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The proposed quality improvement of tofu production at UD. XYZ using DMAIC method

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ABSTRACT

Tofu is known as people's food because the price is cheap and easily accessible by all levels of society. Tofu is in great demand. Besides its affordable price, this food is also healthy and can be processed into various dishes. Quality control is essential for a company to minimize the costs caused by product defects. It can help the company if there are irregularities in the production process. With a large number of irregularities in production, the company will experience losses in quality, cost and quantity. This research was conducted to control and improve the quality of tofu at UD. XYZ uses the Six Sigma method through the Define, Measure, Analyse, Improve, and Control stages. Based on the analysis results, the sigma value is 3.4, and the DPMO value is 29,189, indicating that improvement is still needed to reduce defects that arise so that the sigma value can be increased. Based on this research, it is suggested to improve the sigma quality by investing time and money to train new company employees and improve the equipment used in the tofu production process. It is purchasing automated equipment to support better production processes. Research on enhancing the quality of tofu production should be carried out periodically at UD. XYZ, as part of the company's continuous improvement.

1. Introduction

Tofu is one industry engaged in food processing from soybean raw materials. Generally, industries that process soybeans into tofu are household-scale industries managed independently by the head of the family and its members. The average number of workers in the tofu industry ranges from 1-5 people, so it is referred to as a household-scale industry (BPS, 2022). Tofu is known as the people's food because the price is cheap and easily accessible by all circles of society. Generally, tofu is used as a side dish to replace meat (animal protein) because the price is lower when compared to meat (Suhartinah et al., 2024).

Quality is an essential indicator for companies to continue to stand with many product competitors. Quality is the suitability of using a product from a company that can undoubtedly meet customer needs and satisfaction (Juran & Godfrey, 1993). Quality control is a system of verifying and controlling a desired level of product or process quality with careful planning, use of appropriate equipment, continuous inspection and corrective action when needed so that quality control is not only an inspection activity or determining whether the product is good (accept) or bad (reject) (Rimantho & Mariani, 2017).

Quality control is essential for a company to minimize the costs caused by defective products (Handoko et al., 2023). It can help the company if there are deviations in the production process. The company will experience losses in terms of quality, cost and quantity due to the number of deviations

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in production. In a manufacturing process, sometimes the products produced need to meet the standards set by the company or are often referred to as rejects. So if this always happens to the company, it can cause cost losses due to the asynchronization between the purchase of raw materials and production results and the existence of defective products that cause them not to sell in the market (Tristianto & Triono, 2022).

UD. XYZ is a tofu and tempeh production manufacturing industry located in the Sumberpucung sub-district, Malang, East Java. The raw materials used in producing tofu are made from selected soybeans. Problems often faced by UD. In production, XYZ is prone to defects, from weighing raw soybean materials, soaking, grinding, boiling, and filtering to printing tofu. UD. XYZ must conduct an appropriate analysis to determine policies so that the occurrence of defective products can be minimized. Good quality tofu has physical characteristics according to predetermined quality standards. The physical characteristics of tofu that meet reasonable quality standards are the smell or aroma of regular tofu, having a typical taste, normally white or yellowish colour, normal physical appearance, and not slimy and not mouldy (BSN, 1998).

Six Sigma is a continuous improvement effort to reduce the variation of the process in order to improve the process's capability to produce error-free products (goods or services) to provide value to customers (Gasperz, 2008). The Six Sigma method is significantly related to applying statistical and other scientific methods to minimize the defect rate (Linderman et al., 2003). The Six Sigma method is one of the business strategies considered capable of improving and maintaining the company's operational excellence (Tjiptono, 2003).

