Reducing waste on wheat flour packaging: an analysis of Lean Six Sigma

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Reducing waste on wheat flour packaging: an analysis of Lean Six Sigma

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Abstract. Reducing defects in the process of packaging wheat flour is important to be done continuously. This study aims to identify and measure the activity of waste that occurred, performance sigma value, and obtain solutions which do by the researcher in Consumer Packing Division PT Z. Waste is measured and assessed using the methods of Lean Six Sigma and Failure Mode and Effect Analysis (FMEA). Based on research, activity categorized waste activities include Defect, Waiting, Non-Utilizing People’s Talent, Transportation, and Motion. Measurement focused on the largest waste Defect is Broken Pack. The result showed the defect per million opportunities (DPMO) value 4089.2475 with level sigma 4.14 and capability process (Cp) 1.31. FMEA showed eight causes factors of the failure broken pack. Four failure mode of which exceeds the critical value that is less of a response operator (Risk Priority Number or RPN=150), lack of control of packaging (RPN=126), less-skilled workers (RPN = 120) and the inaccuracy of allocating the number of workers (RPN=105). Therefore, on the job training, proper allocation of workers during breaks, the packaging audit of the suppliers, and increase the number of workers needed to support the packaging efficiency of wheat flour.

1. Introduction
In the processing industry, the inspection in each process is important to ensure quality and efficient production. Furthermore, it reduces the waste of production and losses [1]. Many of the wastage was not identified, so that it is detrimental. Therefore, it needed to identify and measure waste to uncover problems and improve performance [2].

Waste is something that does not have added value in the production. Elimination of waste increases the value of the production system [3]. An example of waste is the completion of a product longer than a defective plan and product [2]. According to Vincent [4], there are 9 waste activities, including environmental, health, and safety (EHS), defects, overproduction, waiting time, not utilizing talent's people, transportation, inventory, motion, excess processing. Identification of waste activity can be assessed by operation type. According to Aherne and Whelton [5], the operation is divided into three types, namely value-added activity (VAA), non-value added activity (NVAA), and necessary but non-value added activity (NNVAA).

There are three main processes in the wheat flour milling industry, namely cleaning, milling, and packing. The packaging produces many defective products caused by a broken pack leak. One method of identifying activities and measuring waste types is Lean Six Sigma. Lean is an approach to reduce
waste by minimizing work in process and eliminating NVAA [6]. The Six Sigma concept is a process that does not produce more than 3.4 defect per million opportunities (DPMO). There are 5 phases include define, measure, analyze, improve, and control (known as DMAIC) [4]. Technically, Sigma is a statistical measure of quality consistency for a particular process or product. According to Desai et al. [7] application of Lean Six Sigma is a process of continually improving production efficiency. This study uses the Lean concept to evaluate the activity that causes waste and the Sigma concept to control packaging performance. Lean Six Sigma analysis is expected to provide improvements to minimize waste.

2. Materials and Method
The research object is a defective product caused by the broken pack in the wheat flour milling industry and limited in the improve phase. The data was then analyzed using the Lean Six Sigma approach includes the define stage, namely identification of product and packaging activities, making Shigeo-style value stream mapping (VSM), and waste identification. Measure phase was conducted by sampling, testing data adequacy, making control charts, calculating sigma, DPMO values, and calculating process capability (Cp). Analyze stage was carried out by a causal diagram and the improvement was by FMEA.

3. Results and Discussion
In the flour milling industry, there are three commercial packages, namely bulk, economical, and premium packages. In addition there is 2 kg of packaging. The wheat was processed into wheat flour using 3 main processes, namely cleaning, milling, and packing. In the packaging are three lines of packaging. The consumer pack division is responsible for guaranteeing the flour formula according to the quality guide for each type of product and meeting the packaging product target from PPIC.

3.1. Define stage
3.1.1. Product identification observed
The products observed were selected from the largest products, namely the economical packing and premium packing which were mostly produced in production line 1, the consumer packing division.

3.1.2 Identification of packaging activities
Based on the identification of wheat flour packaging activities, there are 26 packaging activities. There are 21 activities or 80.76% are VAA, which is calculated using equation (1), 3 activities or 11.53% are NVAA which is calculated using equation (2), and 2 activities or 7.69% (NNVAA).

\[
Value Added Ratio = \frac{Total Value Added Time}{Total Lead Time}
\]  \hspace{1cm} (1)

\[
Non Value Added Ratio = 1 - Value Added Ratio
\]  \hspace{1cm} (2)

3.1.3. Making a Shigeo-style value stream mapping
The define stage uses VSM to facilitate identification. One type of VSM is the Shigeo-Style VSM. Shigeo-Style VSM describes process data such as traditional VSM but resembles SIPOC maps [6]. VSM depiction to identify waste in the packaging process (Figure 1). Wheat flour packaging consists of 3 main processes, namely preparation material, filling, and packing with a total of each elapsed time of 15.5, 15.553, and 32.25 minutes. The whole lead time is 63.303 minutes, with 43.003 minutes being the Value-Added Time (VAT). There are 20.3 minutes of non-value added time (NVAT) that the potential to cause waste and need to be eliminated.
3.1.4. Identify waste (form E-downtime)
Packaging analysis identified seven types of waste activities, namely environmental, safety, and health (EHS), defect, waiting, non utilizing talent, transportation, and motion. From these seven waste activities, the broken pack was chosen because it has the highest value compared to the broken box. The frequency of the two types of deviations in Figure 2.

