INTERNATIONAL JOURNAL ON ADVANCED TECHNOLOGY, ENGINEERING, AND INFORMATION SYSTEM
(IJATEIS)
VOLUME 1 ISSUE 2 (2022)

# QUALITY ANALYSIS OF BAKERY PRODUCTS USING THE SIX SIGMA METHOD AND FAILURE MODE AND EFFECT ANALYSIS (FMEA) CASE STUDY ON CV. XYZ

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**Abstract**

*CV. XYZ is a bakery production company which also contributes as a part of culinary industry. During producing, CV. XYZ faces problem regarding the high percentage of its defective products which namely blueberry blankon bread, banana chocolate bread, and coffee bread. This research aims to find out the value of DPMO and determining the value of Sigma for product quality by using Six Sigma method. Six sigma method was used since its able to control the number of defective products, find out the product defects by using Sigma value, improve product defects, and provide recommendations for improving the quality of product by using FMEA method on those three products. The result shows that DPMO value for Coffee Bread is 17,757 along with sigma value of 3,61. The DPMO value for blueberry blankon bread is 18,048 with sigma value of 3.60. Lastly, the DPMO value of chocolate banana bread is 17.644 with sigma value of 3.61. Thus, it is necessary to analyze the causes of quality defects and recommend solutions in order to improve the quality of products. Defects on product/s are caused by four factors which particularly human, material, method and machine. Hence, there are three ideas of proposed improvement on defect products based on FMEA.*

Keywords: *DPMO, FMEA, Product Quality, Six Sigma*

## 1. INTRODUCTION

As a result of the company's rivalry growing more selective, the company now wants to deliver the best performance to customers in order to attract consumers in today's industrial environment, which is increasing on an annual basis. The approach to achieve this level is to have high product quality that is tailored to the requirements of the consumer, since this serves as a trigger for increased levels of customer contentment. Customers frequently have the misconception that a higher price indicates a higher level of quality, so in order for the company to remain competitive, it is essential that they continue to enhance product quality even as prices rise. It is quite important for there to be quality control, and it must be implemented in order for the organization to become aware of deviations from manufacturing procedures that point to errors.

One way to control product quality is to use the six sigma method using the Define, Measure, Analyze, Improve, and Control (DMAIC) concept (Muis, 2016). Six sigma is a statistical concept that can minimize failure variations up to 3.4 Defects Per Million Opportunities (DPMO) because six sigma can be used as a standard for industrial system performance, achieving high sigma values, industrial system performance is developing (Lestari, 2020). Implementation of the six sigma method in the research was conducted by

Rosyidi & Izzah (2021), through their research with the six sigma method approach in controlling the quality of bakpia bread products at PT. Baasithu Boga Services Gresik obtained a sigma value of 3.23 and proposed improvements for charred defects, bulging defects, dented defects, and size defects. In addition, Abdurrahman & Al-Faritsy (2021) aims to improve the quality of Sponge Bread products with the Six Sigma and FMEA methods, by producing a Sigma level value of Bolu Ayu Albarokah Sponge production of 4.36 with strategies as well as proposed improvements for the types of overcooked, shredding, and sticky defects.

CV. XYZ is a company that is involved in the production of bakery products, making it one of the culinary industries. As a business that operates in the culinary industry, CV. XYZ facing challenges in the form of the occurrence of defective products, the biggest percentage of which can be found in different types of bread products, especially blueberry blankon bread products, banana chocolate bread, and coffee bread. Therefore, based on the above problems, a research entitled "Quality Analysis of Bakery Products using the Six Sigma Method and Failure Mode and Effect Analysis (FMEA) Case Study on CV. XYZ" with the hope of helping companies overcome existing problems with proposed recommendations to improve the quality of bakery products and achieve zero defects.

## 2. LITERTURE REVIEW

### 2.1. Quality

Quality, as defined by Render & Heizer (2001), is a product's or service's capacity to satisfy both explicit and implicit demands. Gaspersz (2015) highlight that quality has the ability to constantly enhance performance at the operational or process level across the board, given sufficient time, money, and other resources.