The Six Sigma method was chosen for its systematic approach to quality improvement through the DMAIC cycle (Costa et al., 2018). This methodology is particularly effective in identifying root causes of defects, reducing process variability, and achieving a higher level of operational efficiency. Its focus on data-driven decision-making and continuous improvement makes it a powerful tool for minimizing defects and maximizing productivity, even in small-scale industries (Fauziah et al., 2014). For UD. XYZ, which often experiences production defects, Six Sigma provides a structured framework to identify inefficiencies and implement corrective actions that directly impact product quality and overall profitability (Costa et al., 2020). Several studies have demonstrated the effectiveness of Six Sigma in improving quality in Micro, Small, and Medium Enterprises (MSMEs) (Hairiyah & Amalia, 2020). For example, previous research highlights how Six Sigma can be tailored to the resource limitations typical of MSMEs while still achieving significant improvements in defect reduction (Snee, 2010). Similarly, another study emphasizes the applicability of Six Sigma in small businesses, showing that even simple implementations of the methodology can yield substantial quality improvements (Antony et al., 2012). In the context of the tofu industry, where resource constraints and process inefficiencies are common, these findings underscore the relevance and feasibility of adopting Six Sigma to address production challenges and enhance product quality (Saleh et al., 2023).

There are five stages of DMAIC as a characteristic of Six Sigma, including applying the DMAIC cycle (Define, Measure, Analyse, Improve, Control). Six Sigma can detect the causes of quality defects: non-standard material quality, undisciplined employees, dirty environment, old machine conditions, and product quality checking intervals (Gasperz, 2008). Applying the Six Sigma method has been proven to bring the company to the lowest level of defective products (Costa et al., 2021). It can even minimize it again until the production process reaches perfection (zero defect) (Vincent Gasperz, 2008). This research will identify the improvement of production quality and the factors that cause defects in tofu products at UD. XYZ and proposals to minimize defects in tofu products at UD. XYZ by using the Six Sigma method.

2. Methods

Based on the type of data required in this study, it consists of quantitative data, namely production data and the number of defects. Meanwhile, based on the source, the data required are primary and secondary. Primary data is data obtained directly through direct observation and recording at UD. XYZ, namely data on production time, production quantity, production flow, and types of defects. The data obtained in the observation results is the overall tofu production data, such as production flow data, production time, and types of defects.

Direct interviews with owners and workers in the UD tofu production process obtain data collection. XYZ to complete data about the production process, such as production process flow, product

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information, and machine information used during the production process. Secondary data from the company contains attribute data in the form of demand for tofu products, the amount of soybeans used, and defective products. The data collected in this study amounted to 30 data by the data sufficiency requirements (Sugiyono, 2016). The data processing stage consists of several stages based on the Six Sigma methodology: DMAIC (Define, Measure, Analyze, Improve, and Control) (Kinlaw, 1992). Fig. 1 is the flowchart of this research.

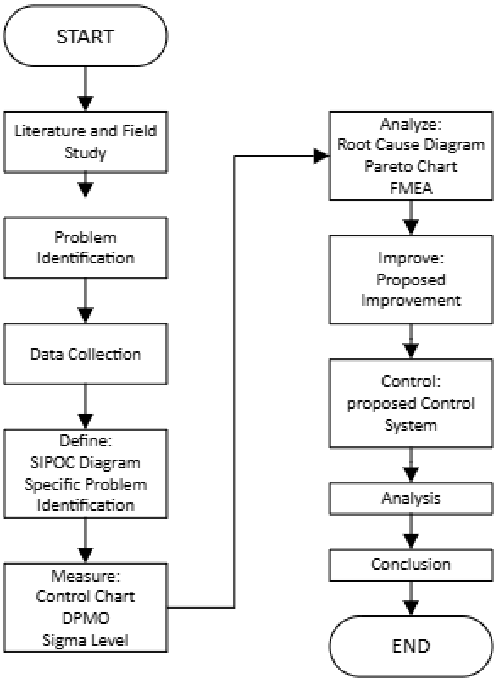

Fig. 1 Flowchart of research.

The Define stage is the first step in explaining the problems at UD. XYZ. This stage uses the SIPOC (Supplier Input Process Output Customer) diagram. The Measure stage will calculate the process performance of UD. XYZ uses several tools in Six Sigma. Measurements that will be carried out include analyzing the p control map (P-Chart), measuring Defect per Million Opportunities (DPMO) and Sigma Level of tofu product defects. In the analysis stage, we identify the leading causes of defects in the tofu production process. The stages that will be carried out include knowing the number of the most dominant failure frequencies, determining the root causes of problems using the Fishbone Diagram, and prioritizing the causes of problems using the Failure Mode Effect Analysis (FMEA) method.

