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Analysis of Production Quality Control at the Smoked Tilapia MSMEs Using the Six Sigma Method with the DMAIC Approach

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ABSTRACT
Objective: *This research aims to determine the sigma value and factors that cause defects in the production process of Mujair Asap MSMEs and determine risk mitigation for product quality control at Mujair Asap MSMEs.* ***Method:*** *In this research, the method used is the Six Sigma method with the Define, Measure, Analyze, Improve and Control stages.* ***Results:*** *As a result of this research, it is known that the highest risk in the Mujair Asap MSME production process is defects in the form of shapes that do not comply with standards. Priorities for improvement are additional training for workers, creation of SOPs, suitability of the raw materials used and appropriate methods and equipment to support MSME productivity and minimize defects in the products produced.* ***Novelty:*** *An important factor in building a business is quality. Quality control is important to maintain consumer loyalty. In a production process, it is often found that the resulting product still does not comply with predetermined standards. In the Mujair Asap Business, the products produced often do not meet the appropriate standards, defective or damaged products result in significant losses if not immediately repaired.*

INTRODUCTION

Sidoarjo City is known as a fish-producing city, especially in areas near the east coast of Tanggulangin District. The fish commonly produced is milkfish. In addition to milkfish, farmers in the tambak area of Sidoarjo City also produce tilapia [1]. In some villages that produce tilapia, they supply it to areas that process tilapia for smoking. One of them is in Pelataran Hamlet, Penatarsewu Village, Tanggulangin District, Sidoarjo Regency, where most of the residents are involved in smoking businesses [2]. Each smoking business operator can use between 75 kg and 100 kg of tilapia daily, which is then divided into raw products and smoked products. The smoking process currently used by business owners still relies on manual methods, from cleaning the fish to the smoking process using charcoal, coconut shells, and coconut fiber [1]. This manual process is considered to potentially cause damage to the product, which could be detrimental to business owners and lead to a decline in the quality of the product being sold [3]. In a single production run, 8.2% of the total product produced is defective and cannot be distributed to merchants. This is because the existing quality is below the determined standard.

At this time, consumers are becoming more selective when making a purchase. Consumers will choose products that offer a fair balance between price and quality. To maintain product quality that can affect consumer satisfaction, good quality control is necessary to implement [4]. Quality is a crucial aspect of a product; therefore, good quality management is needed to ensure maximum product output [5]. Quality management not only focuses on the quality of the product produced, but is also used to find ways to achieve the best quality so that consumer satisfaction can be achieved [6].

This study uses the Six Sigma method and the DMAIC (Define, Measure, Analyze, Improve, and Control) approach. The Six Sigma method is used to determine the sigma value of each problem, followed by a search for the root causes of the problems and improvement solutions [7]. Based on the above description, this study controls the quality of smoked tilapia using the DMAIC concept approach, obtaining the sigma value of failures and the causes of those failures. This research is expected to serve as a reference for controlling the production of smoked tilapia, allowing us to identify product defect risks and propose suggestions for more effective and efficient system improvements.

The objectives of this research are: (1) To identify the causes of the highest defect rates in the production process of Mujair Asap MSMEs. (2) To determine risk mitigation strategies for product quality control in Mujair Asap MSMEs.

RESEARCH METHOD

A. Time and Place of Research

This research was conducted in Pelataran Hamlet, Penatarsewu Village, Tanggulangin District, Sidoarjo. This research began in November 2023 and will continue until January 2024.

This research began by conducting a literature study using several journal sources, books, and a number of articles related to the problems faced. In addition to conducting a literature study, a direct survey of the target MSMEs was also carried out, followed by interviews with MSME owners regarding the production process and the distribution of questionnaires to MSME owners and experts. Data collection utilized the results of interviews and questionnaires obtained from the respondents. Data processing then used the Six Sigma method with the DMAIC (Define, Measure, Analyze, Improve, and Control) approach, aiming to identify potential failure modes and necessary improvements for the future.

