Reduction in Rejection Rate of Soy Sauce Packaging via Six Sigma

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ABSTRACT
The Six Sigma methodology is the most powerful quality improvement technique. This research deals with applying the Six Sigma methodology in reducing the rejection rate of soy sauce packaging in food production. The DMAIC methodology of Six Sigma provides a step-by-step quality improvement methodology in which statistical techniques are applied. The leakage and cutting error problems were identified in the Define phase. The extent of the problem was measured in the Measure phase. The current DPMO value was 5,794.39, and sigma level at 4.0245. The root cause of the problem and the improvement priority were identified in the Analyze phase by applying the fishbone diagram and FMEA. The design of new Standard Operating Procedures (SOPs) and preventive maintenance schedule were used in the Improve phase to increase the sigma level by 50-60 percent and decrease DPMO by 99 percent for the upcoming four months implementation. Furthermore, a control plan was provided in the Control phase to monitor and sustain the achieved improvements.

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1. Introduction
In the manufacturing industry, producing quality goods is an important thing [1] [2]. Achieving good quality is one operation strategy if a company wants to win the competition [3]. That is why production results affect a product’s quality and the price at which the product is sold, and its profit [4]. Hence, to maximize the production results, a company always has to pay attention to minimizing the rejection rate of a product. If the defects decrease, then the utilization of resources and the profit can be maximized [5] [6]. Several quality-control methods are used to guarantee the quality of the company’s product [7] [8]. Quality control has a special role in improving the quality and process by reducing products’ defect rates until there are no more defects left. Suppose the quality control is carried out correctly. In that case, a company will achieve a much higher level
of effectiveness and efficiency than before. The effectiveness means every process is capable to achieve the company’s main goal which is maximum profit [9] [10]. While, the efficiency means the state or quality of being efficient, or able to accomplish something with the least waste of time and cost [11] [12].

Six sigma is a step-wise quality improvement methodology using specific tools and methodologies that lead to fact-based decision-making. Many manufacturing companies often apply the Six Sigma method to decrease product defects and increase product quality [13]. Six Sigma method gives many benefits and advantages to a company in productivity levels, decreasing the failure of a process, and increasing the usage [14]. This method has been proven to be a method that can increase the quality in many industry types. It can also be used to achieve, maintain, and maximize business success by decreasing the process's variation, decreasing the failure of a process, and increasing profits [15] [16]. When customers receive certain products and some defects in the product, they will eventually return the products [17] [18]. That condition will cause an inadequate balance between profit and cost of a company because the product has to be reproduced. By reproducing a 'new' product, it will increase raw material and production costs. Six sigma method is proven to be effective in reducing waste and increasing the profit margin as well as making the company has a competitive advantage to beat the rivals [19] [20].

This paper highlights the Six Sigma methodology's potential, detailing the soy sauce packaging problems in the large food industry. Reducing rejection rate as a quality strategy ensures development and increases the position of the company. It is based on six main principles that should be implemented in companies that want to develop and increase their market position. The very first point is the focus on the customer. Every action taken should agree with customers' needs and requirements [17] [18]. Six Sigma is also based on facts used to perform a detailed systematic analysis. It is based on continuous improvement of all aspects of functioning development in the organization and cooperation without boundaries at every company level. Therefore, this study aims to reduce the rejection rate of soy sauce packaging by applying the Six Sigma methodology.

This paper's structure is presented as follows: Six Sigma Methodology and data collection are presented in section 2 (methods). The results of Six Sigma Methodology are presented in section 3 (results and discussion). Furthermore, section 4 outlines the conclusion and suggestions for further research.

2. Methods

2.1 The Six Sigma Methodology

The Define-Measure-Analyze-Improve-Control (DMAIC) approach of Six Sigma methodology was used to achieve the research objective. A step-by-step procedure was followed and implemented to control the identified process variation in the product's manufacturing process. The proposed DMAIC procedure for this study is shown in Fig. 1.

2.1.1 Define procedure

In the Define step, the problem of quality in the production area is defined. It consists of identifying the problem and the purpose of using the Six Sigma method to solve the problems, designing a Six Sigma team, designing a Flow Process Chart (FPC), and designing a SIPOC (Suppliers, Inputs, Processes, Outputs, and Customers) diagram [21] [22].

