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Improving the Quality of the Chocolate Production Process at Wahana Interfood Nusantara Company Using DMAIC Method

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ABSTRACT

In this century, consumers, as product users, are becoming more critical and pickier in their product selection due to technological and economic advances in the global market. Wahana Interfood Nusantara Company is Indonesia's most complete cocoa bean processing company under the SCHOKO brand. The study aims to identify the effects of implementing the DMAIC methodology in improving the quality of the chocolate production process at Wahana Interfood Nusantara Company. This study uses the DMAIC method (Define, Measure, Analyze, Improve, and Control). They obtained 5 Critical to Quality: broken, cracked, peeled-off, soft, and porous. The DPMO value was 4788.49, and the Sigma value was 2.496, which means that the white couverture chocolate production process is in Indonesia's average Sigma value industry. It was found that 80% of the most dominant defects were peeled off (38.5%), cracked (28.7%), and broken (25.3%). Suggestions for improvements are given to carry out regular machine maintenance, conduct employee training, and carry out SOPs correctly.

Keywords: Chocolate, DMAIC, Manufacturing, Quality Control, Six Sigma

INTRODUCTION

In this century, consumers, as product users, are becoming more critical and pickier in their product selection due to technological and economic advances in the global market. Competition in the industrial sector and client satisfaction necessitate constant innovation by companies. The quality of a product is just as important to consumers as the quantity. Product quality is a benchmark for assessing the maturity of the manufacturing industry in producing quality products. Arianty and Siregar (2021) found that high-quality products usually attract more customers because people always seek excellent products. Consumers will judge a good company if it has covered three aspects of the production process, which include zero defects (no defects), zero breakdowns (no failed processes), and zero accidents (no accidents). However, these three aspects are very difficult to achieve if the control of the production process is not implemented properly (Bakti & Kartika, 2020).

Quality control aims to expand, design, create and serve high-quality products that are economical, useful, and satisfy the consumer (Ishikawa, 1981). Product defects can have a detrimental impact on a company's bottom line by diminishing customer satisfaction and confidence in a product.

Quality control can also be interpreted as an integrated effort within a company to maintain the quality of the goods produced to match the characteristics and specifications of the products produced (Bakti & Kartika, 2020). Moreover, Quality control is the most convenient way to sustain the products' quality to comply with the specifications established based on company policy. Technically, quality control aims to determine whether it is going according to plan, has been carried out efficiently, and is possible improvements (Nasution & Sodikin, 2018).

Quality problems are common in production processes, including the chocolate production process. They also occur in Wahana Interfood Nusantara Company. A company's output is not meeting customer expectations because the white couverture chocolate on the body surface is not very good. It is difficult to achieve zero faults throughout the entire production process. Typically, this cause-and-effect study involves man, method, machines, material, and environment. Therefore, the most effective way to enhance the process is to minimize errors as much as feasible.

The study aims to identify the effects of implementing the DMAIC methodology in improving the quality of the chocolate production process at Wahana Interfood Nusantara Company.

LITERATURE REVIEW

Definition of Quality

Quality is an essential aspect of the development of the company. Currently, most consumers have started to make quality the main parameter in determining a product or service choice. Moreover, quality is often a means of promotion that aims to increase or decrease the selling value of the company's products. Consumers cannot easily believe various advertisements on the internet, such as on social media. On the other hand, consumers can easily believe in someone's testimony about an item's quality. Therefore, quality is currently one of the strategies used to win the competition among the many products on the market. Consumers no longer use price as a standard to buy goods, but they are more concerned with the durability of the goods they buy. Quality has different meanings; one of the definitions of quality is a product or service that has product characteristics according to the user's wishes and meets the specified requirements (Montgomery, 2020).

The definition of quality control is a way to sustain the quality of the goods produced by the product specifications determined at the discretion of a company's management. Based on this definition, it can be inferred that quality assurance is a strategy and everyday activities/actions taken to achieve, sustain and increase the quality of goods or services to reach existing requirements and meet customer satisfaction (Assuari, 2008).