According to Assauri (2012), quality is an attribute that is possessed by an object or result and is responsible for bringing the object or result into conformity with the requirements of the purpose for which it is required. As a result, quality control is a management technique that is used to preserve, improve, and preserve quality by lowering the quantity of defective products in order to give advantages and meet the needs of customers (Mizuno, 2013).

Meanwhile, Yamit (2013), highlight the concept quality as in Montgomery (2014) that "Compatibility quality shows how well a product meets the specifications and tolerances required for the design." Quality management encompasses all facets of operations management, production line planning, equipment, planning, and tracking of results, and is therefore inseparable from the term Quality. In addition to measuring quality on an individual level across groups, corporations, and national performance targets, measuring quality is a necessary part of any quality improvement process (Ariani, 2013).

### 2.2. Quality Control

Amanah & Harahap (2018) sees quality control as "a deliberate process whereby goods or services are monitored and adjusted to ensure they continue to fulfill their intended purpose and satisfy their intended users." Irwan & Haryono (2015) argue that quality control promotes customer satisfaction by ensuring that products and services consistently fulfill

established criteria for quality. Quality control helps save resources because it limits the amount of unnecessary variance that can result in lost time, money, and productivity.

According to Heizer (2015) the main purpose of quality control is to find out how well the process and results of a product or service are produced in accordance with the standards set by the company. While the general objectives of quality control include:

1) The final product has specifications that comply with the established quality standards.
2) Enables efficient product development, inspection and production costs.
3) The principle of quality control is the ability of a process to process a product by continuously achieving and improving the processes carried out for analysis and obtaining information that can be used to control and improve processes.

### 2.3. Six Sigma

Six Sigma is a rigorous process and helps to focus almost certainly on product development and improvement. The term "*Sigma*" comes from the Greek word (σ) which means a statistical term that measures the degree of deviation of a process from the appropriate quality standard. The essence of Six Sigma is that if we can measure the number of defects in a process, then can systematically decide how to eliminate these defects and produce error-free or zero-defect output. According to Tannady (2015), Six Sigma is a vision of quality improvement with a target of 3.4 defects per million opportunities (DPMO) per product (goods or service) transaction. Therefore, it can be said that Six Sigma is the pursuit of excellence (zero defects).

According to Syukron (2012) Six sigma consists of the words Six and Sigma. In this context, six have the same interpretation as number six and sigma is the symbol for standard deviation. Six sigma is a structured process improvement methodology that focuses on reducing process variability while reducing errors (products/services out of specification) using statistics and problem solving tools intensively. Six sigma as a conversion process error probability of 0.00034% or up to 3.4 parts in 1 million products. The main idea in Six Sigma is that we can measure the number of systematic defects in a process, how to describe the defects systematically and get zero defects. There are some features that needs to be equated in the six sigma method before further stage: (Muis, 2016)

1) Critical to Quality (CTQ)
   Critical to Quality (CTQ) is an important characteristic about the customer. A product, process or activity element that has a direct impact on customer satisfaction.
2) Opportunity
   Opportunity is the scale of each event providing hope that the limited CTQ specifications will be met.
3) Defect
   Defect is a problem related to customer dissatisfaction due to inconsistent results.
4) Defect Per Opportunity (DPO)
   It is an error measurement calculated by the Six Sigma Quality Improvement Program showing the number of errors or errors per opportunity and can be calculated using a formula.

$$DPO = \frac{Number\ of\ defect}{Number\ of\ UnitxCTQ}$$

5) Defects Per Million Opportunities (DPMO)
Defects Per Million Opportunities (DPMO) is a measure of failure indicating failures per million opportunities. DPMO has the formula as follows:

$$DPMO = \frac{Number\ of\ defect}{Number\ of\ UnitxCTQ}\ X\ 1.000.000$$

According to Pyzdek & Keller (2014) Six Sigma is a quality concept that accounts for 3.4 defects per million products and is followed by an increase in the number of customers. By using the application of six sigma is expected to satisfy customers, increase company profits or reduce production costs, and transfer the company's surplus to one's business. As for the steps in six sigma, namely DMAIC (Define, Measure, Analyze, Improve, and Control). DMAIC is a continuous improvement process towards the six sigma target value. DMAIC is carried out systematically based on science and facts. Pyzdek & Keller (2014) define stages as follows:

1) Define stage
The six sigma program for quality improvement begins with this define stage. Its aim is to evaluate the target audience and choose the improvement activity's goals. Bass (2007) state that the goal of this stage is to define a process or product problem. This stage involves identifying the study topic that will serve as the center of the issue to be resolved.

2) Stage Measure
At the measure stage define the Critical to Quality (CTQ) attribute. A plan made from the measurement data can then be used as a key that is directly related to customer needs and desires. Then measure the statistically measured quality characteristics. This stage is intended to measure process performance standards in product manufacturing by making control maps as the initial stage of the measure after determining the CTQ.

P Control chart is one of the control charts used in attribute quality control to detect defects or failures in the final product. Control charts can facilitate the monitoring or control of the production process, thereby providing information about when and when it is best to improve quality. The goal of this p-control chart is to carry out quality control, it is a quality certificate and must be destroyed by melting or recycling because the data used as samples for observation is not good and damaged products cannot be repaired.

To make a control map, it is necessary to calculate the percentage of damage (p), center line or central line (CL), upper control limit or Upper Control Limit (UCL), lower control limit or Lower Control Limit (LCL) with the following formula (Montgomery, 2014):

$$P = \frac{np}{n}$$

$$CL = \bar{P} = \frac{\sum np}{\sum n}$$

$$UCL = \bar{P} + 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

$$LCL = \bar{P} - 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

3) Analyze Stage

According to Lestari (2020), this analyze step is to determine the cause of the problem. This step allows control with fishbone diagrams to analyze the causes of failure. Cause-effect or fishbone diagram is the relationship between the disturbance and its cause, namely the fish head is the effect and the bones are the cause, and there are sub bones which are more detailed causes. Fishbone diagram aims to identify and analyze the factors that significantly affect the output. There are 5 main factors to consider, including people, methods, machines, raw materials, and the environment (Sukirno et al., 2022).

4) Improve Stage

At this stage, improvements are made to the system by determining the most appropriate solution to be applied to the activity to be changed. This step implements an action plan to implement six sigma quality improvement. According to Rachman (2012) Failure Modes Effect Analysis (FMEA) analyzes system reliability from information that predicts the reliability of the system, the underlying design and processes, and the causes of non-compliance with system reliability and safety requirements, design and design processes. Tools used for "Failure Modes" means methods or modes in which a process is likely to fail. Errors are identified errors or deficiencies that specifically affect the customer. According to setiani (2016) FMEA is a process, guideline, and templates for identifying and prioritizing potential problems. This method has many applications in a six sigma environment. Here are the steps to create an FMEA:

a) Define product process
b) List of possible problems
c) Assess the problem in terms of impact, likelihood and detection
d) Calculation of Risk Priority Number (RPN) and Priority Action
e) Take action to reduce risk

FMEA analysis uses three variables to identify problems, including severity (S), occurrence (O), and detection (D). Then calculated the value of the Risk Priority Number (RPN) and proposed improvements based on the highest priority to the lowest RPN. The RPN formula is shown below.

$$\text{RPN} = \text{S X O X D}$$

5) Control Stage

The Control Stage is the final operational phase of Six Sigma quality improvement. Quality improvement results are also provided at this stage, providing best practices and using standard operating instructions and owner accountability or owner accountability procedures (Lynch et al., 2003).

## 3. RESEARCH METHOD

This research focuses on the number of defects that can be found in the qualities of Blankon Bluberry Bread, Banana Chocolate Bread, and Coffee Bread between the beginning of December 2021 and the end of December 2021. This is due to the fact that the rate at which defects can be eliminated in these three products being the highest. The research was carried out in a total of five stages: define, measure, analyze, improve, and control stages. This was done in order to bring the percentage of defect products found within those three

products. The method uses six sigma method which includes the DMAIC (Define, Measure, Analysis, Improve and Control) stages. The figure below shows the flowchart/troubleshooting processes.