The Improve phase is a stage that aims to make improvements or propose actions that can be taken against the causes of problems obtained from FMEA, and the Analyze phase. The Control stage is the last phase in DMAIC. In the control stage, the formulation of improvement standards is carried out to improve production quality. In the control. In the improvement stage, recommendations for improvement plans and control proposals are made regarding the actions suggested in the improvement stage.

3. Results and Discussion

Define Stage

The SIPOC (Supplier-Inputs-Process-Outputs-Customer) diagram is used to describe the flow of the tofu production process from material procurement to consumers agram SIPOC (*Supplier-Inputs-Process-Outputs-Customer*) (Rimantho & Mariani, 2017). Fig. 2 is a SIPOC diagram of the tofu production process at UD. XYZ.

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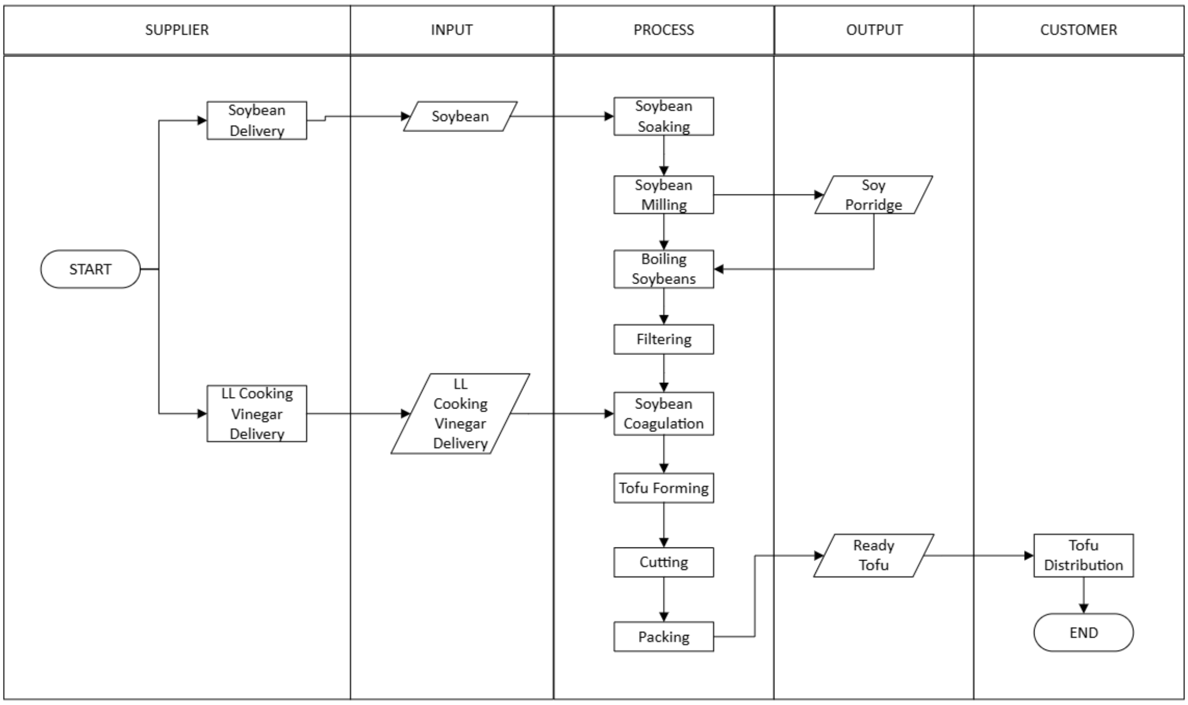

Fig. 2 SIPOC Diagram of Tofu Production at UD. XYZ (Source: Observation, 2023).

Measure Stage

At this stage, a series of calculations are carried out to determine the level of ability of the production process, namely analyzing the control map (P-Chart), measuring the P control map (P-chart), which is a tool for monitoring and quality control processes, measuring the level of sigma value and DPMO (Defect Per Million Opportunities) (Irwan & Haryono, 2015).