Quality control is a planned technique and action taken to achieve, maintain and improve the quality of a product to conform to predetermined standards and meet customer satisfaction (Harahap, Parinduri, Ama, & Fitria, 2018). Moreover, quality control is an effort to maintain the quality of the products produced by the agreed product specifications based on company policy (Nasution & Sodikin, 2018).

Dimensions of Quality

The quality of a product can be described and evaluated in various ways using the dimensions of quality. The quality dimension has eight components: performance, reliability, durability, serviceability, aesthetics, features, Perceived quality, and compliance with standards (Gaspersz, 2007).

Quality has different meanings; one of the definitions of quality is a product or service that has product characteristics according to the user's wishes and meets the specified requirements (Montgomery, 2020). Quality improvement is carried out not only on the final product but also in the work-in-progress process so that defects or errors can still be corrected (Rahman & Perdana, 2021).

Quality Improvement Using Six Sigma

Six Sigma (σ) is a Greek alphabet that denotes the standard deviation of a process. Standard deviation measures the variation or number of distributions of a process average. Sigma is a statistical measurement unit that describes the distribution of the average value (mean) of each process or procedure. According to statistics, the number of defects a process has is known as the "Six Sigma" concept. 3.4 defects per million opportunities is the standard for Six Sigma. While Six Sigma's primary goal is to eliminate defects, it also emphasizes continuous improvement efforts that are expected to reduce the number of defective products to zero if they are carried out regularly (Zero defects) (Gaspersz, 2007). Meanwhile, the concept of six sigma is often used as an advanced process of quality control. However, companies must be able to provide satisfaction to customers with good product quality so that they will get more significant profits (Rahman & Perdana, 2021).

Organizations nowadays seek higher manufacturing quality and process capabilities to reach productivity goals such as long-term competitiveness, profit margins, and market share. Six Sigma is a business improvement method employed in various industries. The goal of the Six Sigma approach is to reduce product defect rates to raise profit margins and improve the financial situation. It improves client retention and happiness while producing the best-in-class product from the best performance (Pyzdek, 2002). Six Sigma differs from other quality efforts in that it applies not only to product quality but also to all elements of business operation by optimizing essential processes (Yang & Basem, 2003).

The DMAIC

The DMAIC is one of the Six Sigma methodologies used to make process improvements to products or ongoing processes. As a problem-solving method, this approach focuses on finding the fundamental causes of a problem, removing, or minimizing the reasons, and maintaining the changes over time (Sibanda & Ramanathan, 2020). The DMAIC method is an approach to improve the quality of a process or product so that it can reduce or eliminate defects that are detrimental to the company (Siregar & Mutiara, 2019). DMAIC has five stages in the problem-solving process related to process improvement and product quality (Montgomery, 2020). The following is an explanation of the DMAIC phases: Define, Measure, Analyze, Improve, and Control.

Define Phase
According to (Montgomery, 2020), the 'Define' phase is the stage where processes contribute to problems that ultimately affect product quality. Moreover, quality improvement is significant for the views of customers and companies.

Measure Phase
The ‘Measure’ phase is the measurement phase that aims to evaluate and understand the current state of the process. In the ’Measure’ phase, data is collected regarding the quality, cost, and production time measures to develop process input variables and process output variables. Data collection can be done by taking from historical data, but historical data does not fully support this stage because there may be incomplete data. As a result, data collection can also be done through direct observation within a specified time (Montgomery, 2020).

Analyze Phase
The ’Analyze’ phase aims to process the data that has been obtained in the ’Measure’ phase. The data is processed to determine causal relationships and understand the various sources of variability. In the ’Analyze’ phase, the potential causes of product defects, quality problems, timing, and production process inefficiency will be determined (Montgomery, 2020).