3.2. Measure stage
3.2.1. Sample measurement and data adequacy test
The defect observed is primary packaging leakage or waste defect broke pack on line 1 of packaging process. Defect broken packs are obtained from the daily report of the consumer packing division. The results of testing the adequacy of the data obtained by the value of n are 7. The value of n is smaller than the number of packaging products studied, namely 17,889 packs. Data is stated to be fulfilled.

Figure 1. Shigeo style VSM wheat flour packaging
3.2.2 *P-Chart.* P-chart is used for process stability evaluation [8]. P control chart is used to find out the actual condition of the packaging and the number of defective products. Map p in Figure 2. Based on the map p, there are no points outside the upper control limit (UCL) and the lower control limit (LCL). It means that packaging is statistically controlled. There are still some points of proportions far apart and approaching the control limit. This condition causes process data to be potentially out of control, such as points number 2 and 4. According to [9] the point near the control limit, it is necessary to calculate the actual control limit, so that UCL on the broken pack p control map is described according to the actual control limit calculation.

![Diagram](image)

Figure 2. Diagram (a) Pareto defect type and (b) P-chart of broken pack

3.2.3. *Calculation of DPMO and sigma level*

DPMO calculation of line 1 of the packaging process in one period is calculated using equation (3):

\[
DPMO = \frac{\sum \text{defect}}{\sum \text{data}} \times 1,000,000
\]  

(3)

The conversion of DPMO value into sigma value resulted in the value of 4.14. The measurement results obtained by DPMO 4089.2475, such as broken packs that affect packaging performance. World-class companies produce DPMO <300 [4]. CP1 line packaging needs continuous improvement to achieve Cp with sigma 6. All industries with an international quality management system must increase continuously [4].

3.2.4. *Measurement of process capability (Cp)*

Cp is measured to predict product suitability with specifications. Cp on the p control chart is known by calculating the yield process. Yield is the probability percentage of the product according to the process specification. Packaging yield is calculated by equation (4) and (5):

\[
\text{Defects per Opportunity (DPO)} = \frac{\sum \text{defect}}{\sum \text{data}}
\]  

(4)

\[
Yield = e^{\frac{\sum \text{defect}}{-DPO}}
\]  

(5)

This result shows that the packaging of defect-free wheat flour is 99.59% and defective products are 0.41%. A process is said to be good if the final yield is 69.15% for Indonesian standards and 99.73% for...
international standards [1]. The packaging of flour in this business is excellent because it is close to international standards. The Cp index is calculated to determine the ability of the packaging process, using equation (5). Cp for attribute data is calculated using equation (6) [10]:

\[
C_p = \frac{\text{level} \, \text{sigma}}{3}
\]  

(6)

Value of Cp is 1.38 which means packaging needs to be improved. If the Cp value <2 indicates, the production process needs to be increased [4].

3.3. Analyze stage
This stage analyzes the causes of waste in the packaging division. Process control to improve quality and productivity by reducing variations in irregularities [4]. Fishbone diagram is used to know the cause of the waste defect (broken pack). There are four main components, namely man, method, material, and machine (Figure 3). The environment factor is not analyzed because it does not affect the broken pack.

3.3.1. Man
Broken pack primary packaging because of human factors. There are three causes, namely the inaccuracy of machine settings, the delay in turning off the engine when the engine fails, and the error setting the speed of the conveyor belt. Incorrect machine settings because unskilled workers operate filling and packing machines when replacing roll packaging. The right operation training setting filling machine for the operator will reduce failure. Hanafi [11] states that training improves competence.

Slow shut down when the engine fails because lazy workers monitor filling and packing machines. The operator is considered less responsive when the engine fails. Hardjana [12] states that training influences the performance of workers. Error in the speed of the conveyor belt because the operator is less skilled at adjusting the discharge speed of the packing. Machine operating standards need to be adequately understood and applied by each worker.

3.3.2. Method
There are two main causes of errors, namely the replacement of packaged in the middle of production and fewer workers in secondary packaging. Changes of flour type cause change finished packaging, so
it is necessary to replace the packaging on the roll of filling and packing machines. Manual and time-consuming packaging replacement. It is needed to coordinate flour stock management with product planning and inventory control (PPIC) and the milling regarding the supply of wheat flour.

The shortage of workers in the packaging division when changing breaks between workers results in workers being overworked. It needs alternative rotation of workers. The consumer packing division needs help from the division of premix chesa packing. The workers' rotation to the chesa premix packing division at rest is complete and the number of workers in the consumer packing division is fulfilled. Arai [13] states that production and does not lose production at rest is to apply workers rolling.