The levels in Six Sigma are used as indicators of the quality of production. The lower the sigma quality, the greater the potential for failure, while the higher the sigma quality, the lower the likelihood of product failure [8]. The analysis technique used in the Six Sigma method is the DMAIC stage concept [9]. DMAIC is the process of eliminating unproductive steps or stages (closed-loop) to achieve effective results [10]. DMAIC is used to address problem-solving related to failure priorities [11]. DMAIC is also a phase that must be passed through during any improvement [12].

The stages in the DMAIC concept are as follows: [13]

1. Define Stage

   This is the stage of defining the problems occurring with product quality, starting with defining the causes of defects and the most potential causes of defects [13]. Quality characteristics or Critical to Quality (CTQ) are key elements directly related to specific customer needs [11]. At this stage, the problem statement and its objectives are using a SIPOC diagram, or Supplier Input Process Output Customer [12].

2. Measure Stage

This stage focuses on the processes that influence CTQ by analyzing the obstacles and constraints that will occur [13]. In this second stage, sigma performance is measured to determine the current working level. There are several steps within this stage:

a. Percentage of Defects

$$P = \frac{\text{Number of Defective Products}}{\text{Production Quantity}} \quad \text{...(1)}$$

Source: [14]

b. Calculation of Center Line (CL)

$$CL = \bar{P} = \frac{\sum np}{\sum n} \quad \text{...(2)}$$

Source: [14]

Explanation:
$\bar{P}$ = Average product defect
$\sum np$ = Total number of defective products produced
$\sum$ n = Total Production Quantity

c. Calculation of Upper Control Limit (UCL)

$$UCL = \bar{P} + 3\sqrt{\frac{p\,(1-p)}{n}} \quad \text{...(3)}$$

Source: [14]

Explanation:
$\bar{P}$ = Average product defect
n = Production quantity

d. Calculation of Lower Control Limit (LCL)

$$LCL = \bar{P} - 3\sqrt{\frac{p\,(1-p)}{n}} \quad \text{...(4)}$$

Source: [14]

Explanation:
$\bar{P}$ = Average product defect
n = Production quantity

e. Calculating Defect Per Unit (DPU) Value

$$DPU = \frac{D}{U} \quad \text{...(5)}$$

Source: [14]

f. Calculating the Defect Per Opportunities (DPO) Value

$$DPO = \frac{\text{Number of Defects}}{Output \times CTQ} \quad \text{...(6)}$$

Source: [14]

g. Calculating Defects per Million Opportunities (DPMO)

$DPMO = DPO \times 1.000.000$ ....(7)

Source: [14]

h. Converting DPOM Values to Sigma Values Using Microsoft Excel

$$\text{Sigma Value} = NORMSINV\ ((1.000.000 - DPMO)/1.000.000) + 1.5 \ldots\ldots..(8)$$

Source: [14]

i. Estimating Production Process Parameters using Control Charts [14].

3. Analyze Stage

   This stage is used to analyze, search for, and identify the causes of defective products that can lead to problems by analyzing the obstacles that occur [15]. CTQ can be defined as an element of a process that directly influences the achievement of the desired quality. Then, an analysis was conducted using brainstorming or a fishbone diagram [14]. This diagram is useful for analyzing and identifying the factors that significantly influence the characteristics of work output quality. Besides also seeks the true causes of a problem [16].

4. Improve Stage

   This is the stage where suggestions for improvement and solutions to existing problems are provided. Then, action proposals are made as an effort for improvement [10]. This stage is a strategy used to increase the sigma value. This improvement will describe the factors causing defects and the plans set in place to improve the product, which can be done at any time [16].

5. Control Stage

   This is the final stage of Six Sigma implementation, which involves checking and is carried out as a form of improvement that has been made to the production process flow [13]. This stage is for controlling the improved process [17]. This stage focuses on monitoring to maintain the improvement efforts made [18].