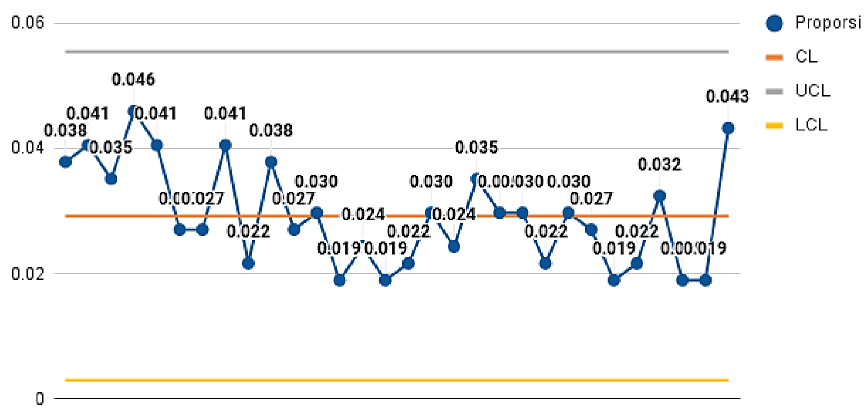

Fig. 3 P-chart control chart on production defect.

Fig. 3 obtained information that the lower control limit (LCL) is 0.003, the centre line (CL) is 0.029, and the upper control limit (UCL) is 0.055. From the UCL and LCL calculations, no data outside the control limits indicates that the production process is still within the control limits regarding product defects.

Table 1 obtained the DPMO value of 29,189, which can be interpreted that in one million opportunities, there will be 29,189 possibilities that the production process will produce defective products. After obtaining the DPMO value, the sigma value can be calculated. The sigma value obtained is 3.4.

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Table 1 DPMO and sigma values

No	Production (Pcs)	Total Defective Products (Pcs)	DPU	DPMO	Sigma Value
1	370	14	0.0378	37,838	3.3
2	370	15	0.0405	40,541	3.2
3	370	13	0.0351	35,135	3.3
4	370	17	0.0459	45,946	3.2
5	370	15	0.0405	40,541	3.2
6	370	10	0.0270	27,027	3.4
7	370	10	0.0270	27,027	3.4
8	370	15	0.0405	40,541	3.2
9	370	8	0.0216	21,622	3.5
10	370	14	0.0378	37,838	3.3
11	370	10	0.0270	27,027	3.4
12	370	11	0.0297	29,730	3.4
13	370	7	0.0189	18,919	3.6
14	370	9	0.0243	24,324	3.5
15	370	7	0.0189	18,919	3.6
16	370	8	0.0216	21,622	3.5
17	370	11	0.0297	29,730	3.4
18	370	9	0.0243	24,324	3.5
19	370	13	0.0351	35,135	3.3
20	370	11	0.0297	29,730	3.4
21	370	11	0.0297	29,730	3.4
22	370	8	0.0216	21,622	3.5
23	370	11	0.0297	29,730	3.4
24	370	10	0.0270	27,027	3.4
25	370	7	0.0189	18,919	3.6
26	370	8	0.0216	21,622	3.5
27	370	12	0.0324	32,432	3.3
28	370	7	0.0189	18,919	3.6
29	370	7	0.0189	18,919	3.6
30	370	16	0.0432	43,243	3.2
Average	370	10.8	0.0292	29,189	3.4

Analyze Stage

The next stage is the analysis stage, using Pareto and fishbone diagrams and compiling Failure Mode and Effect Analysis (FMEA). FMEA is a systematic process to identify potential failures to fulfil the intended function, identify possible causes of failure so that the cause can be eliminated, and find the cause of failure so that the cause can be reduced (Press, 2003).

