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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.

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

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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].

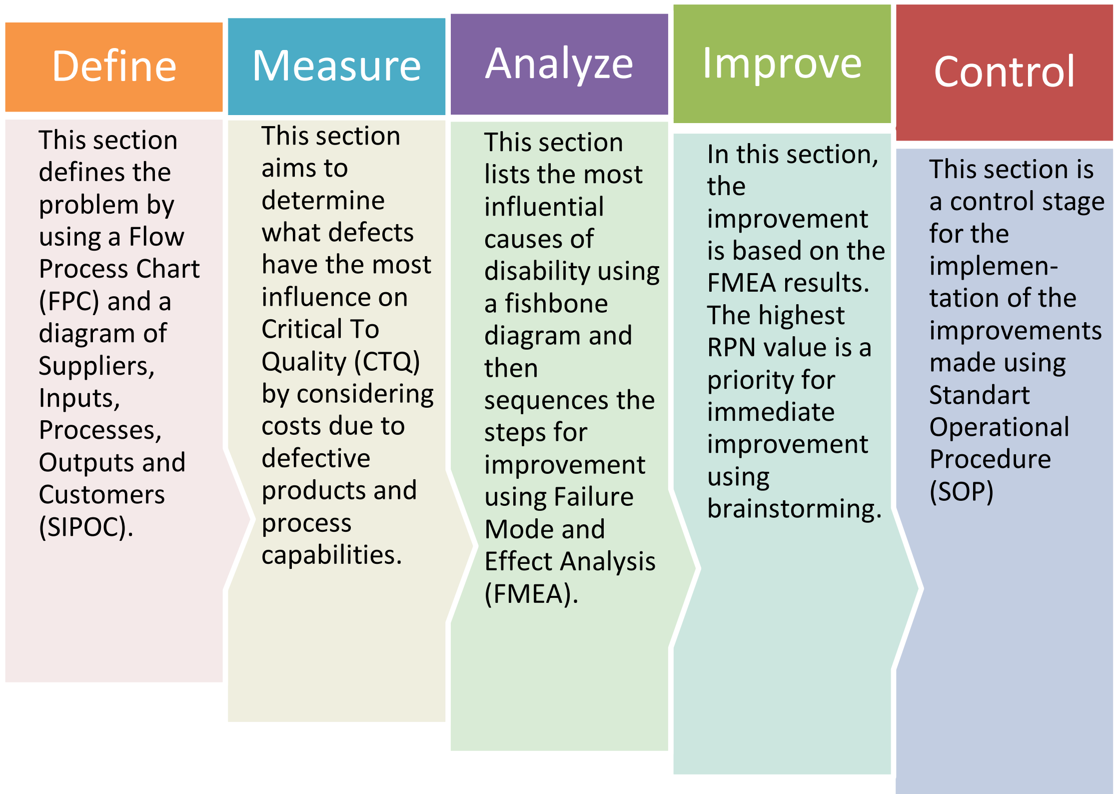

Fig. 1. Proposed DMAIC Procedure

$$DPO = \frac{\text{Total Unit of Defect}}{\text{Total Unit x CTQ Opportunity}} \quad (1)$$

$$DPMO = DPO \text{ x } 1.000.000 \quad (2)$$

$$Yield = (1 - \frac{\text{Total Unit of Defect}}{\text{Total Unit x CTQ Opportunity}}) \text{ x } 100\% \quad (3)$$

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 u control chart is applied. The control chart calculations are shown in equations (4), (5), (6), and (7) [21] [22]:

The Defect Proportion

$$\bar{u} = \frac{\text{Total defect}}{n} \quad (4)$$

n = Total sample of observation

The Center Line

$$CL = \bar{u} \quad (5)$$

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The Lower Control Limit

$$LCL = \bar{u} - i\sqrt{\frac{\bar{u}}{ni}} \tag{6}$$

The Upper Control Limit

$$UCL = \bar{u} + i\sqrt{\frac{\bar{u}}{ni}} \tag{7}$$

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.

$$RPN = S \, x \, O \, x \, D \tag{8}$$

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].