Figure 1 is a research flowchart diagram showing the overall research process using a flowchart diagram:

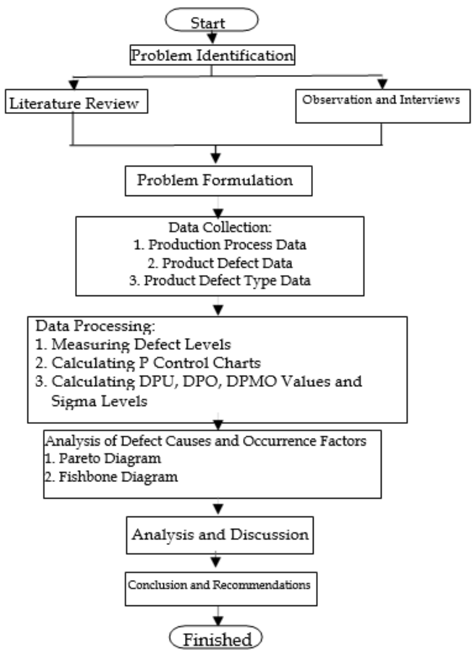

Figure 1. Flowchart Diagram.

Research Steps: This research begins by conducting a literature review of various sources, such as journals, books, and articles. Then, a field study was also conducted, consisting of observations of MSMEs and interviews with the owners of Mujair Asap MSMEs, covering the production process from start to finish, in order to identify production processes that are prone to product failure. The results of the field study were used in determining the problem formulation. Then, data collection was carried out through interviews and weekly production and sales data collection. Interviews were conducted with the resource person, who is the owner of the Smoked Mujair MSME. Next, data processing was done using the DMAIC method, which is used to determine the defect rate, DPMO value, and Sigma value for each production process. Finally, analysis and conclusions were drawn, along with recommendations.

RESULTS AND DISCUSSION

Data processing in this study uses the Six Sigma stages with the following steps:

1. Define

In every production, there are still rejected products, which is a loss. This will be identified by looking at the number of rejected products for each rejection criterion and presenting the characteristics of the defect types. The production process of this Smoked Tilapia MSME is defined using the SIPOC diagram (Supplier, Input, Process, Output, Customers).

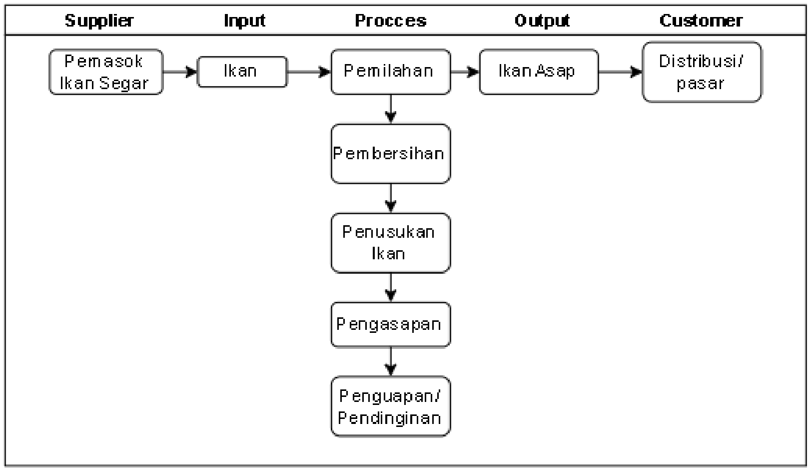

Figure 2. shows the SIPOC diagram flow for the Smoked Tilapia MSME.

Figure 2. Production Process Flow of Small and Medium Enterprises (SMEs) for Smoked Tilapia. Figure 2 illustrates the production process flow for the Smoked Tilapia SME. The Smoked Tilapia SME aims for a high-quality final product with a low defect rate. The presence of defects in the product is caused by many factors that occur during the production process. Table 1 shows the types and causes of defects in smoked fish products.

1. Determining the value of CTQ (Critical to Quality)

Table 1. CTQ (Critical to Quality).