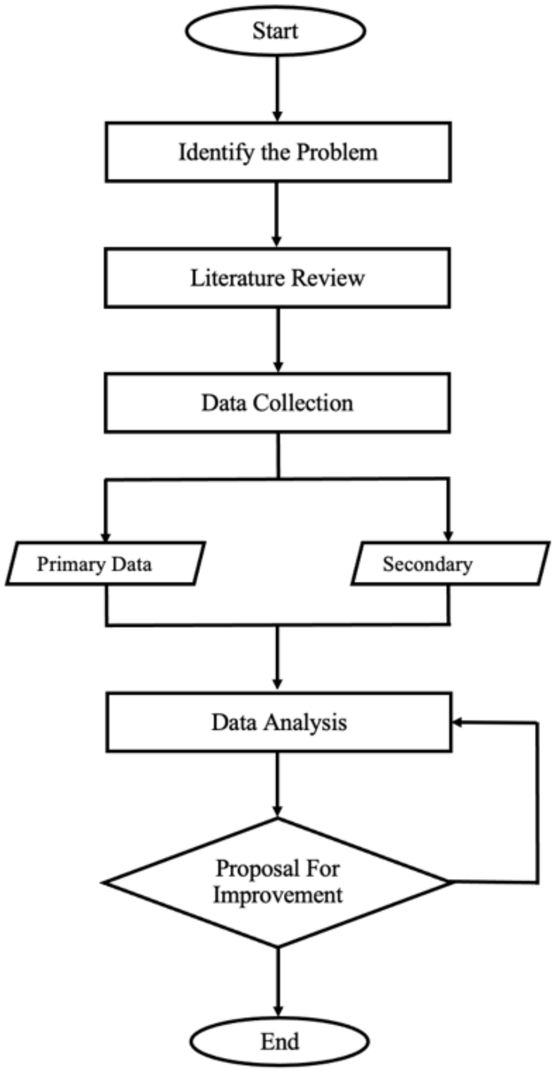
Improve Phase
The ’Improve’ phase is the stage that is carried out after the analysis phase is complete, where at this improve phase, changes will be made to produce the desired impact on process performance. The “Improve” phase aims to develop solutions to problems, provide proposed solutions, and implement these solutions (Montgomery, 2020).

Control Phase
The ’Control’ phase is the final phase in DMAIC, where this phase is carried out to complete all work and implement the proposed improvements given in the improvement phase to improve the quality of process control (Montgomery, 2020).

Implementation in the Food Industry to Improve Quality
According to Kovach & Cho (2011), using examples from other industries, the authors show how Lean Six Sigma may be successfully implemented in the food business and how this can lead to continual quality improvement. The implementation of the DMAIC method is to help reduce 50% of the cost of the production process by reducing the number of defective products, so that good products increase and employees' skills increase. This method uses data to reduce or eliminate defective products during manufacturing. Therefore, the DMAIC method is primarily used by the food industry to improve the production process and improve the resulting product (Meena, Manik, & Sakhala, 2022).

RESEARCH METHOD

Figure 1. Flowchart



The above flowchart shows the methodology applied to carry out the case study. The author interviewed the QC manager about the activities involved in the production process. Qualitative interviews were conducted to obtain direct information about certain situations and conditions, complete a scientific investigation, and receive data. Collect data to analyze Six Sigma methods in the manufacturing industry. There are two types of data collection: primary and secondary. Primary data was collected to determine how much white counter chocolate was produced, how many of those products had defects, and what kinds of defects those white counter chocolate products had. From January through July of 2022, the secondary data is taken from the production history. From January to July 2022, they have access to the historical data on the number of production records. The DMAIC Six Sigma problem-solving approach is used for data analysis. Despite the brainstorming and investigation sessions' suggestions and preventative measures, the number of defects has not decreased. Additional investigations and analyses are being conducted to determine the root cause in the production area.

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Research Approach

Production Data of White Couverture Chocolate

The defect data taken is a product of white couverture chocolate that has gone through the molding process every month from January 2022 until July 2022.

