IMPLEMENTATION OF LEAN MANUFACTURING IN REDUCING WASTE AND IMPROVING EFFICIENCY IN TAPIOCA FLOUR PRODUCTION

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Abstract

PT XYZ manufactures tapioca flour. This company faces various wastes in its production process, including defects, waiting, unnecessary inventory, overprocessing, unnecessary motion, overproduction, and transportation. This study uses a lean manufacturing approach, Value Stream Mapping, to identify and minimize waste, enhancing production time efficiency, and the kaizen method as a proposed improvement. The research was carried out through production flow mapping using Current Value Stream Mapping (CVSM) to pinpoint inefficiencies, Value Stream Analysis Tools (VALSAT) to determine tools, and fishbone diagrams for root cause analysis. Production efficiency is measured by Process Cycle Efficiency (PCE) before and after repairs. Proposed improvements include the implementation of kaizen through PDCA and 5S methods, as well as the preparation of Standard Operating Procedures (SOP) and the use of trolleys to improve the efficiency of product transfer. The results indicated a reduction in production lead time from 1,429 minutes to 1,194 minutes and a PCE increase from 63.89% to 76.47%.

Keywords: Efficiency, Kaizen, Lean Manufacturing, Production, Value Stream Mapping, Waste

INTRODUCTION

In today's era of globalization, many industries have grown rapidly and competed to increase competitiveness. Companies need to optimize resources to improve product quality, quantity, and operational efficiency. However, the success of improving production quality depends on efforts to reduce waste (Maulana, 2019). Waste is a non-value-adding activity (Sabara et al., 2024). Production time is the duration needed to meet demand and is an important factor in improving company efficiency (Moengin, 2021). Efficiency can be improved by optimizing process time through waste identification and reduction. Waste analysis is expected to increase efficiency and reduce waste in production units (Fitriadi, 2019).

PT XYZ is a food manufacturing company that processes cassava into tapika flour to meet consumer demand in various regions in Indonesia. The company has an average production capacity of 70 tons of raw materials per day, producing about 21 tons of tapioca flour. PT XYZ carries out the production process through several stages, including separating cassava from the stem, cleaning, washing, grating, filtering, settling, heating, packaging, and storage in the warehouse. The total production duration reached 1,429 minutes.

In PT XYZ there is still waste classified as 7 wastes. Defects, overcooked or undercooked flour due to unstable oven temperatures, and less tight packaging cause contamination and product defects. Waiting, occurs when waiting for the oven to reach the ideal temperature before the heating process begins. Unnecessary inventory, the accumulation of stock in warehouse without a clear distribution plan. Overprocessing, separation of cassava stems and tubers is carried out more than once. Unnecessary motion, the transfer of finished products to the warehouse after packaging is still carried out in an inefficient way. Transportation, the transfer of starch from scavenging to the oven area is carried out by an unoptimal method, using wooden planks and passing through a slippery uphill path. Overproduction, the production of tapioca flour exceeding consumer orders leads to stock buildup and an imbalance between production capacity and demand.

Based on the problems in the company, a questionnaire was distributed to eight respondents who understood the tapioca flour production process at PT XYZ, each representing each production department. This questionnaire identifies waste in PT XYZ’s tapioca flour production.

Table 1.
The Weight of Waste at PT XYZ

No	Waste	Weight (%)
1	Defect	6,06%
2	Waiting	10,91%
3	Unnecessary Inventory	11,52%
4	Overprocessing	18,79%
5	Unnecessary Motion	18,18%
6	Transportation	21,21%
7	Overproduction	13,33%

Source: Questionnaire Distribution

The table above reveals the order of waste from the highest to the lowest weight. The order of waste based on weight is transportation 21.21%, overprocessing 18.79%, unnecessary motion 18.18%, overproduction 13.33%, unnecessary inventory 11.52%, waiting 10.91%, and defect 6.06%. Lean manufacturing is a sstructured approach to minimizing waste in production process to reduce activities without added value (Jufrijal, 2022). Value Stream Mapping optimizes material and information flow, increase productivity, competitiveness, and support the effective implementation of the system (Novitasari, 2020). Process Cycle Efficiency measures the efficiency of factories in production (Sabara et al., 2024). Kaizen is proposed by updating and improving the production process (Suherman, 2023). Through the implementation of kaizen, waste is gradually reduced, having a significant impact on various aspects of production.

This research seeks to minimize and enhance production time efficiency with lean manufacturing approaches and value stream mapping to eliminate production waste. Improvements are proposed using the kaizen method, in the hope of optimizing the production process and improving the company's operational efficiency.

REVIEW OF LITERATURE

Waste

Waste adds no value and should be eliminated for a smoother production process (Parwati et al., 2023). The definition for seven types of waste lacking value is as follows (Sabara et al., 2024) defect is a defective product of labor shortage during production, rework, and customer complaints. Waiting, occurs when materials, information, equipment or equipment are not yet available, including when employees are just observing or waiting for the next process. Unnecessary inventory, storage exceeds warehouse capacity. Overprocessing, inconformity in production operations due to less than optimal procedures or systems. Unnecessary motion, unnecessary movement. Transportation, waste of time due to the long distance between the warehouse and the production area as well as the movement of materials. Overproduction, production exceeds customer demand, leading to stock buildup.