No	CTQ	Description	Impact
1	Election	The process of sorting fish from suppliers, the fish are not fresh.	The final product of smoked fish becomes bland and has a pungent smell.
2	Fish Stabbing	Stabbing with a wood, stabbing fish in the wrong position.	The fish was damaged and fell during the smoking process.
3	Smoking	1. Smoking process using fire 1. 2. Does not use dry coconut shells	1. Uneven color and a bitter taste due to burning. 2. The embers were difficult to light and didn't burn well, resulting in the fish not being cooked thru.

Research was conducted on Smoked Mujair MSMEs, based on interviews with the owners of Smoked Mujair MSMEs and interviews with workers to identify the obstacles causing product failure at each stage of production.

2. Table of production process defect data for Mujair Asap MSMEs for the period November 2023 – January 2024 .

Table 2. Production and Reject Data for Smoked Mujair Fish.

No.	Month	Unit	Good	Bland Fish Meat	Defective Defective Product / Not Meeting Standards	Uneven Color and Bitter Taste	Total
1.	November '23						
	Week I		566	23	21	16	60
	Week II	Kg	532	9	14	26	49
	Week III		540	14	28	20	62
	Week IV		491	18	21	20	59
			2129				230
2.	December '23						
	Week I		565	13	29	15	57
	Week II		580	25	31	13	69
	Week III	Kg	535	34	8	9	51
	Week IV		590	19	31	6	56
			2270				244
3.	January '24						
	Week I		532	11	32	13	56
	Week II		579	29	36	9	74
	Week III	Kg	590	31	19	15	65
	Week IV		555	23	21	13	57
			2256				252
			Total	249	291	175	
	Total		6655		Total		726

Table 2 above explains the product defect data, from which it can be seen that product defects in the form of defective products are the largest defect, totaling 291 kg. The next largest defect category is products with stale/bland fish meat, totaling 249 kg, followed by products with uneven/too dark color, totaling 175 kg. The total product defects for Smoked Tilapia during the observation period of November 2023 – January 2024 are 726 kg.

2. Measure

After defining the problem to be analyzed, this stage will focus on measuring the process capability level using a P Chart or control chart to determine quality control at Mujair Smoked Fish MSMEs. Then, the proportion of defects and DPMO (Defects Per Million Opportunities) will be calculated, along with the Sigma value, to determine the current performance of the MSMEs.

Table 3. Calculation of P Control Chart.

Period	Production Quantity	Number of Defects	Proportion	P	UCL	CL	LCL
1	626	60	0,0958	0,0958	0,1325	0,0970	0,0615
2	581	49	0,0843	0,0843	0,1339	0,0970	0,0602
3	602	62	0,1030	0,1030	0,1332	0,0970	0,0608
4	550	59	0,1073	0,1073	0,1349	0,0970	0,0592
5	622	57	0,0916	0,0916	0,1326	0,0970	0,0614
6	649	69	0,1063	0,1063	0,1319	0,0970	0,0622
7	586	51	0,0870	0,0870	0,1337	0,0970	0,0603
8	646	56	0,0867	0,0867	0,1320	0,0970	0,0621
9	588	56	0,0952	0,0952	0,1336	0,0970	0,0604
10	653	74	0,1133	0,1133	0,1318	0,0970	0,0623
11	655	65	0,0992	0,0992	0,1317	0,0970	0,0623
12	612	57	0,0931	0,0931	0,1329	0,0970	0,0611
TOTAL	7370	715	1,163057177		70400	0,03164881	
Average	614,1666667	59,58333333	0,096921431				

As can be seen in Table 3, this is the calculation of the percentage of defects, the upper control limit or UCL, the center line or CL, and the calculation of the lower control limit or LCL. The lower limit (UCL) value is 0.132, the center line (CL) value is 0.0970, and the upper limit (LCL) value is 0.062.

