Use of Six Sigma Methods to Reduce Packaging Defect in Sweetened Condensed Milk Sachets: A Case Study in XYZ Milk Industry, Indonesia

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Abstract. The purpose of this study was to determine the causes of the defects in sweetened condensed milk sachets packaging of XYZ Milk Industry, Indonesia and take corrective actions on the problem. The use of Six Sigma method with DMAIC (Define, Measure, Analyze, Improve, and Control) is expected to increase sigma level. Pareto diagram, Ishikawa diagram, and why-why analysis were utilized as tools to analyze the cause of defects on products. Three major packaging defects were identified, namely horizontal leak, folded, and vertical leaks, which were caused by machine A, machine B, machine C, respectively. Based on the results of the analysis, the main problem was caused by inappropriate condition of the machine part such as dirty sealer, hollow on nozzle, and worn stator pump. By focusing on improvements of the problem, sigma level increased from 4.58 to 4.79. Therefore, periodic maintenance activities are important to do so that all machines may perform in its best conditions and comply with internal and regulatory quality standards.

Keywords: Sweetened Condensed Milk Sachets, Quality, Leaking, Six Sigma, DMAIC

1. Introduction

Sweetened condensed milk is one of the highly consumed processed dairy products in Indonesia owing to its shelf-life and affordability. The preference for sweet tasting dairy beverages, ability to be stored correctly in traditional retail facilities and high affordability are few of the main reasons this product is high in consumer demand. However, industries now face some challenges related to packaging integrity of sweetened condensed milk sachets as it is easily defected. The packaging defects resulted in a decreased in physical quality and increased possibility of contaminants. Based on field observations, packaging leaks occur mainly during production process, specifically during filling and sealing.

To deal with the problem, six sigma method was implemented in the process of sweetened condensed milk production, especially in the process of filling and sealing. Six sigma is a continuous improvement measure that focuses on consumers by minimizing defects and variations so that 3.4 defects are achieved per one million opportunities in a process [1, 2]. Six sigma is used to improve
quality by analyzing data to determine the root causes of quality problems and to apply control measures [3].

In this research, Six sigma method is used to analyze the cause of leaks that occurred in the packaging of sweetened condensed milk sachets and to take corrective actions. The use of six sigma is carried out using a systematic stage of DMAIC (Define, Measure, Analyze, Improve, and Control) to achieve zero defects in a process [4]. By using six sigma method, XYZ milk industry expects to maintain the consistency of the products and meet the quality demand of consumers throughout Indonesia.

2. Six Sigma Methods

The analysis was carried out using six sigma method with DMAIC phases consisting of Define, Measure, Analyze, and Improve to reduce leaks in the packaging of sweetened condensed milk during filling and sealing process and to take corrective actions from the problem analysed.

Define: In define phase, the problem is first defined along with the purpose of the research. SIPOC (Supplier - Input - Process - Output - Customer) diagram is made to determine the process involved and the components in it, and the interactions between processes. In addition, sequence of process that occur in the filling and sealing process is also defined.

Measure: In measure phase, data of packaging leaks collected is made into the Pareto diagram using Microsoft Excel and control charts using Minitab 17 Statistical Software. Sigma levels are measured by converting the calculation of DPMO (Defects Per Million Opportunities) values. Determination of CTQ (Critical to Quality) is first carried out to calculate DPMO values. Calculations are then carried out with the following formula (1) [3].

\[
DPMO = \frac{\text{the amount of defects found}}{\text{the amount of samples} \times \text{CTQ}} \times 1000000 \quad (1)
\]

Sigma levels are calculated using Microsoft Excel with the following formula (2) [5].

\[
= \text{NORMSINV}((1000000-DPMO)/1000000) + 1.5 \quad (2)
\]

Analyze: In analyze stage, the analysis is carried out using cause and effect diagram (fishbone diagram) and why-why analysis. The cause and effect diagram is used to describe the factors that cause leak problems. The main problems identified are then analyzed by giving out several questions using why-why analysis which then the results can be used as improvement targets.

Improve: In the improve phase, the solution to the causes of problems found in sweetened condensed milk sachets is determined based on results of the analysis obtained. Possible corrective actions are to be carried out. Data is collected once again and calculation of DPMO values and sigma levels are also done using the same formulas above.