3.3.3. Machine
Blades sealer filling and packing machines blunt and sealer heaters are broken, so the packaging leaks. Heating sealers break up because they are worn out. The right time to replace filling engine components and packing requires skilled operators. The incidence of heater sealers breaks up minimally and the risk of engine breakdown decreases. Machines need to be monitored regularly.

Blunt sealer blades cause melting plastic packaging attached to the sealer blade. Many primary packs are not perfectly cut so they leak, and when it is filled, the flour falls onto the conveyor belt. Adding coolant to the filling machine facing directly with the sealer blade is expected to extend the life of the sealer blade. Levitt [14] states that cooling holes in engine increase the reliability of the sealing machine.

3.3.4. Material
Poor packaging from suppliers causes broken packs to leak. Primary packaging is too thin and easy to tear, so it needs control of the packaging supplier. The company needs to communicate the desired packaging quality and monitor packaging quality. It needs testing before use.

3.4 Improve the stage
3.4.1 Cause factor analysis with FMEA
The main causes of product defects, such as fishbone diagrams, are analyzed by Failure Mode and Effect Analysis (FMEA). FMEA results cause broken pack packaging in Table 1. At the repair stage, it is filled with every possible value of detection, frequency of assurance, and degree of severity according to observation process on scale of 1-10. Critical Value RPN, calculated by dividing Total RPN with Risk Amount, is 87.

FMEA results have 8 factors that cause defects. Four of these failure modes exceeded the critical value, namely the operator was less responsive (RPN = 150), less control of packaging (RPN = 126), less-skilled workers (RPN = 120), and inaccurate allocation of workers (RPN = 105).

3.4.2. Recommendation for improvement
Based on FMEA, it is known that the majority of packaging failures are due to human resources. Employee responsiveness is very important, so it is important to conduct an understanding of training on the risk of losing production. The consumer pack division needs to control roll packaging from suppliers. Suggestions to improve is presented in Table 2.
### Table 1. FMEA flour packaging process

<table>
<thead>
<tr>
<th>No</th>
<th>Failure</th>
<th>Failure Mode</th>
<th>Failure Effect</th>
<th>S</th>
<th>O</th>
<th>D</th>
<th>RPN</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Packaged substitution in the production</td>
<td>Stock flour is used up</td>
<td>Need re-filling &amp; packing machine adjustment</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Lack of workers in secondary packaging</td>
<td>The allocation of workers is less precise</td>
<td>Products accumulate in the conveyor belt cause bottlenecks</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>105</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Inaccurate filling machine</td>
<td>lack of skilled workers</td>
<td>Many perfect non-sticky packaging causes broken packs, and clipped packaging is not precise</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>120</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Inaccurate speed of conveyor belt resulting in bottlenecks</td>
<td>Fewer experts in an adjustment of discharge packing</td>
<td>Broken pack</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Delay in shutdown the filling &amp; packing during machine failure</td>
<td>Operator responsiveness</td>
<td>There is a bottleneck that causes a broken pack</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>150</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Blunt sealer blades</td>
<td>The hot plastic seal attached to the packaging machine</td>
<td>The package is not cut perfectly</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Heater sealer disconnects</td>
<td>Packed old sealers</td>
<td>The packaging is not well full</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Poor packaging quality</td>
<td>The control lack of consumer pack suppliers</td>
<td>The packaging is too thin and easy to tear</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>126</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>696</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Suggestions for improvement of flour packaging based on FMEA

<table>
<thead>
<tr>
<th>No</th>
<th>Failure</th>
<th>Failure Mode</th>
<th>Recommendation for Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delay in shutting down the filling &amp; packing machine when the engine failure</td>
<td>The operator is not responsive</td>
<td>Addition number of operators on each machine in the consumer pack division</td>
</tr>
<tr>
<td>2</td>
<td>Poor packaging quality</td>
<td>Control consumer pack division to less packaging suppliers</td>
<td>The packaging is too thin and easy to tear</td>
</tr>
<tr>
<td>3</td>
<td>Inaccurate setting filling machine</td>
<td>Less skilled workers</td>
<td>The packaging is not perfectly attached and labels cutting are not precision</td>
</tr>
<tr>
<td>4</td>
<td>Lack of workers in secondary packaging</td>
<td>The allocation of workers is less precise</td>
<td>Products accumulate in the conveyor belt cause bottleneck</td>
</tr>
</tbody>
</table>

### 4. Conclusions

The consumer packing division at the company was identified seven types of waste activities, namely environmental, safety, and health (EHS), defect, waiting, non utilizing talent, transportation, and motion. There are 43.003 minutes of value-added activity and 20.3 minutes of operation does not provide waste. The waste type that affects packaging performance is a broken pack. DPMO for wheat packaging is 4089.2475, Sigma value is 4.14, process capability is 99.59%, and process capability index is 1.38. On the job training, allocating workers at rest time, packaging audits to suppliers, and adding workers can improve the packaging efficiency of wheat flour.
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