Calculation of UCL, CL, and LCL

Therefore, Figure 3 shows the P control chart for the calculation of the upper, center, and lower limits for the period from November 2023 to January 2024, as seen in Figure 3.

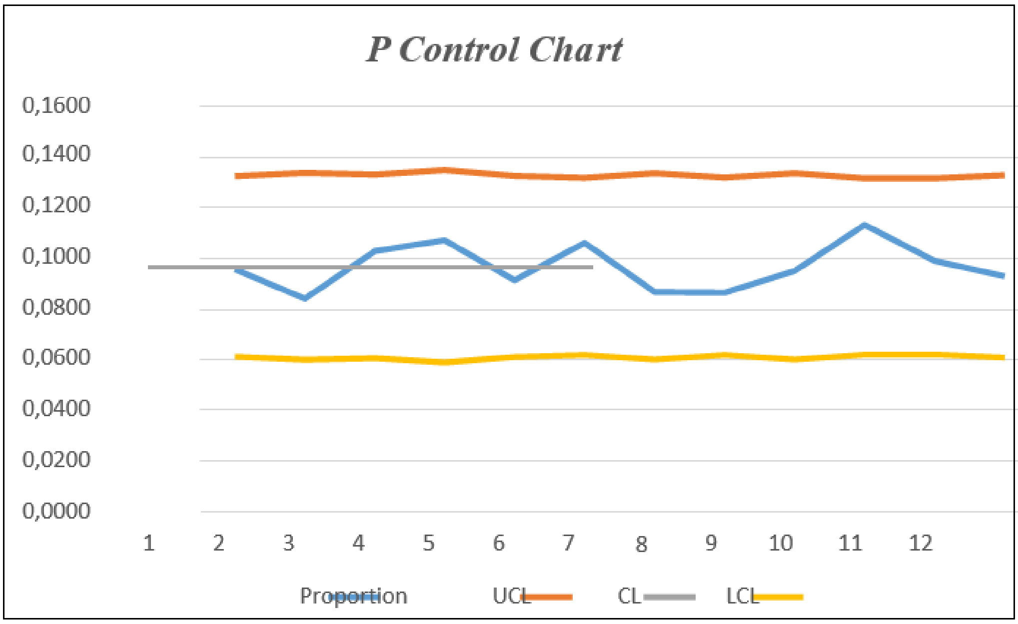

Figure 3. P Control Chart for the Period November 2023 – January 2024.

Figure 3 illustrates that the P-control chart for November is at 0.097612, for December it is at 0.092919, and for January it is at 0.100234. Thru continuous improvement efforts, it can be seen that there is no significant change in the P-control chart, as the P-value remains between the UCL value of 0.132 and the LCL value of 0.062, and does not exceed the UCL and LCL lines. Therefore, the process capability for the period November 2023 - January 2024 is running well because the overall proportion of defects is within the control limits. Next, calculations were performed for one million possible defects, as shown in Table 4.

Table 4. Calculation of DPO, DPMO, and Sigma Value.

Month	Week	Production Quantity	Number of Defects	CTQ	DPU	DPO	DPMO	Sigma Level
November	I	616	50	3	0,1060	0,035335689	35335,69	3,31
	II	581	49	3	0,0921	0,030701754	30701,75	3,37
	III	582	42	3	0,1148	0,038271605	38271,60	3,27
	IV	557	66	3	0,1202	0,040054311	40054,31	3,25
December	I	599	34	3	0,1009	0,033628319	33628,32	3,33
	II	629	49	3	0,1190	0,039655172	39655,17	3,25
	III	584	49	3	0,1159	0,038629283	38629,28	3,27
	IV	646	56	3	0,0949	0,031638418	31638,42	3,36
January	I	578	46	3	0,1053	0,035087719	35087,72	3,31
	II	633	54	3	0,1278	0,042602188	42602,19	3,22
	III	644	54	3	0,1102	0,036723164	36723,16	3,29
	IV	612	57	3	0,1027	0,034234234	34234,23	3,32
TOTAL		7261	606	3				

In Table 4, it can be seen that the average sigma value for MSMEs is approximately 3.30. In terms of sigma assessment, it can be interpreted that the quality control process that has been carried out is running well. Quality control is still needed to increase the sigma value obtained in order to minimize the possibility of defects recurring.