3. Results and Discussion

3.1 Define

Define is the first step in the analysis of research which is conducted by defining existing problems. One of the main problems faced by XYZ milk industry is packaging leaks on sweetened condensed milk sachets. Leakage can be defined as something that is hollow so water (or air) can exit or enter. Leakage is likely to occur in the sealing area, which is carried out both horizontally and vertically. Sealing is done to seal the packaging where the sealing process is carried out with heat application [6].

Packaging leaks can be divided into 6 types, namely horizontal leak, vertical leak, folded, overlap, torn, and delaminated. Horizontal leak is a type of leaks where leakage occurs in the horizontal end of packaging, whereas vertical leak occurs in the vertical end of packaging. Folded is a type of leaks where leakage occurs due to packaging being folded, which usually occurs on the edge of the packaging. Overlap is a type of leaks where the right and left sides of packaging are not parallel which causes excess on the right or left side. Torn is a type of leaks where the packaging is torn on the body of the packaging. Delaminated is a type of leaks where the packaging peels off on the body of the packaging. The illustration of types of packaging leaks is shown in Figure 1.
Packaging leak problems of sweetened condensed milk sachets are supported by complaints received by XYZ milk industry at the end of 2018. The complaints may come from products produced in the same month the complaint was received or even from products produced in previous months. Complaints received were mostly defective products that cause leaks in the product packaging. Products with leaks are converted into percentage as shown in Table 1. Based on the data, three machines have large average percentage of packaging leaks compared to other machines. The machines are machine A, machine C, and machine D, with percentage of leakage of 8.56%; 5.53%; and 5.66% consecutively. Therefore, these three machines were chosen to be objects of this research, which need to be observed and analyzed further in order to reduce the packaging leak problems.

Packaging leakage can occur during the production process of sweetened condensed milk sachets in XYZ milk industry, which lasts 24 hours non-stop, unless there is a product changeover that usually comes with CIP (Cleaning-in-Place). Packaging leakage usually occurs in the filling and sealing process because the process involves heat application which may fail and cause leakage. In addition, production operators also play an active role in filling and sealing process. Therefore, the detailed process flow that takes place in the filling and sealing machine is described to find out the root part or process that may cause leakage problems.

| Machine Name | September 2018 | October 2018 | November 2018 | Average |
|--------------|----------------|--------------|---------------|---------|
| Machine A    | 7.73%          | 11.11%       | 6.84%         | 8.56%   |
| Machine B    | 1.99%          | 1.81%        | 2.28%         | 2.03%   |
| Machine C    | 7.95%          | 3.88%        | 4.75%         | 5.53%   |
| Machine D    | 3.75%          | 6.20%        | 7.03%         | 5.66%   |
| Machine E    | 2.21%          | 1.55%        | 7.60%         | 3.79%   |
| Machine F    | 1.77%          | 1.55%        | 2.47%         | 1.93%   |
| Machine G    | 4.42%          | 0.00%        | 1.90%         | 2.11%   |
| Machine H    | 3.97%          | 3.36%        | 2.28%         | 3.20%   |
| Machine I    | 2.87%          | 3.88%        | 4.37%         | 3.71%   |
| Machine J    | 1.77%          | 5.68%        | 4.18%         | 3.88%   |
| Machine K    | 7.51%          | 1.81%        | 3.42%         | 4.25%   |
| Machine L    | 2.87%          | 2.07%        | 3.23%         | 2.72%   |
| Machine M    | 4.86%          | 3.36%        | 5.32%         | 4.51%   |
| Machine N    | 2.65%          | 0.78%        | 1.52%         | 1.65%   |
| Machine O    | 3.75%          | 3.10%        | 6.65%         | 4.50%   |
| Machine P    | 0.00%          | 3.36%        | 4.56%         | 2.64%   |

Source: Database of XYZ Milk Industry

The type of filling and sealing machine used in XYZ milk industry is a Vertical Form, Fill, Seal (VFFS) machine that works automatically and continuously. Briefly, the machine operates in a process flow as follows; aluminium foil packaging in the form of roll moves around the film roll feed. While
moving, the front side of the packaging is coded using laser. The packaging is then divided into two parts by the splitter, namely the front and back sides. The split packaging is sealed vertically while it is filled with sweetened condensed milk through a nozzle which is previously stored in the hopper. The hopper is a temporary milk storage tank received from the central storage tank. In the hopper, N₂ (nitrogen) is added in order to replace or eliminate O₂ (oxygen) which can get into the packaging. Nitrogen can inhibit the growth of aerobic organisms that can damage food [7]. Squeezer holds the milk-contained packaging before it is sealed horizontally. Perforated cuts are given on sealed packaging. The packaging is then split into 6 sachets. The sweetened condensed milk sachets are moved on the conveyor belt to be forwarded to the packing area.

