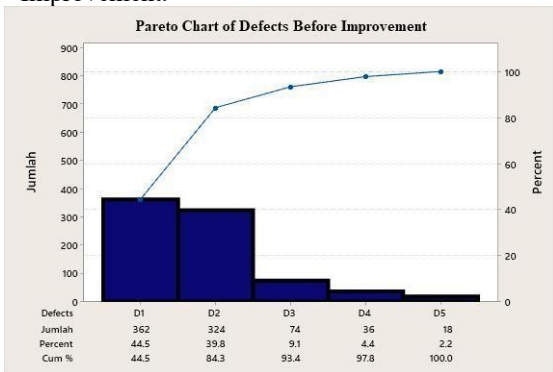
This research identified D1 and D2 as the primary packaging defects, which together account for over 80% of the total defects issues. By employing the DMAIC method, we analyzed the root causes using fishbone diagrams and FMEA. Improvements such as training, standardizing nut sizes, and installing sensors effectively reduced the RPN values, as confirmed by a paired t-test ($P < 0.05$). Consistent with prior research emphasizing training and machine control [19], [10], this research also integrated a robust control phase, including routine supervision, sensor checks, and raw material quality control. Consequently, the research not only reduced defects but also established a sustainable quality control system, enhancing process reliability and company competitiveness [1], [7].

A. RESULT

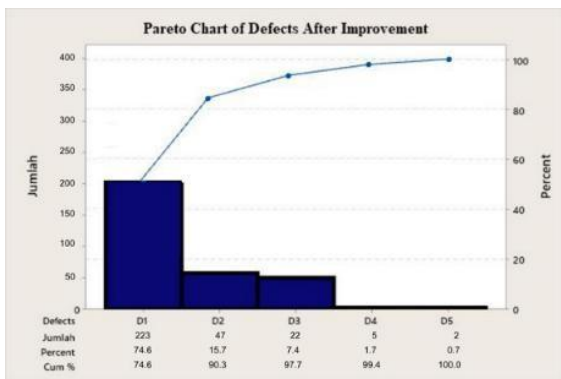
Based on the analysis results from the data processing in previous research conducted as initial data for observing defect levels, several important findings were obtained, including:

1. Define Phase Findings

CTQ factors were identified using Pareto diagrams, as shown in Figure 1. Pareto Diagram Before Improvement and Figure 2. Pareto Diagram After Improvement.



Source: Data Processed using Minitab
Figure 3. Pareto Diagram Before Improvement



Source: Data Processed using Minitab
Figure 4. Pareto Diagram After Improvement

In Figures 3 and 4, two main types of defects were identified: D1 and D2. These two defects became the top priority for immediate corrective recommendations. Before improvement, D1 accounted for 44.5% of defects and increased to 74.7% post-improvement, while D2 decreased from 39.8% to 15.7%, showing significant improvement in sealing quality. Overall, the combined contribution of D1 and D2 slightly increased from 84.3% to 90.3%, highlighting their continued dominance and the need for ongoing process monitoring and refinement.

2. Pre- and Post-Improvement Data Analysis

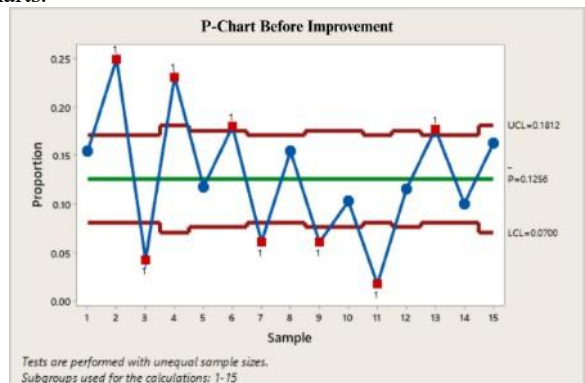
CTQ data before and after improvement are summarized in Table 1. Furthermore, the measure phase involved monitoring variation using control charts (p-charts), as illustrated in Figure 5. Before Improvement and Figure 6. After Improvement. The pre- and post-improvement research data are presented below in Table 1. CTQ data before and after improvement in the improve phase are as follows:

Table 1. Pre- and Post-Improvement Data

Day	Pre-Improvement Data			Day	Post-Improvement Data		
	Total Products Inspected	Total Defective Products	C T Q		Total Products Inspected	Total Defective Products	C T Q
1	480	74	2	1	480	20	2
2	480	120	2	2	480	25	2
3	480	20	2	3	480	30	2
4	320	74	2	4	320	23	2
5	400	47	2	5	400	13	2
6	400	72	2	6	400	22	2
7	480	29	2	7	480	30	2
8	480	74	2	8	480	15	2
9	400	24	2	9	400	26	2
10	400	41	2	10	400	15	2
11	480	8	2	11	480	20	2
12	400	46	2	12	400	12	2
13	480	85	2	13	480	20	2
14	480	48	2	14	480	18	2
15	320	52	2	15	320	10	2
Total	6.480	814	2	Total	6.480	299	2

Source: Data processed using Excel

Subsequently, measurements were conducted in the Measure phase by analyzing variations in both variable and attribute data through the creation of control charts or p-charts.



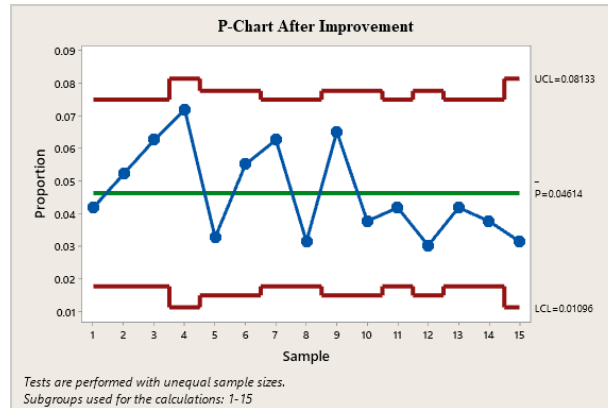
Source: Data Processed using Minitab

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Figure 5. P-Chart Control Graph Before Improvement in the Improve Phase

Figure 5 shows that the p-control chart before improvements had four data points on data days 2, 4, 6, and 13 that

were outside control limits, indicating the process was out of control and required corrective action.



Source: Data Processed using Minitab

Figure 6. P-Chart Control Graph After Improvement in the Improve Phase

Figure 6 after improvements, it shows all data points within control limits, confirming statistical control of the process.

3. Result of Comparing FMEA RPN Values Before and After

Quality control results were obtained by comparing FMEA RPN values before and after implementing improvements. A paired T-test confirmed the statistical significance of these changes. Failure modes were ranked by RPN to prioritize corrective actions, with pre-improvement values

Table 2. RPN Values Pre-Improvement

Code	Priority Number	Type of Defect	S	O	D	RPN	Proposed Corrective Action
A1	1	Non-conforming Product Weight in Packaging	8	7	6	336	Providing training, coaching, and enhanced supervision for operators
A2	2		8	8	5	320	Standardizing the size of atom peanuts
A3	3	Improper Packaging Seal Quality	7	7	5	245	Installing sensors on the Masema machine to detect the size of atom peanuts or developing standardized size specifications
A4	4		7	7	6	294	Standardizing the size of atom peanuts
A5	5		7	6	6	252	Providing training to ensure operators understand the importance of accurate placement of atom peanuts to reduce defective and rejected packaging

Corrective actions in the Improve phase were prioritized based on FMEA RPN values, focusing on high-risk failure modes first in Table 2. This targeted approach addresses the most critical sources of packaging defects.

Table 3. RPN Values Post-Improvement

Code	Priority Number	Type of Defect	S	O	D	RPN	Proposed Corrective Action
A1	1	Non-conforming Product Weight in Packaging	7	5	5	175	Maximizing training, coaching, and enhanced supervision of operator performance
A2	2		7	6	4	168	Developing standardized size specifications for atom peanuts
A3	3	Improper Packaging Seal Quality	6	6	4	144	Conducting regular inspections of the sensors
A4	4		5	4	5	100	Developing standardized size specifications for atom peanuts
A5	5		4	5	4	80	Maximizing training efforts to ensure that operators understand the importance of accurate placement of atom peanuts to reduce defective and rejected packaging

Table 3 shows the post-improvement FMEA RPN values, highlighting a significant reduction. A paired t-test was conducted to statistically compare pre- and post-improvement RPN values, confirming the effectiveness of the improvements.