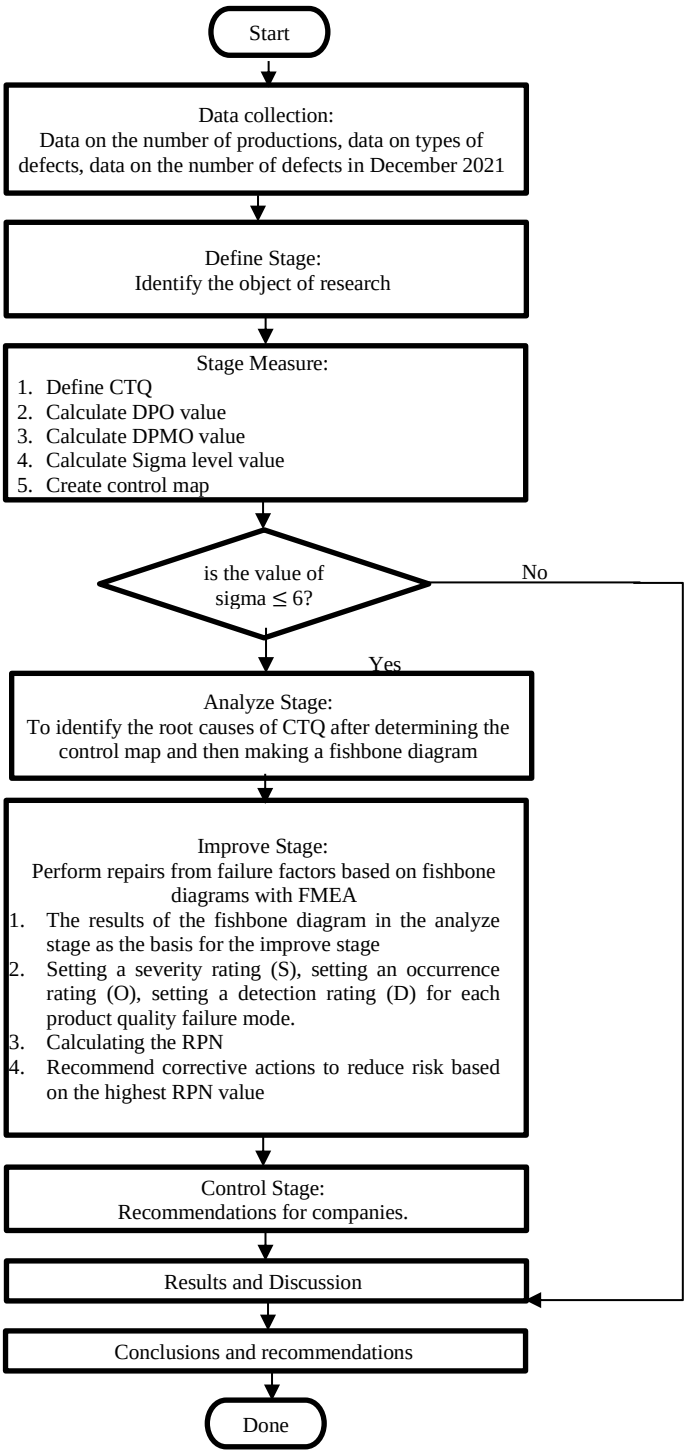



**Figure 1** Troubleshooting Steps

## 4. RESULT AND DISCUSSION

### 4.1. Define stage

At this stage, it is necessary to identify against the object under study. The problem that is often faced by CV. XYZ is the high number of defects that occur in the bread production process experiencing issue in the production of 3 bakery products in the production process of blankon bluberry bread, banana chocolate bread, and coffee bread in December 2021 since the percentages of defects within these three products is the highest.