The illustration of the process flow of sweetened condensed milk sachets in filling and sealing machine is done with SIPOC (Supplier - Input - Process - Output - Customer) diagram as seen in Figure 2. SIPOC diagrams can be used to identify problems that occur in the process by grouping various elements related to the process [8]. Supplier is the party that supplies goods or services. Input is a resource like humans and raw materials that enter into a system to produce a desired output. The process converts input into output which will then be received by the customer.

![Figure 2. SIPOC Diagram of Sweetened Condensed Milk Sachets in Filling and Sealing Machine](image)

In Figure 2, it can be seen that supplier(s) are the Process department of XYZ milk industry for sweetened condensed milk and packaging supplier, SA and TN industries, for the supplier of packaging material. To produce output of sweetened condensed milk sachets, input needed consists of sweetened condensed milk, aluminum foil packaging, machine operators, and production codes. The input then undergoes a process of coding with laser, filling of sweetened condensed milk into the aluminum foil packaging, and packaging sealing. As for process, the filling and sealing stages are the cause of leakage problems in sweetened condensed milk sachets. Sweetened condensed milk sachets are then sent to the customer, which is the packing department, to be packed into plastic and cardboard packaging.

3.2 Measure

To measure the defect of packaging, samples were randomly collected from each shift and data of packaging leaks are converted into percentage for machine A, C, and D as shown in Table 2.

| Table 2. Packaging Leakage Percentage Produced from Machine A, C, and D (Before Improvement) |
|-----------------------------------------------|----------------|----------------|
| Number of Samples                             | 93,840         | 88,920         | 35,280         |
| Number of Leakage(s)                          | 101            | 113            | 12             |
| % Leakage                                     | 0.1076%        | 0.1271%        | 0.0340%        |

Machine C has the largest percentage of leakage which is 0.1271%, followed by machine A with a leakage percentage of 0.1076%. Both of these machines surpassed the lowest percentage tolerance of the company that is equal to 0.05%. Machine D has the smallest percentage of leakage, which is 0.0340%, where the value is below the company standard. Even so, improvement of machine D is still undertaken because complaints received regarding leakage is quite high. The leakage data is then made into the pareto diagram that is used to sort leakage category from the highest to lowest. Pareto diagram is also helpful for finding focus of the problem so that the right corrective action will be taken. According to Jayakumar et al. [9], some samples that do not meet standards (or defects) can affect the overall problem.
Figure 3. Pareto Diagram of Packaging Leaks Before Improvement from Machine A (a), Machine C (b), Machine D (c).

Pareto diagrams of packaging leaks of sweetened condensed milk sachets produced by machine A, C, and D are shown in Figure 3. The x axis is the leakage category and the primary y axis (left) is the total of leakage(s) expressed as a percentage of the total number of samples. The secondary y axis (right) expresses the cumulative percentage of leakage.
number of leakages and the secondary y axis (right) is a cumulative percentage of leakage problems. Products with leaks from the highest to the lowest produced by machine A consecutively is horizontal leak, vertical leak, folded, delaminated, torn, and overlap. Based on Pareto principle known as the 80/20 rule, the 83.17% of the leakage problems that occur on machine A were caused by horizontal leak and vertical leak. Products with leaks from the highest to the lowest produced by machine C consecutively is folded, overlap, horizontal leak, vertical leak, delaminated, and torn. Based on Pareto principle known as the 80/20 rule, 84.07% of the leakage problems that occur on machine C are caused by folded, overlap, and horizontal leak. Products with leaks from the highest to the lowest produced by machine D consecutively is vertical leak, horizontally leak, torn, overlap, delaminated, and folded. Based on Pareto principle known as the 80/20 rule, 91.67% of the leakage problems that occur on machine D are caused by the vertical leak and horizontal leak.

Control charts of packaging leaks of sweetened condensed milk sachets produced by machine A, C, and D are presented in Figure 4. The x axis is the sample number for each sample taken on a different day. The y axis is the proportion of leakage. The UCL (Upper Control Limit) value in the chart is a value of 3 sigma above centerline, which is the average of leakage proportion. While the LCL (Lower Control Limit) value in the chart is a value of 3 sigma below the centerline.