Figure 7. Paired T-Test Results

Paired T-Test and CI: Before, After				
Descriptive Statistics				
Sample	N	Mean	StDev	SE Mean
Before	5	289.4	40.3	18.0
After	5	133.4	41.9	18.7

Estimation for Paired Difference				
Mean	StDev	SE Mean	95% CI for $\mu_{\text{difference}}$	
156.0	34.5	15.4	(113.1, 198.9)	

$\mu_{\text{difference}}$: mean of (Before - After)

Test	
T-Value	P-Value
10.11	0.001

Null hypothesis $H_0: \mu_{\text{difference}} = 0$
 Alternative hypothesis $H_1: \mu_{\text{difference}} \neq 0$

Source: Data Processed using Minitab

The analysis produced a T-Value of 10.11 and a P-Value of 0.001, both of which are below the significance level of 0.05, according to the findings of the hypothesis test. As a result, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This suggests that the RPN values from the FMEA research before and after the suggested improvements were put into place differed statistically significantly. As a result, the outcomes validate how well the enhancements worked to drastically lower packaging flaws. The findings of this research are in accordance with prior research [12], [13], [14], which identified material inconsistencies and sealing defects as primary contributors to packaging failures. This research emphasizes sustainability by using the entire DMAIC cycle, including a thorough control phase, in contrast to previous studies that mostly concentrated on the Improve phase. Consistent quality, fewer flaws, and improved process stability and efficiency are guaranteed by a sustainable system sensor check, operator training, and material standardization.

In this research, the control phase was conducted by comparing the data before and after the implementation of improvements based on the types of defects found in the packaging of Shanghai Super Atom Peanut products, as presented in the table below:

Table 4. Comparison of Defect Type Percentages Before and After the Implementation of Improvements

No.	Type of Packaging Defect	Before Improvement	After Improvement	Percentage Reduction
1.	Non-conforming Product Weight (D1)	362	223	38.40%
2.	Improper Sealing Quality (D2)	324	47	85.49%
3.	Missing Expiration Date (D3)	74	22	70.27%
4.	Overlapping Packaging (D4)	36	5	86.11%

T-Test Explanation :

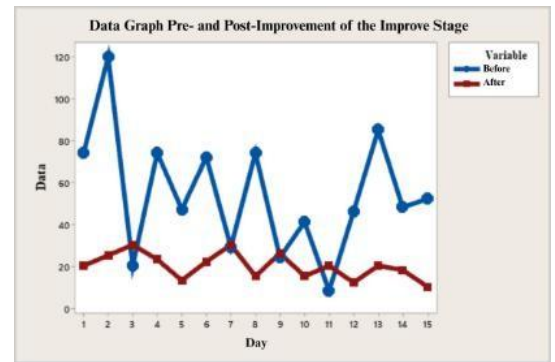
H_0 : Null Hypothesis

H_1 : Alternative Hypothesis

P-Value : The probability value used to determine whether the observed results are statistically significant enough to reject the null hypothesis (H_0)

5.	Side Stripping onPackaging Surface (D5)	18	2	88.89%
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Subsequently, a comparison was conducted between the data before and after the implementation of improvements during the *Improve* phase of quality control. The results of this comparison are presented in the graph below:



Source: Data Processed using Minitab

Figure 8. Graph of Pre- and Post-Improvement Data in the Improve Phase

The results from the comparison graph of pre- and post-improvement data demonstrate a substantial reduction in the number of defective products. The chart shows that prior to the improvement, the process was out of control, as evidenced by the data on days 2, 4, 6, and 13, represented by the blue line. After the improvements were implemented during the improve phase, the red line indicates that the process data fell within control limits. This graph provides strong evidence that corrective measures such as the implementation of standardized product dimensions, installation of automatic sensors, and enhanced operator supervision have effectively and consistently reduced the defect rate. Overall, the graph reinforces

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the success of the DMAIC methodology in improving process control, stabilizing product quality, and minimizing defect variability within a relatively short period.