2.1.2 Measure procedure

The Measure step is constructed to know which types of defects mainly influence the problem (Critical to Quality/CTQ), how much cost the company has to pay for the
defective products (Cost of Poor Quality), and the capability process, which consists of DPO, DPMO, Sigma level and yield. The equation of capability process is shown in equations (1), (2), and (3) [21] [22].

\[
DPO = \frac{\text{Total Unit of Defect}}{\text{Total Unit} \times \text{CTQ Opportunity}}
\]  

(1)

\[
DPMO = DPO \times 1,000,000
\]  

(2)

\[
Yield = (1 - \frac{\text{Total Unit of Defect}}{\text{Total Unit} \times \text{CTQ Opportunity}}) \times 100\%
\]  

(3)

In this phase, the quality tools used are the Pareto diagram for determining CTQ. The control chart is used to see a process's stability. The control charts are applied. The control chart calculations are shown in equations (4), (5), (6), and (7) [21] [22]:

The Defect Proportion

\[
\bar{u} = \frac{\text{Total defect}}{n}
\]  

(4)

\[n = \text{Total sample of observation}\]

The Center Line

\[CL = \bar{u}\]

(5)

Fig. 1. Proposed DMAIC Procedure
The Lower Control Limit
\[ LCL = \bar{u} - i \sqrt{\frac{\bar{u}}{n_i}} \] (6)

The Upper Control Limit
\[ UCL = \bar{u} + i \sqrt{\frac{\bar{u}}{n_i}} \] (7)

2.1.3 Analyze procedure

In the Analyze phase, the sources that cause the most significant defect are being sorted using the fishbone diagram. The fishbone diagram combined with the brainstorming process determines five main factors: man, material, machine, method, and environment [23]. After identifying the root cause of the defect, the next step is to determine which root causes have to be solved first. The Failure Mode and Effect Analysis (FMEA) is applied. This analysis considers three factors Occurrence (O), Severity (S), and Detection (D), to get the highest Risk Priority Number (RPN). The equation is shown in equations (8) [23].

Occurrence (O), Severity (S), and Detection (D) ratings for each Failure Mode are based on a scale of 1 to 10. In occurrence, 1 shows Rarely, and 10 describes Frequently. In severity, 1 indicates Not Significant, and 10 represents Dangerous. Furthermore, in detection, 1 refers to Easily Detected, and 10 explains Detection Very Unlikely.

\[ RPN = S \times O \times D \] (8)

2.1.4 Improve procedure

After the highest RPN has been determined, Improvements can be made [24] [25]. The improvement is based on the FMEA results. The highest RPN value is a priority for immediate improvement. This phase implements an analysis determining the improvement given. This stage is based on the brainstorming process analysis steps of actions [26] [27].

2.1.5 Control procedure

This Control phase is only part of the final controlling process of the improvement given if an implementation has been successfully carried out [28] [29]. This phase can be done by monitoring all results and documenting the process until creating Standard Operation Procedures (SOPs) for successful improvement [30].

2.2 Data Collection

All information needed is divided into two groups of data, namely primary and secondary data. The primary data is obtained by conducting field study and observation, such as the company's working condition, the soy sauce packaging production process, the operator's working condition, and all machines and tools used during six months operation (July-December 2019). The secondary data consists of the 2018 and 2019 production history of soy sauce packages and the total defective units for each package. The record on every single defect that occurs in the process.
3. Results and Discussion

3.1 Define

The main problem in the soy sauce packaging process is reducing the high rejection rate of soy sauce packaging. Fig. 2 shows the process of how to package soy sauce, as shown below.

![Flow Process Chart of Soy Sauce Pouch Packaging](image)

Fig. 2. Flow Process Chart of Soy Sauce Pouch Packaging

Fig. 3 indicates information about the stages in the production process from suppliers to customers in diagrams of Suppliers, Inputs, Processes, Outputs, and Customers (SIPOC). In the process section, there are two activities: making pouch
packaging and conducting bottle packaging. The process of making pouch packaging consists of several activities, such as opening the pouch, filling the pouch, sealing the pouch, cutting and labeling the pouch, and packaging the pouch. Making bottle packaging consists of bottle filling, bottle sealing, bottle cutting and labeling, and bottle packaging.

![SIPOC diagram](image)

3.2 Measure

As shown in Fig. 4, the two types of defects that cause the most significant problems are that package is not sealed properly and the occurrence of an error in cutting. The Cost of poor quality paid-for product defects is 415,149,600 IDR, which is a significantly high cost for the company.