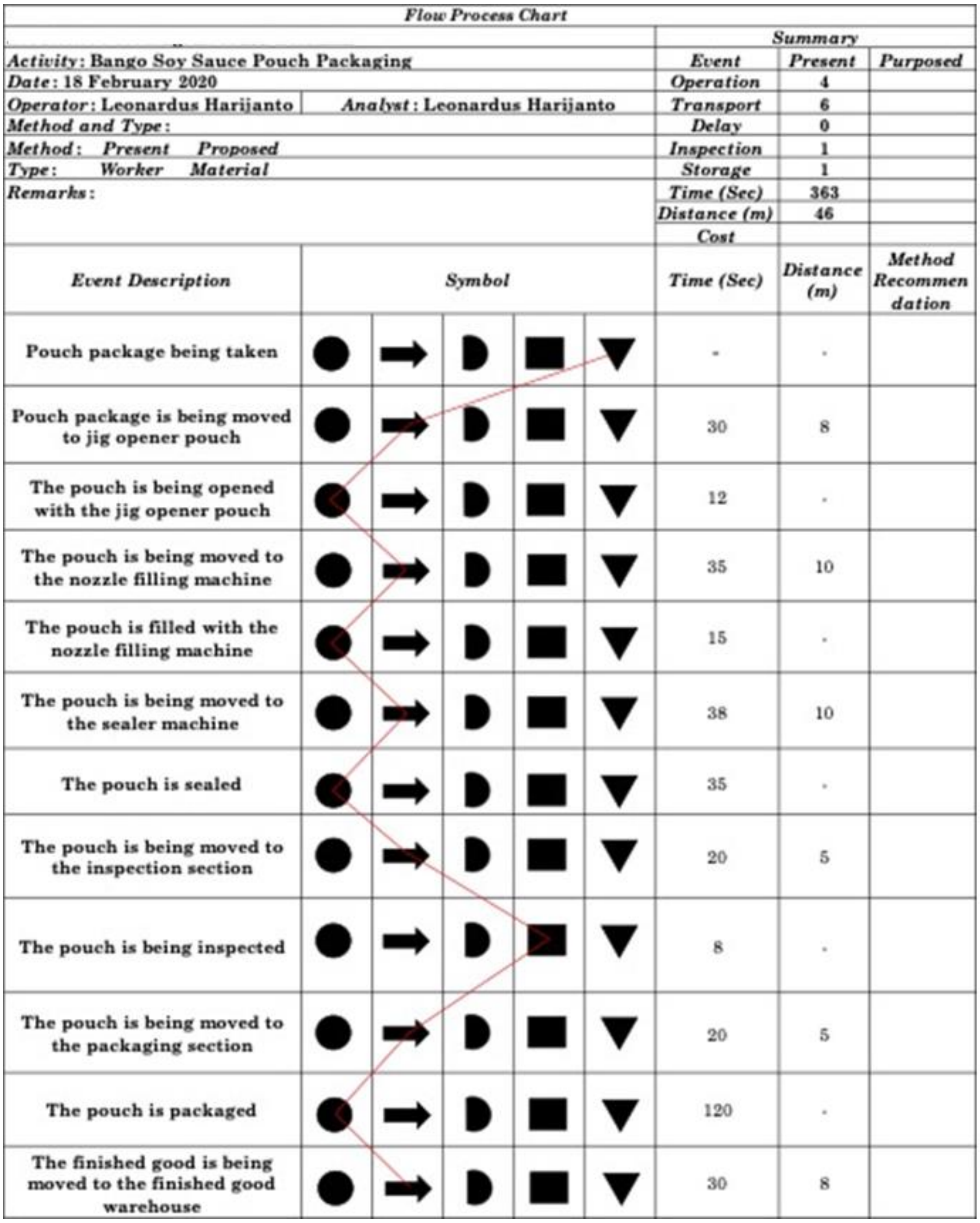
2.2 Data Collection

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

	Summary		
Activity: Bango Soy Sauce Pouch Packaging	*Event*	*Present*	*Purposed*
Date: 18 February 2020	*Operation*	4	
Operator: Leonardus Harijanto *Analyst*: Leonardus Harijanto	*Transport*	6	
Method and Type:	*Delay*	0	
Method: *Present* *Proposed*	*Inspection*	1	
Type: *Worker* *Material*	*Storage*	1	
Remarks:	*Time (Sec)*	363	
	Distance (m)	46	
	Cost		

Event Description	*Symbol*	*Time (Sec)*	*Distance (m)*	*Method Recommendation*
Pouch package being taken	▼	-	-	
Pouch package is being moved to jig opener pouch	➡	30	8	
The pouch is being opened with the jig opener pouch	●	12	-	
The pouch is being moved to the nozzle filling machine	➡	35	10	
The pouch is filled with the nozzle filling machine	●	15	-	
The pouch is being moved to the sealer machine	➡	38	10	
The pouch is sealed	●	35	-	
The pouch is being moved to the inspection section	➡	20	5	
The pouch is being inspected	■	8	-	
The pouch is being moved to the packaging section	➡	20	5	
The pouch is packaged	●	120	-	
The finished good is being moved to the finished good warehouse	➡	30	8	

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

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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.