The packaging leaks produced by machine A increased, decreased and increased again while there was a decrease in machine D. However, the leakage of products produced by both machines is within the control limit because they are between the UCL and LCL. According to Montgomery [10], the process characteristics that have decreased indicate that there is no unusual source of variation in the process. Leaks produced by machine C decreased and increased where some points are outside of UCL or LCL. This shows that there is a source of unusual variation of leaks produced by machine C.

DPMO and sigma levels for each machine can be seen in Table 3. Machine A, C, and D have DPMO values consecutively of 1,076.30; 1,270.81; and 340.14 where if converted to sigma levels are
consecutively 4.57; 4.52; and 4.90. While the overall DPMO value of packaging leaks produced by the three machines is 1.036.51 which is converted to a sigma level of 4.58.

| Machine | Number of Leakage(s) | Number of samples | DPMO        | Sigma Level |
|---------|----------------------|-------------------|-------------|-------------|
| A       | 101                  | 93,840            | 1,076.30    | 4.57        |
| C       | 113                  | 88,920            | 1,270.81    | 4.52        |
| D       | 12                   | 35,280            | 340.14      | 4.90        |
| Total   | 226                  | 218,040           | AVE: 1,036.51 | AVE: 4.58 |

3.3 Analyze

The potential cause of the packaging leak problem on machine A, C, and D is made into cause and effect diagram shown in Figure 5. which is divided into 4 categories, namely man, machine, material, and method. Why-why analysis is used to analyze packaging leak problems based on the highest leakage category by asking the question "why?" five times to obtain the factors that are the source of the problem. The main leakage problem faced by machine A is the horizontal leak category. Horizontal leak occurs due to overfilling, milk remaining in the seal section of sachet packaging, unsealed packaging, inappropriate perforation cut, and improper temperature and pressure settings. After a number of "why?" questions were given, the source of horizontal leak problems was obtained, including operators who were undisciplined and negligent in carrying out their duties, hollow nozzles, worn stator pumps, dirty sealers, uneven sealer surfaces and inconsistent quality of packaging material.

The main leakage problem faced by machine C is the folded leak category. Folded occurs due to uneven foil and improper nozzle position. After several "why?" questions were given, the source of the folded problem was obtained, including operators were negligent in carrying out their duties, dirt was blocking the foil roller, and the position of the nozzle was not suitable.

The main leakage problem faced by machine D is the vertical leak category. The factors that cause vertical leak problems are almost the same as horizontal leak, which are overfilling, milk remaining in the seal section of packaging, unsealed packaging, unsuitable perforation cut, improper temperature and pressure settings.
and pressure settings, and blunt splitters. After several "why?" questions were given, the source of the problem of vertical leak was obtained, including operators who were undisciplined and negligent in carrying out their duties, hollow nozzles, worn stator pumps, dirty sealers, uneven surface sealers, inconsistent quality of packaging material, and maintenance of the splitter used.

3.4 Improve

After analyzing the cause of the problems, improvement plan is made based on the results of the analysis obtained. Improvements are focused on repairing and maintaining the machines. To overcome the problem of leakage in the machine, several improvement plans were determined, such as replacing the hollow nozzle, replacing the worn stator pump, replacing the cleaning tool for sealer, adding a shim plate to cover the surface unevenness of sealer, and updating the matrix parameters in each machine and OPL (One Point Lesson) regarding splitter replacement.

Based on the analysis, there is a correlation between the hollow nozzle and horizontal leak category. Therefore, replacement of a hollow nozzle was done on machine A but not on machine C and D. In addition, improvisation on the nozzle were also done by reducing the diameter of nozzle output hole from 4 mm to 2 mm, this may reduce material losses as the larger the diameter of nozzle, the more products are wasted. To balance replacement of the hollow nozzle, the worn stator pump was also replaced. When stator pump is unstable, nozzle will release the product uncontrollably and will physically contaminate the machine. Consistently, only the stator pump on machine A was replaced.