### 4.2. Measure Stage

Measure is the second stage of Six Sigma by measuring the object of research, namely blueberry blankon bread, banana chocolate bread, and coffee bread. The measure stage begins with determining the CTQ and measuring the defect data of the three products by attribute, calculating the DPMO value, calculating the sigma level obtained from the table for converting the DPMO value into the sigma level.

#### 4.2.1. Determining Critical to Quality (CTQ)

Based on the problem, bread products consist of 3 CTQs, including burnt or overcook which is a product defect where the bread product absorbs too much heat, so that the bread product turns black in color, imperfect shape which is a product defect where the bread product dough which is not perfect, so that the shape of the bread product is far from the normal shape and the cutting is not perfect which is a product defect where the slice of the bread product is not perfect due to the laying of the bread, so that many pieces of bread are unwanted.

#### 4.2.2. Calculating DPMO Value and Sigma Level

Based on the production data and the number of defective products for blueberry blankon bread, banana chocolate bread, and coffee bread, the DPO, DMPO and sigma levels values are calculated according to equations (1) and (2) so that a summary of the calculation results is obtained as shown in table 1.

**Table 1** Summary of DPO Value, DPMO, and Sigma Level Calculation

| Product Name | Production Quantity | Number of Defective Products | DPO | DPMO | *Sigma level* |
|---|---|---|---|---|---|
| Coffee Bread | 16,275 | 867 | 0.017757 | 17757 | 3.60 |
| Blueberry Blankon Bread | 12,710 | 676 | 0.018049 | 18049 | 3.60 |
| Banana Chocolate Bread | 12.865 | 676 | 0.017644 | 17644 | 3.61 |
| Average | | | | | 3.6067 |

Based on the calculation data of DPO, DPMO and sigma levels above, it shows that the sigma level of coffee bread products, blueberry blankon bread and banana chocolate bread is still less than 6 sigma, therefore improvements need to be made by analyzing the factors causing defects in the analyze stage.

#### 4.2.3. Creating a Proportion Control Map

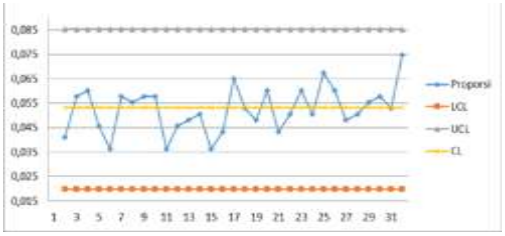
Based on the calculation data for the value of DPO, DPMO and the level of defective sigma of blueberry blankon bread, banana chocolate bread, and coffee bread, the proportion

values, CL (Control Limit), UCL (Under Control Limit), and LCL (Lower Control Limit) are calculated according to the equation (3-6) so that a summary of the calculation results is obtained as in table 2.

**Table 2** Summary of P Control Map Calculation Results

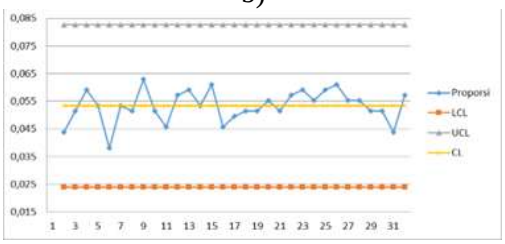
| Product name | Number of Observations (n) | Defect | Proportion (Between Low-High) | CL | UCL | LCL |
|---|---|---|---|---|---|---|
| Coffee Bread | 16,275 | 867 | 0.03810-0.06286 | 0.05327 | 0.08263 | 0.02392 |
| Blueberry Blankon Bread | 12,710 | 676 | 0.02439-0.07561 | 0.05319 | 0.08628 | 0.02009 |
| Banana Chocolate Bread | 12.865 | 676 | 0.03614-0.07470 | 0.05255 | 0.08527 | 0.01983 |

After calculating the proportion values, CL (Control Limit), UCL (Under Control Limit), and LCL (Lower Control Limit), the next step is to create a P control map graph.




a)


b)




c)

**Figure 2** P-Control Map and Moving Range (I-MR) of a) banana chocholate bread; b) blankon blueberry bread; and c) coffee bread

Based on Figure 2, from the proportion control map that serves to explain changes in parameter data from time to time for coffee bread products, blueberry blankon bread and

banana chocolate bread during December 2021, this shows that all data generated are still within control limits (no which is out of control) but the percentage of defects is still above the company's tolerance limit.