Table 1. Production Data of White Couverture Chocolate

Month	Total of Productions (Pcs)	Criteria of Defects					Total of Defects (Pcs)
		Peeled off	Cracked	Broken	Soft	Porous	
Jan	49598	335	284	514	96	15	1244
Feb	32987	220	145	341	64	8	778
Mar	53520	312	310	521	73	16	1232
Apr	50745	391	388	395	54	13	1241
May	56725	409	356	512	82	18	1377
Jun	28410	201	171	225	41	6	644
Jul	26564	183	154	241	47	7	632
TOTAL	298549	2051	1808	2749	457	83	7148

Calculation of Control P Chart Attribute

Making a control chart p is done to determine the central limit of defects in the resulting product and whether the production results are still within normal limits. The data collection includes the number of production and defects taken from January 2022 until July 2022. The steps in making the p-control chart are as follows:

1. Production and defect data are collected from January 2022 to July 2022.
2. Calculation of control p chart attribute
   $CL = \bar{p} = \frac{\text{Total of Defects}}{\text{Total of Production}}$
3. Calculation of the UCL.
   $= \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$
4. Calculating the LCL
   $= \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

Calculation of DPMO (Defect per Million Opportunities)

Defect Per Million Opportunities (DPMO) is a method used to measure the defect level in a product implemented in Six Sigma. The DPMO value will be used to determine the capability of the production process and the sigma level of the process. To calculate the value of DPMO and sigma level, the Defects per Unit (DPU) and Defects per Opportunity (DPO) are calculated first.

$$DPMO = \frac{\text{Number of Defects}}{\text{Number of Units x Opportunities per unit}} \text{ x } 1.000.000$$

RESULTS

This chapter presents data collected and data processing to solve problems in the molding process of white couverture chocolate products at Wahana Interfood Nusantara Company. The define and measure stages explain the data collection. While the analysis, improvement, and control stages explain data processing.

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Define Phase
In the define stage, the Critical to Quality (CTQ) is determined with the aim of knowing the physical quality characteristic of white couverture chocolate. Several products have defects in producing the White Couverture Chocolate product, so they are classified as defective. Product quality characteristics identified from interviews with the factory and direct observation obtained three types of defects. The types of defects that occur in White Couverture Chocolate products are as follows: Broken, cracked, soft, peeled-off, and porous.

Measure Phase
This is the second step in applying the Six Sigma methodology. The data obtained from the define stage is calculated at the measurement stage. This measurement is carried out to determine the performance of the molding process and the number of defective products that occur. Making a control chart determines whether a production process is within the control limits. The control chart P is based on the proportion of defective products from the White Couverture Chocolate product from January 2022 to July 2022. Because the monthly production number varies, each calculation method's CL, UCL, and LCL calculations are not the same.

1. Calculation of the CL or the process average:
   $CL = \bar{p} = \frac{\text{Total of Defects}}{\text{Total of Production}} = \frac{7148}{298549} = 0.024$
2. Calculation of the UCL.
   $= \bar{P} + 3\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}$
   $= 0.025 + 3\sqrt{\frac{0{,}024\,(1-0{,}024)}{49598}}$
   $= 0.026$
3. Calculating the LCL
   $= \bar{P} - 3\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}}$
   $= 0.024 - 3\sqrt{\frac{0{,}024\,(1-0{,}024)}{49598}}$
   $= 0.022$

The results of the calculation of data for P control charts in other months can be seen in the table below:

Table 2. Data recapitulation of CL, UCL, and LCL

No	Month	Total of Productions	Total of Defects	% Defects	CL	UCL	LCL
1	January	49598	1244	0.025	0.024	0.026	0.022
2	February	32987	778	0.024	0.024	0.026	0.021
3	March	53520	1232	0.023	0.024	0.026	0.022
4	April	50745	1241	0.024	0.024	0.026	0.022
5	Mei	56725	1377	0.024	0.024	0.026	0.022
6	June	28410	644	0.023	0.024	0.027	0.021
7	July	26564	632	0.024	0.024	0.027	0.021
TOTAL		298549	7148				