![Pareto Chart](image)

Fig. 5 projects the u control chart of the process by using the equation (4), (5), (6), and (7). The u chart is an attribute control chart used with data collected in subgroups of varying sizes. u charts show how the process, measured by the number of nonconformities per item or group of items, changes over time. Nonconformities are defects or occurrences found in the sampled subgroups. The findings suggest that the processes have variations above and below the control limit line caused by special cases such as the machine's damage and the loss of power usage.
3.3 Analyze

This phase proposes a Standard Operating Procedure for the sealing machine. It creates a preventive maintenance schedule for the Jig Pouch Opener Machine to solve the most significant defect problem. The solutions were presented using a fishbone diagram, FMEA, and a brainstorming process with its leaders and stakeholders. Fig. 6 and Fig. 7 integrate the fishbone diagrams for packing leaks and cutting errors.

Fig. 5. U Control Chart

The capability process for soy sauce packaging is computed by using equations (1), (2), and (3). The value of DPO, DP, Sigma Level, and Yield are 0.00579; 5794.39; 4.0245, and 99.42%. The Sigma level indicates that the company already has a good level of sigma category for the most manufacturing industry in Indonesia.

Fig. 6. Fishbone diagram for leaky packaging

Fig. 7. Fishbone diagram for cutting errors
Fig. 7. Fishbone diagram for cutting errors

The SOPs are designed to overcome the "package is not sealed properly" due to frequent operator errors in handling the machine. The Jig Pouch Opener Machine’s preventive maintenance schedule is intended to overcome the problem of "error in cutting" caused by sensor problems and lack of regular scheduling. The solutions are based on the highest Risk Priority Number (RPN) using equation (8). Fig. 8 and Fig. 9 show the results of determining the priority of repairs that should be carried out first.

3.4 Improve

The Improve section is usually an implementation of the problem solution. Therefore, this study provides a design concept of the solution, namely SOPs design and preventive maintenance schedule. Fig. 10 indicates an example of the sealing machine SOP design.

The maintenance schedule has been successfully designed using a Corrective Maintenance Model, namely The Age Replacement Model. Table 1 presents the sensor component maintenance schedule of the Jig Pouch Opener Machine.

3.5 Control

In this phase, the implementation of SOPs and maintenance schedules is monitored and evaluated. It is based on the improvement solutions with the help of quality documentation tools such as a check-up table for the machine, a replacement table for the machine, and a table for calculating the increase or decrease of DPMO and Sigma level. Table 2 shows the target of DPMO decrease and Six Sigma Level increase. It only shows the target because there is no implementation done yet. The results are shown below.
### FMECA Cutting Packaging Labels Problem

| Failure Mode | Effect of Failure | Current Controls | Recommended Corrective Action |
|--------------|------------------|------------------|------------------------------|
| Incorrect measurement | Cardboard packaging labels are too long or short | Notify the operator of the correct measurement | Conduct training on the correct measurement |
| Misoperating machines | The glue is not tight | Notify the operator of the correct measurement | Conduct training on the correct measurement |
| No corrective action can be done | There is no corrective action that can be done | | |
Fig. 10. SOP of Sealer Machine
Table 1. Maintenance Schedule for Jig Pouch Opener Machine