### 4.3. Analyze Stage

On the basis of the outcomes of the discussion between the production process operator and the production description, as well as the results of the DPMO calculation presented above, that the sigma value is still lower than 6 sigma, which means that an additional step of analysis is required. The analysis stage is the third step of the Six sigma methodology, where the identification of the root causes of CTQ through fishbone diagrams is carried out simultaneously with the analysis of the results of the sigma level measurements carried out in the previous step.

#### 4.3.1. Fishbone diagrams for burn or overcook defects

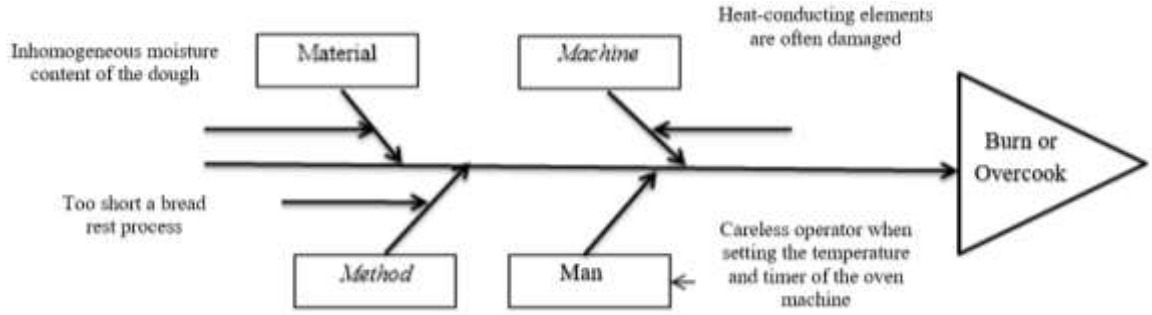



**Figure 3** Fishbone diagram of a burn or overcook defect

#### 4.3.2. Fishbone diagrams for Incorrect Shape defects

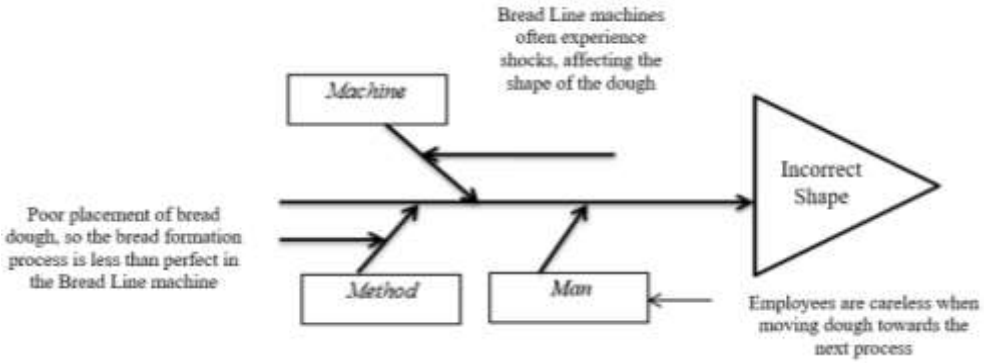



**Figure 4** Fishbone diagram for Incorrect Shape Defect

### 4.3.3. Fishbone diagrams for Imperfect Cutting defects

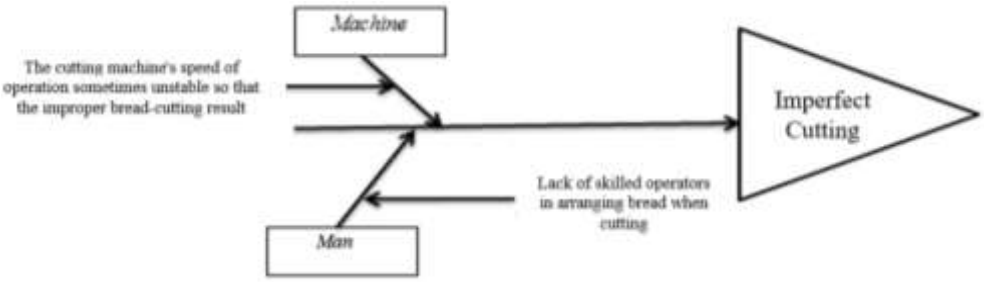



**Figure 5** Fishbone diagram for Imperfect Cutting Defect

### 4.4. Improve Stage

In the improve stage, various ideas are proposed to addres various defects or errors that occur.

### 4.4.1. FMEA

Calculating the risk priority number (RPN) and priority actions and taking actions to reduce risk, as follows:

1) FMEA Burn or Overcook

**Table 3** Burn or Overbook according to FME

| Modes of Failure | Effect of Failure | S | Causes of Failure | O | Current Controls | D | RPN |
|---|---|---|---|---|---|---|---|
| Burn or Overcook | The result of bread products that are black and bitter | 8 | **Method**<br>The bread rest process is too short | 4 | Can increase the rest process time in the company's SOP and check the dough twice | 3 | 96 |
| | | | **Man**<br>Careless operator when setting oven temperature and timer | 5 | Conduct a briefing before starting the oven and supervision process | 2 | 80 |
| | | | **Machine**<br>The heat-conducting element is often damaged | 3 | Perform maintenance and inspection of the oven machine on a regular basis | 3 | 72 |
| | | | **Material**<br>Inhomogeneous dough moisture content | 3 | The water content in the bread dough is strictly controlled according to the company's SOP | 2 | 80 |

The recommendations for improvement are listed in Table 3, which is sorted by priority number from the largest to the smallest RPN value. As for an imperfect bread rest process,