Table 5. Data on the Percentage of Defects in Smoked Tilapia Products.

Defect Type	Defect Percentage Total	Percentage	Cumulative
Bland Meat	249	35%	35%
Incorrect Shape	291	41%	76%
Uneven Color and Bitter Taste	175	24%	100%
Total	715		

Table 5 shows that, based on the calculations above, the types of product defects in smoked tilapia production are: defects in the form of shape not meeting standards with a percentage of 41%, defects in the form of bland meat with a percentage of 35%, and defects in the form of uneven/too dark color with a percentage of 24%. Based on the data above, it can be concluded that the highest defect is in the form of shape not meeting standards. And that data can be represented in a Pareto diagram like Figure 4:

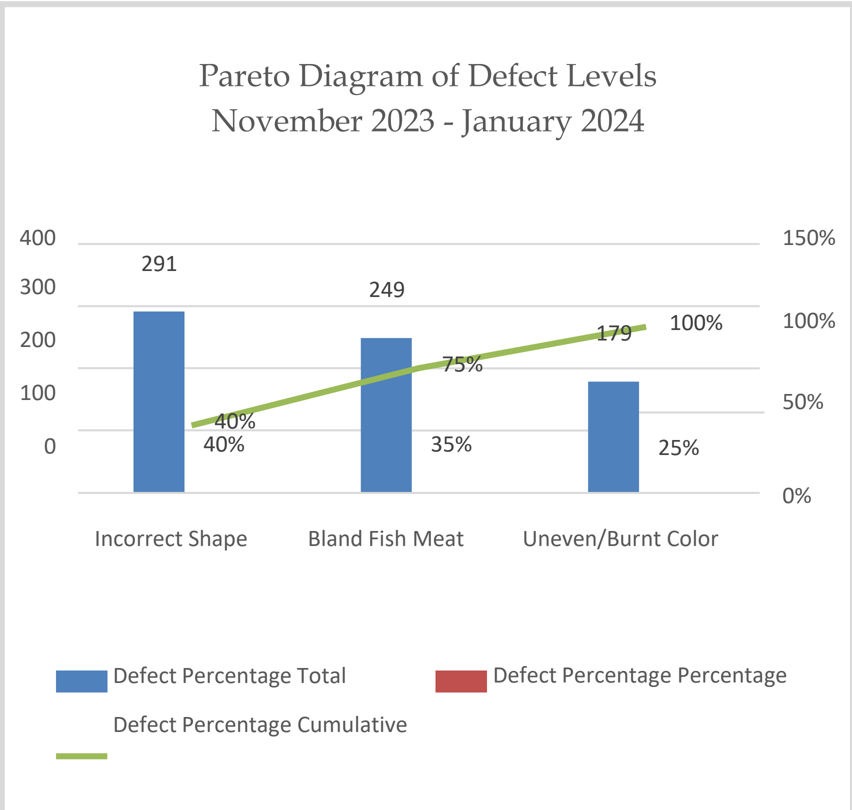

Figure 4. Pareto Diagram.

Figure 4 illustrates the Pareto diagram of existing defects, showing that the first bar represents the second-largest scale with a defect type of bland meat at 249 Kg. The second bar, with the largest defect type of non-standard shape at 291 Kg, and the third bar, with the lowest scale and defect type of uneven color at 175 Kg.

3. Analyze

An analysis is used to identify the factors causing defects in smoked tilapia production. In the Analyze stage, the highest or most dominant causes of defects will be identified and analyzed using a cause-and-effect diagram or fishbone diagram. The fishbone diagram can be seen in Figure 5.