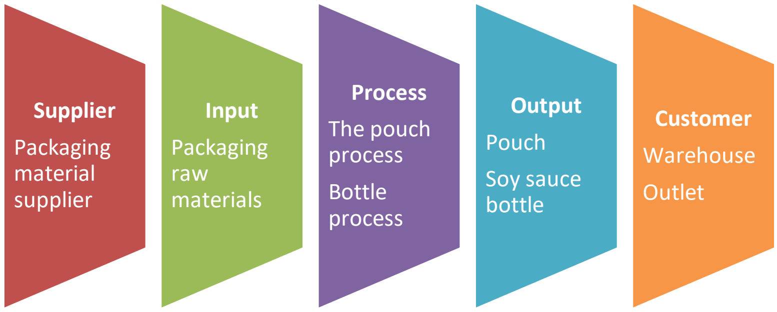

Fig. 3. SIPOC diagram

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.

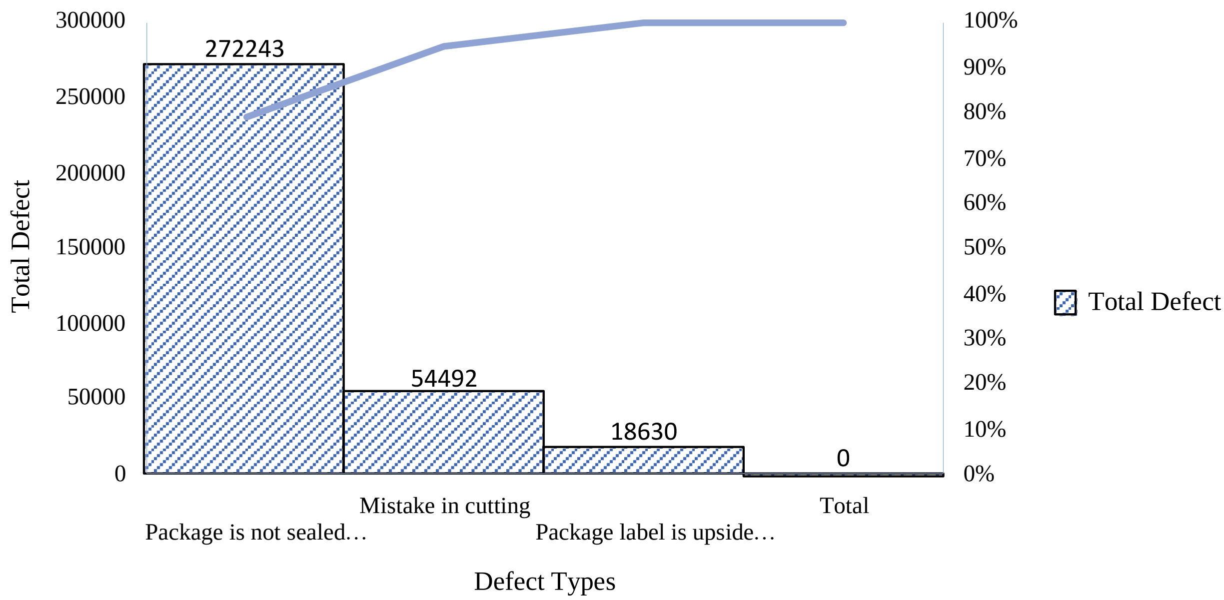

Fig. 4. Pareto Chart

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.