the RPN result is 96 with recommendations for improvement that can increase the rest process time in the company's SOP and recheck the dough. In the case of careless operators when setting the temperature and the oven machine timer, the RPN result is 80 with recommendations for improvement, conducting a briefing before starting the oven and monitoring process. For the condition of the heat-conducting elements that often experience damage, the RPN results are 72 with recommendations for improvement, such as carry out maintenance and periodic inspection of the oven machine. For the condition of the imperfect dough material, the RPN result is 48 with recommendations for improving the water content in strictly controlled according to the company's SOP with overall improvement recommendations.

2) Incorrect Shape FMEA

**Table 4** Incorrect Shape according to FMEA

| Modes of Failure | Effect of Failure | S | Causes of Failure | O | Current Controls | D | RPN |
|---|---|---|---|---|---|---|---|
| Imperfect Shape | The desired shape of the bread product does not match the targeted shape | 6 | **Method** Placement of bread dough is not good so that the process of forming bread is not perfect in the Bread Line machine | 5 | Ensure and recheck that the setting of the bread dough on the bread line machine is in accordance with the table process procedures | 4 | 120 |
| | | | **Machine** Bread line machines often experience shocks that affect the shape of the dough | 4 | Checking the reset settings before turning on the bread line machine in the bread dough table process | 3 | 72 |
| | | | **Man** Careless employees when transferring dough to the next process | 4 | Provide direction and supervise employees when making transfers | 2 | 48 |

The recommendations for improvement are listed in Table 4, sorted by priority number from the largest to the smallest RPN value. As a result of the poor placement of bread dough, the process of forming bread in the bread line machine is imperfect, and the RPN result is 120 with recommendations for improvement, including ensuring and rechecking that the setting for placing bread dough on the bread line machine conforms to the table process procedures. For the state of the bread line machine, it often experiences shocks so that it affects the shape of the dough to obtain an RPN of 72 with recommendations for improvement to check the settings again before turning on the bread line machine in the bread dough table process.