Replacement of cleaning tool for sealers was carried out on the basis of complaints received from machine operators. Cleaning tool used was wire brush that gets easily damaged because of high temperature of sealer and difficult to clean. Therefore, wire brush is replaced with a new wire brush with the same model but with slightly different characteristics. The new brush has handles with thickness of 8 mm, which is twice the thickness of the previous one that is 4 mm. A thicker brush handle is expected to prevent or slow down the wire brush to bend. Apart from the different in thickness of the handle, the new wire brush has a slightly larger distance between wires and also thicker wire compared to the previous one. All of these changes are expected to optimize the sealer cleaning process so that sealer can be maintained clean and reduce product leakage. In addition, it can minimize the cost of purchasing a new wire brush if the current wire brush model is durable in long run.

The addition of shim plate was carried out on the surface of the uneven horizontal sealer as an option for replacing the whole sealer which costs quite expensive. Just like the nozzle replacement, the addition of shim plate was only done on the horizontal sealer of machine A. Shim is a piece of wood, metal, or other material used to fill the space between two objects or two object faces [11]. Carbon test was done as a form of machine maintenance to determine the sealer performance that can be seen from the color shown on carbon paper. From the results (Figure 6) the technician could determine how thick the shim is needed to patch the cracks in the sealer. Adding the shim plate to the surface of the cracked sealer is expected to optimize sealer performance in order to reduce packaging leakage. In addition, there is a reduction in costs incurred because it can repair the cracked sealer without having to replace it as a whole.

![Figure 6. Carbon Test Paper for Horizontal Sealer 1 Before Improvement (a), After Improvement (b), Horizontal Sealer 2 Before Improvement (c), After Improvement (d).](image-url)
After applying the improvement plan on machine A, C, and D, re-sampling was conducted to test how much leakage had occurred or whether the improvement plan was made suitable for the needs of machine. Data of packaging leaks of sweetened condensed milk sachets after the improvement are then made into percentage for machine A, C, and D as shown in Table 4. Machine A has the largest percentage of leakage among the three machines with a percentage of 0.0897%. However, machine A experienced a leak reduction of almost 0.02% from the previous 0.1076%. Machine D has a leakage percentage of 0.0251% where there is a decrease of around 0.01% from the previous 0.0340%. Machine C which previously had the highest leakage percentage decreased significantly to 0.0189% from the previous 0.1271%.

**Table 4. Packaging Leakage Percentage Produced from Machine A, C, and D (After Improvement)**

| Number of Leakage(s) | Machine A | Machine C | Machine D |
|----------------------|-----------|-----------|-----------|
| Number of Samples    | 62,400    | 63,360    | 23,880    |
| %Leakage             | 0.0897%   | 0.0189%   | 0.0251%   |

The results of DPMO value and the sigma level calculation for each machine after improvement can be seen in Table 5. Machine A, C, and D have DPMO values of 897.44, 189.39, 494.52 consecutively where if converted to sigma levels they are 4.62, 5.05, and 4.98. Each machine has an increase in sigma level after it has been repaired. While the overall DPMO value of packaging leakage is 494.52 which was converted to a sigma value of 4.79. The corrective action taken succeeded in increasing the sigma level of the three machines from the previous value of 4.58. However, this value is still far from the value of six sigma which has a defect percentage of 99.9997%.

**Table 5. DPMO dan Sigma Levels of Machine A, C, dan D (After Improvement)**

| Machine | Number of Leakage(s) | Number of Samples | DPMO | Sigma Level |
|---------|----------------------|-------------------|------|-------------|
| A       | 56                   | 62400             | 897.44 | 4.62        |
| C       | 12                   | 63360             | 189.39 | 5.05        |
| D       | 6                    | 23880             | 251.26 | 4.98        |
| Total   | 74                   | 149640            | AVE: 494.52 | AVE: 4.79 |

4. Conclusion

Results showed that the highest leakage category in sweetened condensed milk sachets produced by machine A, machine C, and machine D in XYZ milk industry respectively are horizontal leak, folded, and vertical leak. By using the six sigma DMAIC (Define, Method, Analyze, Improve, Control) method, the major problem within the packaging leaks identified is machine performance and methods related to machine maintenance. Corrective action was done by replacing the machine parts, such as replacement of the hollow nozzle and worn stator pump, reduction of nozzle diameter, addition of shim plate to horizontal sealer, and maintenance activities which include the replacement of sealer cleaning tool (wire brush), renewal of machine parameters and OPL (One Point Lesson) related to the splitter replacement. This improvement increased sigma level from 4.58 to 4.79. This shows that the use of six sigma method was effective to increase quality of sweetened condensed milk sachets due to a decrease in the percentage of packaging leakage that occurred.

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