Pareto diagrams can identify the most critical issues affecting quality improvement efforts and guide allocating limited resources to solve problems (Raman & Basavaraj, 2019). Fig. 4 shows that the most dominant defect is the size of the finished tofu product that does not meet the standard of 29.01% or 94 units of defective products in 30 days of observation. The second defect is the flabby texture of the tofu, so it cannot be marketed at 25.62% or 83 units of defective products. Other causes of defects, such as dirt on tofu products, amounted to 25.31%, with 82 units of defective products. Defects in holes found in finished tofu products amounted to 20.06%, with many defective products at 65 units. Therefore, it is necessary to make improvements to avoid failures in finished tofu products that will be distributed.

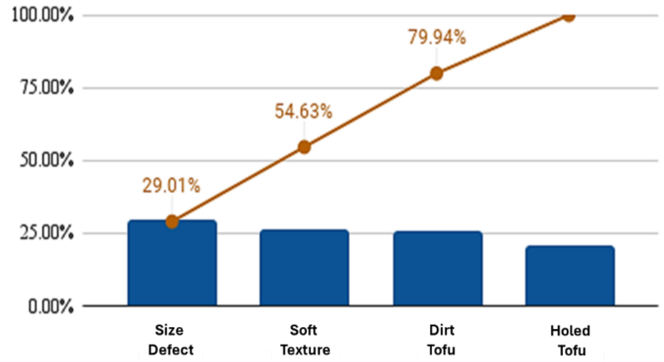

Fig. 4 Pareto diagram of production defects.

Fig. 5 is a fishbone diagram of the causes of size defects. Factors causing size defects in tofu are identified using the 4M concept guidelines (Man, Method, Material, Machine). Material factors, the quality of tofu that does not meet the standards is the cause of the problems that arise, such as the thickness of the tofu to be cut not according to the standard because, during the tofu moulding process, the volume of soybean juice to be poured is not appropriate. Method Factor (Method) Data from interviews with owners and labourers at UD. XYZ that size defects are caused because workers do not know the SOP for printing tofu, and there is no specific task for workers, so they only use estimates in cutting according to shape during the tofu printing process. Machine factor: The machine becomes a factor in production at UD.XYZ, there is a tofu-cutting tool. The blades used are blunt, causing size defects in the tofu. Man factor, the moulding and cutting process requires the skill and concentration of the workers. The human error factor cannot be avoided; fatigue due to prolonged activity can cause decreased worker performance. Cutting training is something that UD. XYZ because it can affect the quality of production.

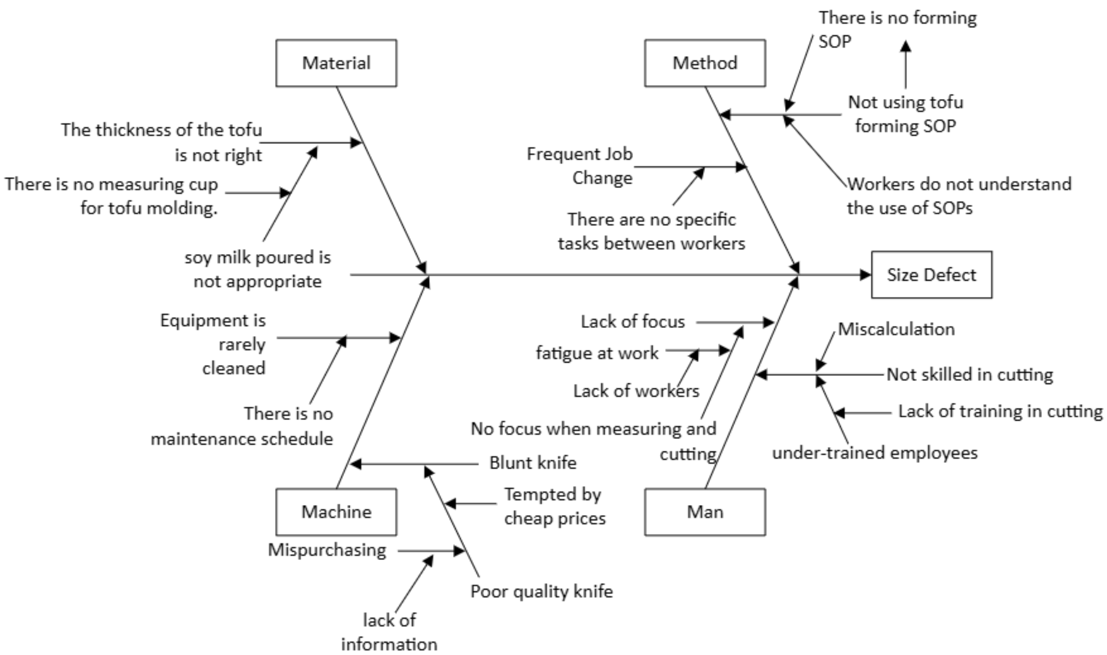

Fig. 5 Fishbone diagram of size defect.