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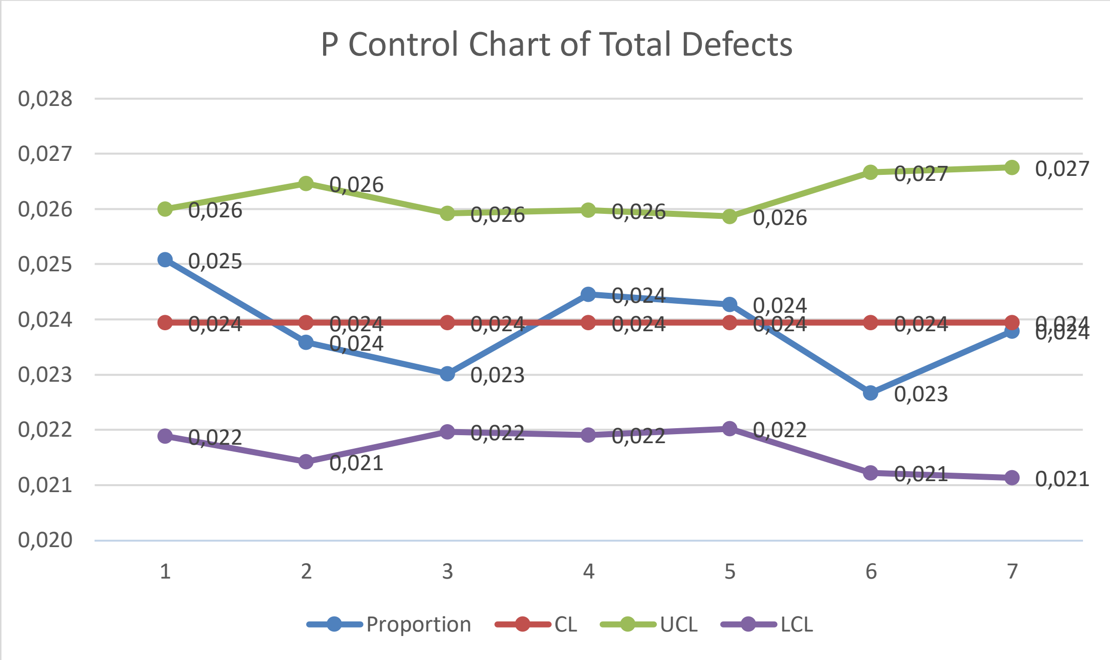
Figure 2. P Chart of Total Defects



Regarding the calculation of the control chart p in table 2 and figure 2, it can be seen that the results of the CL, UCL, and LCL values are 0.024, 0.026, and 0.022 showing that all data results were in control, or no data is out of control. Furthermore, the calculation of DPMO (Defect Per Million Opportunities).

The next measurement phase measures the level of sigma and Defect Per Million Opportunities (DPMO). DPMO aims to calculate the sigma of the white couverture chocolate production process.

Calculate DPU (Defect Per Unit)

$$\text{DPU} = \frac{\text{Defect}}{\text{Unit}} = \frac{7148}{298549} = 0.024$$

DPMO (Defect Per Million Opportunities)

$$= \frac{\text{Total of Defects}}{\text{Total of Units x CTQ}} \text{ x } 1000000$$

$$= \frac{7148}{298549 \text{ x } 5} \text{ x } 1000000$$

$$= 4788.49$$

Sigma Level

$$\text{Normsinv}\left(\frac{1000000-\text{DPMO}}{1000000}\right) + 1.5 = \left(\frac{1000000-4788.49}{1000000}\right) + 1.5 = 2.495$$