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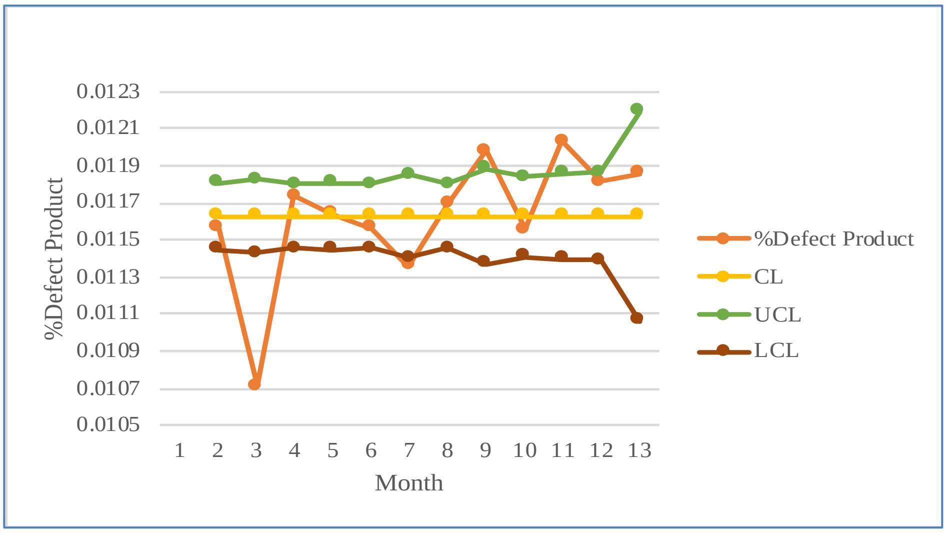

Fig. 5. U Control Chart

The capability process for soy sauce packaging is computed by using equations (1), (2), and (3). The value of DPO, DPMO, 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.

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.