B. DISCUSSION

This research adopts a comparative approach to evaluate the effectiveness of the Six Sigma methodology using the DMAIC framework in minimizing defects within the food packaging process, specifically for Shanghai Atom Peanut products. The research identified two dominant CTQ defects D1 and D2. Following the implementation of targeted improvements, including product standardization, sensor installation, and enhanced operator training, the number of defective products was significantly reduced from 814 to 299 units, based on a consistent sample size of 6,480 units. This outcome was statistically validated through a paired T-test, which yielded a P-Value of 0.001, confirming the significance of the improvements. These findings were then analyzed in comparison with several previous research efforts employing similar methodologies [12], identified five defects in peanut packaging, with body leakage at 53.3%, but focused only on the Improve phase. Similarly [13], offered improvement suggestions using Six Sigma and Kaizen but lacked implementation and validation. This research not only proposed corrective actions but also validated them statistically, with the RPN for D1 decreasing from 336 to 175 [14]. reported defect reduction at PT. PP2 but did not evaluate control mechanisms for sustainability. This research, however, established a robust control system through supervision, material standardization, and sensor integration as a tool for both short-term and long-term quality improvement in the food industry.

V. CONCLUSION

Based on the data processing and analysis using the Six Sigma methodology with the DMAIC approach, this study successfully achieved its research objectives, including the following:

1. Based on the data analysis using the Pareto diagram and CTQ identification, two major types of defects were found to have the greatest impact on packaging quality: D1 and D2. These two defects cumulatively accounted for 84.3% of the total defects, with initial data indicating instability in the packaging process of the Kacang Atom Shanghai Super Pack on days 2, 4, 6, and 13. Following improvements in the Improve phase using the FMEA method, such as the installation of sensors on machines and enhancement of operator supervision, evaluation results showed a significant reduction in the number of defective products, from 814 units to 299 units.
2. The improvement efforts to address CTQs were carried out using the FMEA method, with the main actions including:
 - a. Installation of automatic sensors on machines to detect and control product weight in real time.
 - b. Enhancement of operator supervision, including strengthening of work procedures and operator training.

- b. The improvements led to a reduction in defective products from 814 units to 299 units, along with a significant decrease in RPN values for both D1 and D2 defects, indicating the success of the risk mitigation actions.
3. The implementation of the Six Sigma methodology with the DMAIC approach in packaging quality control was successfully and systematically applied to the quality control of the packaging process, with the following results:
 - a. The Define–Analyze phases successfully identified the root causes of defects in a structured manner.
 - b. The Improve phase resulted in significant process improvements.
 - c. In the Control phase, all data points in the control chart were within the control limits, indicating a stable process.
 - d. The results of the statistical test using a paired t-test showed a p-value of 0.001, indicating that the improvements made were statistically significant.
 - e. Based on the comparison of defect rates by type before and after the improvements through the implementation of the Six Sigma DMAIC approach, the data are as follows:
 - 1) D1 reduced from 362 to 223 units.
 - 2) D2 reduced from 324 to 47 units.
 - 3) D3 reduced from 74 to 22 units.
 - 4) D4 reduced from 36 to 5 units.
 - 5) D5 reduced from 18 to 2 units.

These results demonstrate that the application of the Six Sigma methodology with the DMAIC approach is effective in reducing defects and improving packaging quality control, contributing to the sustainable improvement of the packaging process quality.

Despite these positive outcomes, this research is limited by its focus on plastic packaging only. Future research is recommended to explore the effectiveness of the DMAIC approach across various packaging materials such as metallized films, cartons, and cans. Further studies should also investigate the application of smart packaging inspection technologies and evaluate the impact of periodic operator training to support continuous quality improvement and operational efficiency.

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