Table 3. DPMO and Sigma Level

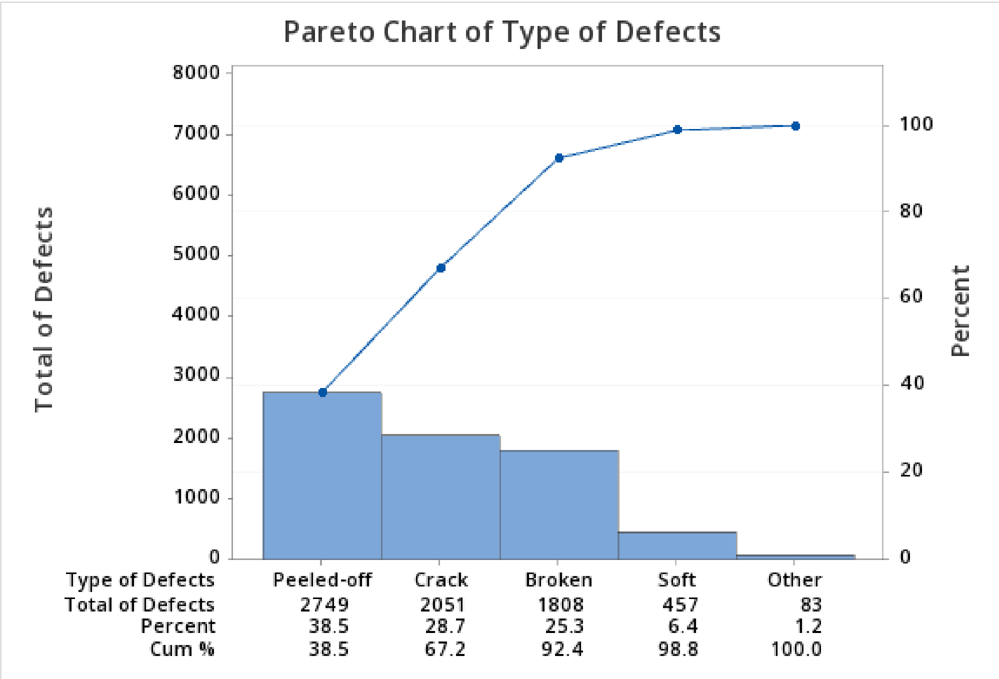
A. ALL Values Required to Calculate Sigma Level			
Defects	7148	DPMO	4788.49
Units	298549	Sigma Level	2.495
Opportunities Per Unit	5		
B. Enter only the known Defects Per Million Opportunities			

Enter DPMO	4788.49	Sigma Level	2.495

Analyze Phase
This is the third step in applying the six-sigma methodology. At the analysis stage, an analysis of the relationship between cause and effect and failures from a production process is carried out. After that, an analysis is carried out to determine the most potential failure of a case regarding product quality.