Fig. 6 is a factor that causes the texture defect of mushy tofu. These factors continue to be analyzed until the root cause of the problem is obtained. Causal factors of mushy tofu texture defects were identified using the 4M concept guidelines (Man, Method, Material, Machine). The material factor of tofu defects due to mushy texture is caused by tofu that is too liquid because mixing vinegar acid

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can reduce the quality of tofu products (Rujianto & Wahyuni, 2018). Method factor: The high value of tofu texture is predicted to be caused by several factors, including pressing and pressing time (Dedy Nur Midayanto & Sudarminto Setyo Yuwono, 2014). A tight pressing process and too long can result in mushy textured tofu (Hairiyah & Amalia, 2020). Machine factor: The machine becomes a factor in production. UD.XYZ uses a Disc Mill machine to grind soybeans. A dirty milling machine, because there is no machine maintenance schedule, can produce dirty soybean pulp and will be carried over to the boiling process; a dirty milling machine can also affect the grinding process imperfectly because there are still soybeans that are not crushed due to the remaining soybeans that are still attached (Muhammad Saleh et al., 2023). Man factor, human problems that are less focused on carrying out work due to fatigue, decrease the quality of the tofu produced. Workers who pay attention to the time during pressing result in shorter pressing times, making the texture of the tofu mushy.

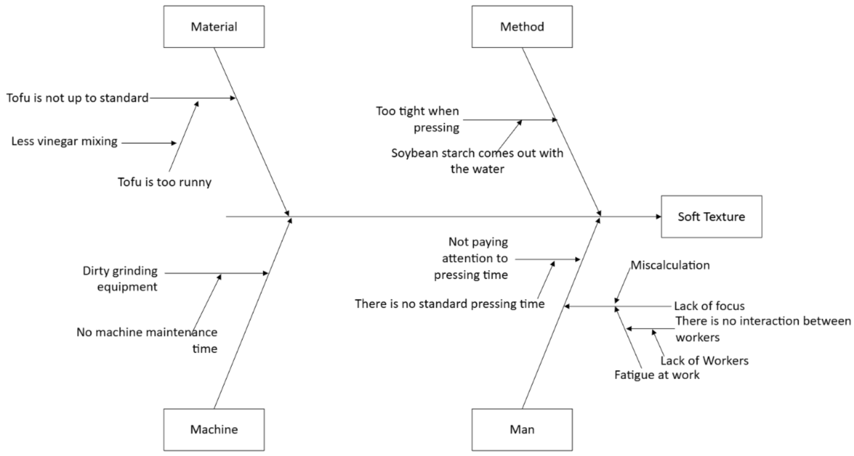

Fig. 6 Fishbone diagram of soft tofu texture.

Based on Table 2, the failure mode is a size that is not up to standard. The percentage of the size defect failure mode compared to other failure modes is 29.01%. The results of the calculation of RPN obtained a blunt knife causes the highest failure of 252, workers are not focused on the process of cutting and moulding the second highest tofu of 245, and no particular measuring container for the tofu moulding process of 210 causes the cause of the third size defect failure. Alternative improvements must be made to minimize failures during the production process.