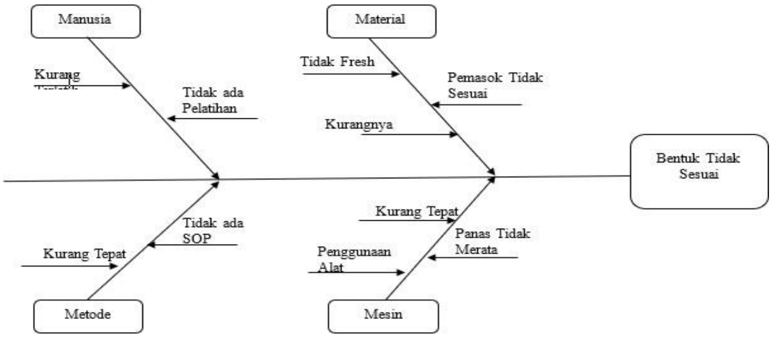

Figure 5. Fishbone Diagram.

From Figure 5, it can be seen that the most dominant cause of defects is the shape not meeting standards, which is caused by several factors, starting from human factors (untrained workers), materials (not fresh due to suppliers not sorting well), methods (inaccurate because there are no SOPs), and machines (improper use of tools resulting in uneven heating). Next, the process will move on to the Improve stage, with the hope of making improvements to increase productivity at the Smoked Tilapia MSME.

4. Improve

Improvement is a plan to improve the production of Smoked Tilapia based on the root causes of the problems identified from the analysis results. In this stage, a proposal for improvement or recommendations is developed to reduce the defects that occur. Improvements to reduce defects:

1. Human Factors
   a. Provide training to existing workers [19].
   b. Increase accuracy and vigilance during the production process [8].
2. Material Factors
   a. Select suppliers with quality according to SOP [1].
   b. Improve quality control of raw materials before production [8].
3. Method Factors
   a. Create SOPs to be used during the production process [8].
4. Machine Factors
   a. Improve equipment maintenance during the production process [1].

5. Control

This control stage focuses on continuous improvement. This improvement will be continuously implemented by various parties by creating or determining standard operating procedures that will be used for production process monitoring to prevent failures, thereby minimizing failures and increasing work productivity.

In this study, it can be seen that the highest risk in the production process of Mujair Smoked SMEs is defects in the form not meeting standards. The priorities for improvement are adding training for workers, creating standard operating procedures (SOPs) for working, sorting the raw materials used to ensure they meet the specified quality, and improving the smoking method for smoked tilapia and the equipment used to support the productivity of the micro, small, and medium enterprises (MSMEs) and minimize product defects.

CONCLUSION

Fundamental Finding : Based on the research conducted, it can be seen that the average sigma value for MSMEs is approximately 3.30. In terms of sigma assessment, this means that the quality control process that has been implemented is running well. Quality control is still needed to improve the sigma value. The highest factor causing defects is due to several factors, with the most significant being human factors, specifically the lack of skill from preparation to the smoking process. This is followed by the use of less-than-fresh materials and finally, the smoking method used. The proposed improvements are designed to address each of these factors, starting with workers being more careful and participating in training provided by local agencies or institutions. This is followed by selecting raw material suppliers and adjusting the smoking method to maintain product quality. **Implication :** Based on the research conducted, it can be seen that the average sigma value for MSMEs is approximately 3.30. In terms of sigma assessment, this means that the quality control process that has been implemented is running well. Quality control is still needed to improve the sigma value. The proposed improvements are designed to address each of these factors, starting with workers being more careful and participating in training provided by local agencies or institutions. This is followed by selecting raw material suppliers and adjusting the smoking method to maintain product quality. **Limitation :** There are several limitations in the research conducted, namely the less intensive observation of Mujair Smoked SMEs, which made it less than optimal, and the observation period was felt to be insufficient, resulting in limited processed data. **Future Research :** Therefore, future research can extend the study duration, increase sales data, and broaden the scope of the research object.

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