Pareto Chart Types of Defects

Figure 3. Pareto Chart of Types of Defects

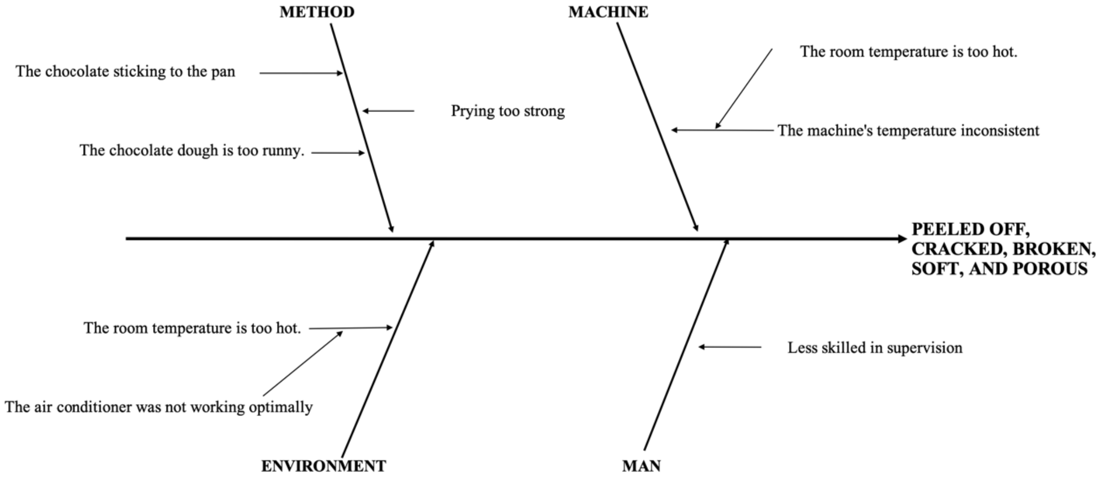


According to the Pareto diagram above, the most dominant types of defects can be seen by their cumulative values. Following the Pareto principle, which states the 80/20 rule, which means that 80 percent of quality problems are caused by 20 percent of the causes of defects. So that the selected types of defects with a cumulative value of up to 80% with the assumption that 80% can represent all types of defects that occur. It can be seen that the types of defects are peeled off (38.5 %), cracked (28.7 %), and broken (25.3 %). The three types of defects will be prioritized in handling this problem. Furthermore, If the three types of defects are handled, then 80% of the problems will be resolved so that the three types of defects are a priority that must be addressed first.

DISCUSSION

Fishbone of Defects
In the analysis process, a cause-and-effect diagram is used (Fishbone Diagram), which is a diagram to identify the factors that influence and cause the product to experience defects in the production of the white couverture chocolate product molding process. The identified factors include workers or employees (people), tools (equipment), the environment (environment), and methods (methods).

Figure 4. Fishbone of Types of Defects



Man

Factors causing defects in white couverture chocolate products are human factors. Factors caused by humans are due to the carelessness of the workforce. This carelessness can be caused by employees talking to each other so that employees do not focus on their work. Carelessness is caused by a lack of supervision and fatigue.

Method

Improper application of the method can result in the chocolate mixture sticking to the pan when the molding process is complete. Thus, requires operator assistance to pry it out with a hook. The harder it sticks the stronger the operator's pry will cause the chocolate to peel when pinched.

Machines

The factor that causes broken, cracked, and peeled-off defects are that the machine is not regularly maintained. This can cause the machines to experience damage, such as the molding machine's temperature is not stable at a particular time. Carrying out maintenance on machines, such as maintenance optimally and regularly, will make the machines work optimally.

Environment

Environmental factors significantly affect the performance of workers and machines because a comfortable environment will make it easier for workers to work. Changes in room temperature during the day can affect the stability of the machines in the room. The machine will have an inconsistent temperature when the room temperature is hot and will change the machine temperature when the production process is carried out.

Improve Phase

The 'Improve' stage was carried out after the 'Analyze' stage was completed. This stage provides suggestions for improvements that aim to improve the quality of white couverture chocolate products. This proposed improvement can also reduce the level of defects in the product and increase the value of the sigma level in the process. This brainstorming was carried out by discussing the proposed improvement options in more detail regarding the existing problems, hoping that the proposed improvements could improve product quality and reduce defects in white couverture chocolate products.

1. Description of the proposed improvements to the failure mode factor machine
2. Description of the proposed improvements to the failure mode factor environment
3. Description of the proposed improvements to the failure mode factor method
4. Description of the proposed improvements to the failure mode factor man

Control Phase

At this stage, it is explained how to control the improvements that have been made at the repair stage so that defects that occur in the molding process of white couverture chocolate products can be minimized. The implementation of maintenance on molding machines and air conditioners is carried out every three months. The form of control that is carried out is to unify the implementation of maintenance by creating a form check sheet containing the maintenance results. The form is filled out by the maintenance officer and then given to the head of maintenance to be checked and signed.

CONCLUSION

Based on observations and investigations at Wahana Interfood Nusantara Company, there are types of defects in the molding process of white couverture chocolate products. The defects were often broken, peeled off, cracked, soft, and porous. Factors that cause defects were human, method, machine, and environmental. This study is limited to the molding area.

From the calculation of the p-value of the control chart, the CL, UCL, and LCL values were 0.024, 0.026, and 0.022 showing that all data results were in control, or no data is out of control. Furthermore, the result calculation of the value of DPU (Defect Per Unit), DPMO (Defects per million opportunities), and the level of Sigma that has been carried out, the results show that the DPU value was 0.024, which means that the probability of the White couverture chocolate product having defects was 2.4% for each unit. The DPMO value was 4788.49. After being converted to a sigma level value, the result was 2.495 Sigma.

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DECLARATION OF CONFLICTING INTERESTS

the authors declared no potential conflicts of interests

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