Table 2 Preparation of FMEA for tofu size defects

Failure	**Fail Mode**	**Failure Effect**	**Factor**	**Causes of Failure**	***Existing Conditions***				***Rank***
					S	***O***	***D***	***RPN***	
Size Defects	There is a size discrepancy in the finished tofu product	Rework products that have size defects or products that are not marketable	Material	No special measuring container for tofu molding	7	5	6	210	3
			Method	No specific tasks between workers	6	4	6	144	7
				There is no tofu printing SOP	8	6	4	192	4
			Man	Training in cutting is lacking	7	6	3	126	9
				Miscalculation	8	8	2	128	8
				Workers are less/less focused	7	7	5	245	2
				Fatigue at work	6	5	5	150	5

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Table 3 Continue

Failure	Fail Mode	Failure Effect	Factor	Causes of Failure	*Existing Conditions*				*Rank*
					S	***O***	***D***	***RPN***	
			Machine	Blunt knife	9	7	4	252	1
				Measuring tool does not fit	6	3	7	126	9
				No schedule for inspection and cleaning of production equipment	7	7	3	147	6

Table 3 is the preparation of the FMEA failure mode of mushy texture in the finished product, which causes the tofu product to be watery and not durable due to several factors causing failure. Calculating the RPN value obtained the cause of failure with the most considerable RPN value. The milling machine has no standard maintenance time with an RPN value of 180. The second is less vinegar acid mixing with an RPN value of 150. The third cause of failure is starch juice coming out with water with an RPN value of 144. Therefore, it is necessary to make improvements to avoid failure using alternative improvements.

Table 4 Compilation of FMEA for mushy texture defects.

Failure	Fail Mode	Failure Effect	Factor	Causes of Failure	*Existing Conditions*				*Rank*
					S	***O***	***D***	***RPN***	
Mushy texture	The mushy texture of the finished product leads to a watery and non-durable product.	Tofu production rework and mushy tofu products cannot be marketed.	Material	Mixing less vinegar acid	5	6	5	150	2
			Method	Soybean starch juice comes out with water	6	4	6	144	3
			Man	Not paying attention to the pressing time	5	4	5	100	4
				Fatigue at work	3	4	6	72	5
			Machine	No standard milling machine maintenance time	6	5	6	180	1

Improve Stage

The improvement stage is the fourth stage in the Six Sigma quality improvement method. The improvement steps taken to improve the tofu production process, namely making improvement proposals using Failure Mode and Effect Analysis (FMEA) and selecting alternative improvements.

Table 5 Alternative improvement of size defect type.

Defect Type	Highest RPN	Alternative Improvements
Size Defects	Blunt knife	Pay more attention to periodic maintenance and repair of the tool.
	Unconscionable employees	Training and supervision of workers.
	There is no special measuring container for tofu printing	Modify the special measuring container of tofu printing so that the tofu essence poured in printing is consistent.
	No SOP of tofu printing process	Create a printing process SOP.

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Table 6 Alternative repair type of smallpox texture of mushy tofu.

Defect Type	Highest RPN	Alternative Improvements
Mushy Texture	No standard milling machine maintenance time	Scheduling maintenance on milling machines.
	Addition of less vinegar acid	Pay attention to the stage of the process of mixing vinegar acid into tofu pulp.
	The pressing process is too tight	Workers must pay attention when pressing so that soybean starch does not come out with water.

Table 4 and Table 5 above show that the highest RPN values for size defects and mushy tofu texture defects can be prepared as a proposed improvement to minimize damage to UD agar products. XYZ does not suffer any material and time losses.

Control Stage

The control stage is carried out after selecting alternative improvement solutions for the company to maintain and monitor the production process to maintain good product quality. Table 6 is an improvement plan that must be carried out to ensure the production process runs smoothly and produces products with good quantity and quality.

Table 7 Improvement plans and control proposals

No.	Improvement Plan	Operating Proposals
1.	Establish clear SOPs so that workers understand the production process.	Establish tofu production SOPs and provide understanding to workers so that the production process runs smoothly and is more targeted (Tristianto & Agus Triono, 2022).
2.	Scheduling maintenance of production machines and equipment.	Perform scheduled maintenance and replace new equipment to support the production process (Lim Sanny et al., 2016).
3.	Checking the production process to ensure good quality products.	Checking the production process until the finished product knows both in terms of quality and quantity during the production process (Aufi Fauziah et al., 2014).
4.	Make production reports every month.	Create a report each month that includes graphs that compare production volumes with the number of defective products for easy evaluation and resolution of the dominant defect types (Lim Sanny et al., 2016).