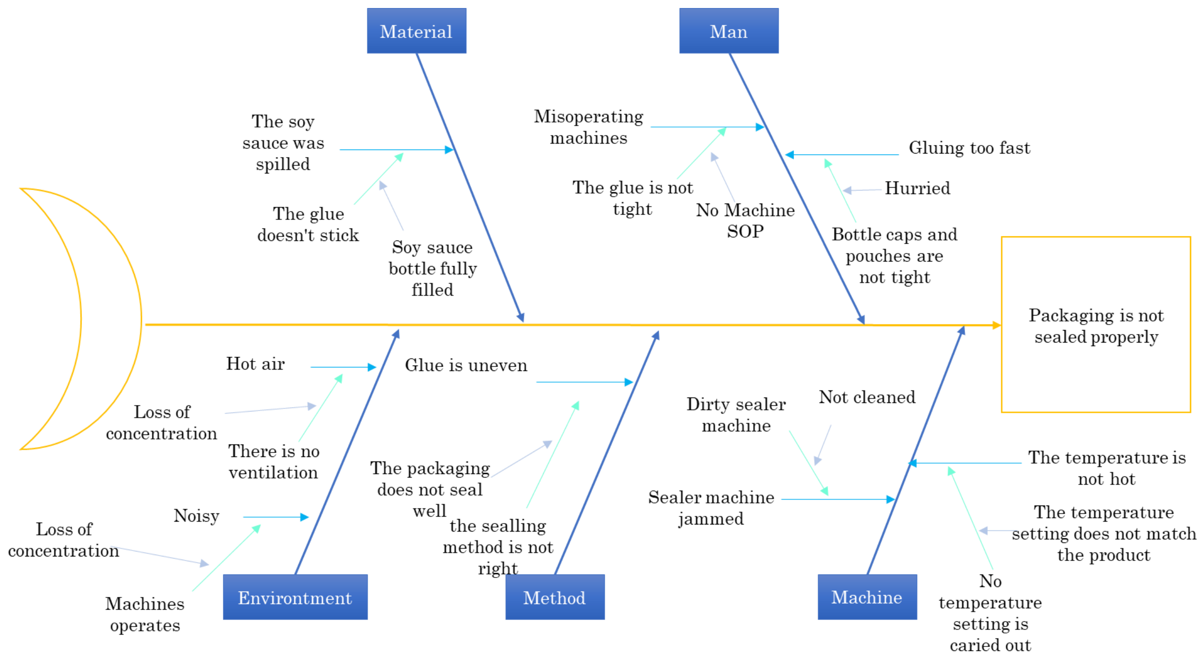

Fig. 6. Fishbone diagram for leaky packaging

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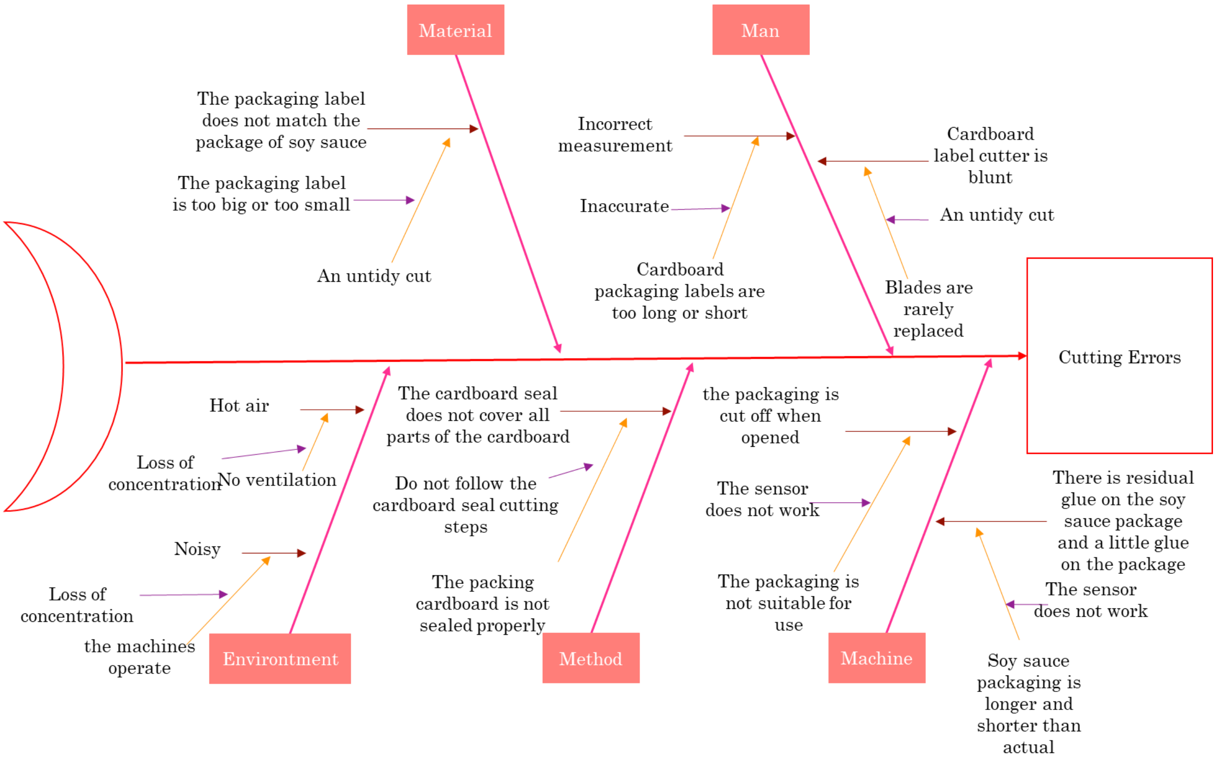

Fig. 7. Fishbone diagram for cutting errors

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.

No	Main Factors	Function or Process	Failure Mode	Effect of Failure	Cause of Failure	Current Controls	S	O	D	RPN	Recommended Corrective Action
							Current Status				
1	Man	Fill the soy sauce package until the soy sauce package is closed	Misoperating machines	The glue is not tight	No Machine SOP	Explanation of the procedure for operating the machine	8	6	8	384	Providing machine SOP and explanation on how to operate the machine properly accompanied by training
			Gluing too fast	Bottle caps and pouches are not tight	Hurried	Notify the operator of the correct gluing procedure	7	7	6	294	Rechecking for each gluing activity
2	Machine		Sealer machine jammed	Dirty sealer machine	Not cleaned	Machine cleaned after machine jammed	8	5	8	320	The machine is carried out for scheduled maintenance
			The temperature is not hot	The temperature setting does not match the product	No temperature setting is caried out	If it is found that the glue does not stick, the temperature is adjusted	7	6	8	336	Re-explain to the operator about the machine SOP
3	Method		Glue is uneven	The packaging does not seal well	the sealling method is not right	Notify the operator of the correct gluing procedure	6	7	8	336	Making SOP for sealing procedures is accompanied by training for operators
4	Material		The soy sauce was spilled	The glue doesn't stick	Soy sauce bottle fully filled	The soy sauce is cleaned before sealing	6	5	9	270	Evaluate to make sure that the packaging is not too full and does not spill
5	Environment		Hot air	Loss of concentration	There is no ventilation	Nothing was done about this	4	8	7	224	There is no corrective action that can be done because it can disrupt the process of production activities that occur at the company
			Noisy		Machines operates	Using earplugs	4	8	7	224	