| Replacement Schedule | Check Up Schedule |
|-----------------------|-------------------|
| **Date** | **Start** | **Finish** | **Date** | **Start** | **Finish** |
| 6 January 2020 | 22.01 | 00.14 | 16 January 2020 | 4.22 | 5.22 |
| 13 January 2020 | 12.14 | 14.27 | 30 January 2020 | 23.44 | 00.44 |
| 7 February 2020 | 21.10 | 23.23 | 15 February 2020 | 19.04 | 20.04 |
| 24 February 2020 | 15.52 | 18.05 | 1 March 2020 | 14.26 | 15.26 |
| 7 March 2020 | 20.20 | 22.33 | 16 March 2020 | 09.48 | 10.48 |
| 13 March 2020 | 10.34 | 12.47 | 31 March 2020 | 05.00 | 06.00 |
| 24 March 2020 | 15.02 | 17.15 | 15 April 2020 | 00.24 | 01.24 |
| 4 April 2020 | 19.30 | 21.43 | 29 April 2020 | 19.46 | 20.46 |
| 11 April 2020 | 09.44 | 11.57 | 14 May 2020 | 15.08 | 16.08 |
| 22 April 2020 | 14.12 | 16.25 | 29 May 2020 | 10.30 | 11.30 |
| 4 May 2020 | 18.40 | 20.53 | 13 June 2020 | 05.52 | 06.52 |
| 11 May 2020 | 08.54 | 11.06 | 28 June 2020 | 01.14 | 02.14 |
| 22 May 2020 | 13.21 | 15.34 | 12 July 2020 | 20.36 | 21.36 |
| 2 June 2020 | 17.49 | 20.02 | 27 July 2020 | 03.58 | 04.58 |
| 8 June 2020 | 08.03 | 10.16 | 10 August 2020 | 23.20 | 00.20 |
| 18 June 2020 | 12.31 | 14.44 | 25 August 2020 | 18.42 | 19.42 |
| 24 June 2020 | 02.45 | 04.58 | 9 Sept 2020 | 14.04 | 15.04 |
| 6 July 2020 | 07.13 | 09.26 | 24 Sept 2020 | 09.26 | 10.26 |
| 17 July 2020 | 11.41 | 13.54 | 8 October 2020 | 04.48 | 05.48 |
| 23 July 2020 | 01.55 | 04.08 | 23 October 2020 | 00.00 | 01.00 |
| 3 August 2020 | 06.23 | 08.36 | 6 November 2020 | 19.22 | 20.22 |
| 8 August 2020 | 20.37 | 22.50 | 21 November 2020 | 14.44 | 15.44 |
| 14 August 2020 | 10.51 | 12.04 | 6 December 2020 | 10.06 | 11.06 |
| 21 August 2020 | 00.05 | 02.18 | 21 December 2020 | 05.28 | 06.28 |
| 2 Sept 2020 | 04.33 | 06.46 | | | |
| 7 Sept 2020 | 18.47 | 21.00 | | | |
| 14 Sept 2020 | 09.01 | 11.14 | | | |
| 19 Sept 2020 | 23.15 | 01.28 | | | |
| 30 Sept 2020 | 03.43 | 05.56 | | | |
| 5 October 2020 | 17.57 | 20.10 | | | |
| 12 October 2020 | 08.11 | 10.24 | | | |
| 17 October 2020 | 22.25 | 00.38 | | | |
| 30 October 2020 | 02.53 | 05.06 | | | |
| 4 November 2020 | 17.07 | 19.20 | | | |
| 10 November 2020 | 07.21 | 09.34 | | | |
| 16 November 2020 | 21.35 | 23.48 | | | |
| 30 November 2020 | 02.03 | 04.16 | | | |
| 11 December 2020 | 06.31 | 08.44 | | | |
| 16 December 2020 | 20.45 | 22.58 | | | |
| 28 December 2020 | 01.13 | 03.26 | | | |
This case study conducted in a large food company dedicated to soy sauce packaging illustrates how Six Sigma may be implemented with higher or less intensity regardless of the type of production process or company. In particular, rejection rate reduction carried out in the company can also be the objective of a quality improvement project. However, quality improvement in this area has not been widely studied in the previous literature, especially regarding the application of the Six Sigma methodology [2] [3] [5] [9] [16] [18] and [31].

After implementing Six Sigma, the company situation reflects the economic benefits measured in the rejection rate improvements. A special mention is needed regarding the significant reduction achieved in the Six Sigma project, according to Senjuntichai, et al. [5], Gijo, et al. [10], and Krishna Priya, et al. [31]. These results are also consistent with previous research results [32] and [33].

4. Conclusion

This study aims to reduce the rejection rate of soy sauce packaging. In this study, there were three types of defect problems in the existing process: packaging that was not appropriately sealed, wrong cutting, and reversed package labeling. The most significant problems were the package not appropriately sealed and wrong cutting defects. The solution provided for solving these problems was by designing appropriate Standard Operation Procedures (SOPs) for the sealing machine and by setting a preventive maintenance schedule for the jig pouch opener machine in order to increase of sigma level by 50-60 percent and to decrease DPMO by 99 percent for the upcoming four months implementation. The results showed that the reject ratio of soy sauce packaging could be reduced. The provided solutions were based on the highest Risk Priority Number (RPN) value. The conducted study suggested that the Six Sigma method can reduce the rejection rate of soy sauce packaging.

For future works, the data analysis can be done through other statistical tests. Combining lean with other sustainable and innovative manufacturing methods such as green for enhancing performance and design thinking can broaden the study perspectives. For further validation of the performance improvement, longitudinal studies can be conducted for a deeper analysis.

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