3) Imperfect Cut FMEA

**Table 5** Imperfect Cut According to FMEA

| Modes of Failure | Effect of Failure | S | Causes of Failure | O | Current Controls | D | RPN |
|---|---|---|---|---|---|---|---|
| Imperfect Cutting | the results of the desired slice of bread product do not match what the targeted cut is | 6 | **Man**<br>Less skilled operator in arranging bread when cutting | 4 | Give directions as well supervising the operator when cutting the bread | 3 | 72 |
| | | | ***Machine***<br>Cutting machine blade speed is sometimes unstable so that the bread is not cut properly | 3 | Checking and rechecking before turning on the cutting machine in the bread cutting process | 3 | 54 |

The recommendations for improvement are listed in Table 5, sorted by priority number from the largest to the smallest RPN value. For conditions that are less skilled in arranging bread during cutting, the RPN results are 72 with recommendations for improvement, giving direction and supervising operators when cutting bread. For the state of the Cutting machine blade speed, sometimes it is unstable so that the cutting of bread is not appropriate to obtain an RPN of 54 with recommendations for improvement to check and recheck before turning on the cutting machine in the bread cutting process.

### 4.4.2. Analysis of Research Results

Based on the results of data processing products for coffee bread, blueberry blankon bread and banana chocolate bread in December 2021 in table 1, then it is known that the blueberry blankon bread product has a sigma value of 3.60 so that the average sigma level is equal to 3.6067, which means that it still does not meet the target, namely towards worldclass company standards or 6σ. Therefore, to achieve 6σ, improvements are made by analyzing the factors that cause defects.

Therefore, the causes of defects are detailed in Table 3. Burnt or overcooked defects are caused by a too short bread resting period, negligent oven temperature and timing settings, often damaged heat-conducting parts, and excessive amounts of inhomogeneous dough water. The proposed improvements include increasing the rest time in the company's standard operating procedure and double-checking the dough, conducting briefings before starting the oven process and supervising the operator, performing maintenance and periodic inspections of the oven machine, and strictly controlling the moisture content in accordance with the standard operating procedure.

In table 4, incorrect placing of bread dough, bread line machines that frequently encounter shocks, and irresponsible staff while transferring dough to the next step are listed as causes of imperfect form defects. The proposed improvement is to recheck that the bread dough setting on the bread line machine is in accordance with the bread dough table process procedures, to check the resettings prior to turning on the bread line machine in the bread

dough table process, and to direct and supervise employees when transferring.

Based on Table 5, poor cutting factors, such as the speed of the blade on the cutting machine, are occasionally unstable and result in less skillful bread cutting. For the proposed improvement, which includes double-checking before turning on the bread-cutting equipment and directing and overseeing the operator during bread-cutting.

Managers in the food business need to think about how to stay profitable in the face of a contracting market, all while satisfying increasingly discerning consumers with first-rate goods and swift assistance (Hsiang-Chin & Ming-Hsien, 2011). Organizations have a choice between two strategic approaches as they work toward this seemingly unachievable goal. First, they can concentrate on boosting the system's effectiveness in its day-to-day functioning. Second, there are steps companies may do to improve the system's reliability.

### 4.5. Control Stage

The quality improvement methodology known as Six Sigma comes to its conclusion with the control stage as the final operational step. In this particular investigation, the control phase was not performed since the improvement phase was limited to the submission of suggestions solely and did not carry out any implementation.

## 5. CONCLUSION

Based on research that has been carried out at CV XYZ, it can be concluded that the results of data processing products for coffee bread, blueberry blankon bread and banana chocolate bread in December that the DPMO value for coffee bread was 17,757 with a sigma value of 3.61, the DPMO value for blueberry blankon bread was obtained. Meanwhile, blueberry blankon bread is 18,048 with a sigma value of 3.60, and the DPMO value for chocolate banana bread is 17,644 with a sigma value of 3.61. Overcooked products use the proposed improvement by adding rest time according to the SOP of bread production, defects with inappropriate shapes can be addressed by ensuring and re-checking that the placement settings of the bread dough on the bread line machine are in accordance with the procedures of the table process, and defects with inappropriate shapes product also can be addressed by briefing and supervising the operator when cutting bread.

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