It is necessary to make a straightforward procedure that can be obeyed by all workers in the production process—control proposals given to UD. XYZ is to establish clear SOPs for the production process and provide understanding to workers so that the production process runs smoothly and is more targeted (Charismanda Adilla Tristianto & Agus Triono, 2022). The second improvement plan was given to UD. XYZ is by scheduling maintenance of production machines and equipment. The most dominant production defect is caused by one blunt knife, and dirt defects are caused by one dirty milling machine. So UD. XYZ must perform scheduled maintenance and replace new equipment to support the production process (Lim Sanny et al., 2016). The third proposal was given to UD. XYZ is Checking the production process to ensure good quality products and checking the production process until the finished product is both in terms of quality and quantity during the production process (Aufi Fauziah et al., 2014). The fourth improvement plan in this study is in the form of proposed controls that can be carried out to improve the production process at UD. XYZ creates a monthly report that includes graphs that compare production volumes with the number of defective products for easy evaluation and resolution of the dominant defect types (Lim Sanny et al., 2016). Improvement of the production process by evaluating tofu product defects is expected to minimize costs and maintain the quality of products sold.

Discussion

The results of the study indicate that defects in tofu production at UD. XYZ is predominantly caused by machine-related issues, insufficient standard operating procedures (SOPs), and human factors such as fatigue and inadequate training. The high RPN value for blunt-cutting tools highlights the urgent need for regular maintenance and upgrades to production equipment. This finding corroborates prior studies emphasizing the critical role of well-maintained equipment in reducing defect rates in manufacturing (Rafi Pratama & Al Faritsy, 2024). Additionally, the lack of clear SOPs in the tofu printing process contributed significantly to production inefficiencies (Indrasari et al., 2021). It's crucial to address this issue through structured task allocation and comprehensive employee guidelines (Charismanda Adilla Tristianto & Agus Triono, 2022).

From a managerial perspective, the adoption of a Six Sigma DMAIC approach provides a systematic framework for identifying and addressing production inefficiencies. The implementation of SOPs, coupled with regular and comprehensive training programs, ensures that employees have the necessary skills to perform tasks with precision, significantly reducing human errors in production. Previous research suggests that training significantly enhances worker performance and product quality in small-scale industries (Widiwati et al., 2024). Moreover, introducing a scheduled maintenance plan for machines can prevent recurrent defects and extend equipment lifespan, ensuring smoother operations and reduced downtime (Vincent Gasperz, 2008).

The implications of these findings extend beyond operational improvements to strategic decision-making. Managers can use defect data and performance metrics, such as the number of defects per batch or the efficiency of each production line, to allocate resources more effectively, prioritize investments in automation, and evaluate the impact of improvements through periodic reporting. For example, incorporating automation in critical processes, such as cutting and pressing, can enhance precision and reduce dependency on manual labor, as supported by studies on automation's role in small-scale production (Snee, 2010). By focusing on both immediate corrective actions and long-term strategic planning, UD. XYZ can not only improve production quality but also strengthen its competitive advantage in the tofu industry.

4. Conclusion

The implementation of the Six Sigma DMAIC methodology at UD. XYZ has effectively identified critical factors causing defects in tofu production. The study's detailed analysis of Fishbone Diagrams and FMEA pinpointed the primary issues, including equipment deficiencies, lack of standard operating procedures, and human error due to insufficient training and fatigue. The sigma level 3.4 and the DPMO value 29,189 underscores the need to improve production quality. Proposed solutions, such as establishing SOPs, regular machine maintenance, and employee training, aim to address these root causes and ensure better control over production quality.

Continuous quality improvement is crucial for maintaining competitive advantage and reducing production losses in small-scale industries like UD. XYZ. By integrating Six Sigma principles into daily operations, the company can minimize defects, optimize resource utilization, and improve customer satisfaction. Future efforts should periodically evaluate the implemented measures and leverage automated tools to streamline production processes further. This study highlights the potential of structured quality control methodologies in achieving operational excellence and serves as a reference for similar enterprises facing production challenges.

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