Fig. 8. FMEA soy sauce packaging filling problem

No	Main Factors	Function or Process	Failure Mode	Effect of Failure	Cause of Failure	Current Controls	S	O	D	RPN	Recommended Corrective Action
							Current Status				
1	Man	Cutting soy sauce cardboard packaging labels	Incorrect measurement	Cardboard packaging labels are too long or short	Inaccurate	Nothing was done about this	3	8	4	96	Cardboard packaging label cutting procedure training that included proper steps
			Cardboard label cutter is blunt	An untidy cut	Blades are rarely replaced	The supervisor checks the sharpness of the blade	5	6	8	240	Planned routine checks of the blade.
2	Machine	Opening the soy sauce pouch	the packaging is cut off when opened	The packaging is not suitable for use	The sensor does not work	Using another soy sauce pouch. For a soy sauce pouch that isn't worth crushing	8	6	9	432	Planned maintenance of machines
		Cutting soy sauce packaging glue	There is residual glue on the soy sauce package and a little glue on the package	Soy sauce packaging is longer and shorter than actual		Checks the sensor used when it is not working	6	5	7	210	Planned maintenance of machines
3	Method	Cutting seal of soy sauce cardboard packaging	The cardboard seal does not cover all parts of the cardboard	The packing cardboard is not sealed properly	Do not follow the cardboard seal cutting steps	Supervisors explain correct packaging procedures	7	7	8	392	Provides training in correct cardboard seal procedures and provision of cardboard packaging procedures to
4	Material	Cutting soy sauce packaging labels	The packaging label does not match the package of soy sauce	An untidy cut	The packaging label is too big or too small	Adjustment of packaging labels is produced by cutting labels that are too large and not using small labels	7	5	8	280	Correct packaging label cutting briefing
5	Environment	The process of cutting soy sauce labels, cardboard labels, packaging glue and sealing cardboard packaging	Hot air	Loss of concentration	No ventilation	Nothing was done about this	4	8	7	224	There is no corrective action that can be done because it can disrupt the process of production activities that occur at the company
			Noisy		The machines operate	Using earplugs	4	8	7	224	

Fig. 9. FMEA cutting packaging labels problem

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	Revision:
SEALER MACHINE STANDARD OPERATING PROCEDURE	Revision Date:
	Page: 1 dari 1

1. Objective

To give a work standard for the operator in using the sealer machine for the bottle packaging as it should be

2. Scope

This procedure consist of cutting, glueing and sealing

3. Work Procedure

Activity	Number	Information	PIC
	1	Machine cleaness check up	Operator
		Check up on the machine heater	
		Check up on the machine sensor	
	2	Check up on the temperature if it is right with the type of package used	Operator
		Check up on the hole where he temperature comes out if it is still working properly or not	
	3	Check up on the availability of the glue being used	Operator
		Check up on the density of the glue	
		Check up on the sharpeness of the cuter being used	
	4	Start up of the machine	Operator
	5	Check up on the bottle sealer if it is sealed properly or not	Operator
	6	Quality check up on the product and whether it has a defect on it and if it has then write it down on the defect form	Operator
		After finished, the operator has to:	
		• Reset the temperature to it's original temperature before being used	
		• Clean up the work station area	
		• Clean up all of the component of the machine and all of the sensor	
		• Report to the supervisor in charge if there is any trouble during the operation	

Fig. 10. SOP of Sealer Machine

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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			

Table 2. The target of DPMO and Sigma Level

Month	Production	Defect Target	DPO Target	DPMO Target	Decrease Percentage	Sigma Baseline	Sigma Baseline Target	Increase Percentage
1	3000000	20000	0.0067	133.3333	99.3333	3.4828	5.14	67.8206
2	3000000	10000	0.003	33	99.7	3.5153	5.49	64.0308
3	2000000	5000	0.0025	12.5	99.75	3.4767	5.75	60.4999
4	3000000	100	0	0.0033	99.9967	3.4804	6	58.0068

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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