Lean Manufacturing

Lean manufacturing is a production strategy that optimizes the use of resources to create value for customers efficiently. This approach eliminates waste, enhancing efficiency, effectiveness, and output quality (Ernawati et al., 2024). This method focuses on identifying and eliminating waste to create an efficient production process (Maulana, 2019).

Value Stream Mapping

Value Stream Mapping visually maps material and information flow from raw materials to finished products. VSM helps identify waste as well as its causes in production (Sabara et al., 2024). This method allows companies to see the big picture in resolving problems, not just in a single process, but in a thorough overhaul. VSM is depicted using symbols that represent various activities (Lestari, 2019).

Kaizen

Kaizen is a minor improvement that is done gradually but is able to give significant results over time. The main focus of kaizen is process improvement, where every progress achieved becomes a new standard of work until a better standard is found (Parwati et al., 2023). Kaizen is oriented towards the involvement of all parties in the organization, from management to workers on the production floor. Its flexibility makes kaizen can be applied as a concept or technique in various business contexts (Rahmanto, 2022). The 5S concept aims to improve efficiency and cleanliness in the work environment (Athaillah, 2023): Seiri (compact), sorting and storing only the necessary equipment to make the work area more organized. Seiton (neat), arranging equipment in the appropriate place so that it is easy to find, reducing search time. Seiso (clean), keeping the machine and work area clean to increase efficiency and extend the life of the equipment. Seiketsu (care), ensuring cleanliness and order are maintained by consistently applying the 5S principle. Shitsuke (diligent), instilling better discipline and work habits so that operational standards are implemented continuously.

RESEARCH METHOD

This study uses lean manufacturing methods that focus on identifying and reducing waste and continuous improvement (Theresia et al., 2020). Tools applied in lean manufacturing include value stream mapping, kaizen, and 5S. VSM maps production flows to identify and eliminate waste, ensuring efficiency, and increase productivity (Ningrum et al., 2022). VSM is depicted with symbols that represent activities in the production process. Through kaizen, waste is gradually reduced and results in a significant increase in value-added time. Meanwhile, the concept of 5S (seiri, seiton, seiso, seiketsu, shitsuke) is applied to create more efficient, organized work environment. Kaizen is participatory, involving all members of the organization, from management to workers on the production floor (Rahmanto, 2022).

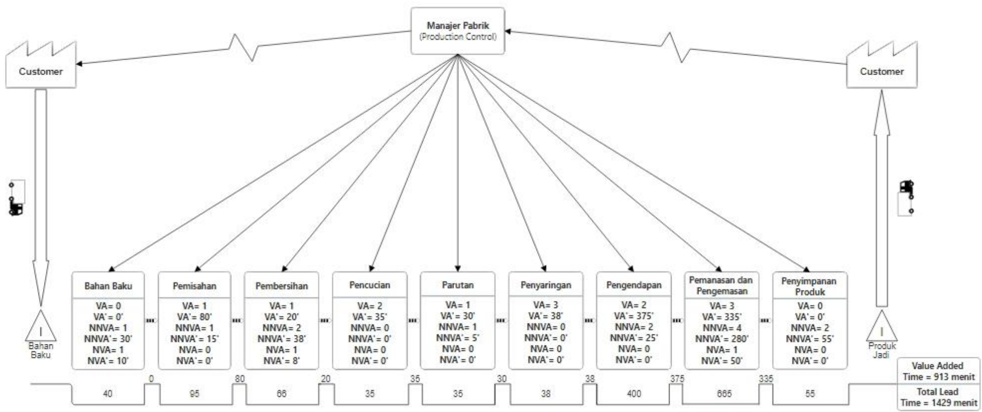
This study collected data through observations, interviews, and questionnaires. Data was gathered from PT XYZ and literature studies related to lean manufacturing. Observation was made by directly observing the production process and the factors that cause waste. Interviews were conducted with related parties to get information about the production process, where the resource persons provided answers according to the company's conditions. Meanwhile, questionnaire data was obtained by distributing questions to individuals with expertise in tapioca flour production. This questionnaire provided data on production waste.

RESULTS AND DISCUSSION

Current Value Stream Mapping

In VSM, information flows begins when a consumer submits an order to the factory manager. The manager then forwards the request to the supplier to ensure the availability of raw materials. After the raw materials are delivered to the factory, the manager instructs the department heads and operators to carry out the production process. The finished product is then delivered to the consumer according to the order. Meanwhile, physical flow starts from production needs. Raw materials in the form of high-quality cassava yams are obtained from suppliers and farmers, both local and imported. PT XYZ uses superior varieties such as casesa and adira which have high starch levels.

Figure 1.
Current Value Stream Mapping



- Total Production Time (Lead Time)
- 1,429 minutes = 85,740 seconds

Based on Figure 1. lead time of tapioca flour making is 1,429 minutes or 85,740 seconds, with a value-added time of 913 minutes or 54,780 seconds.

- Process Cycle Efficiency (PCE) Calculation

$$Process\ Cycle\ Efficiency = \frac{Value\ Added}{Total\ Lead\ Time} \times 100 = \frac{913}{1429} \times 100 = 63{,}89\%$$

Questionnaire Data Processing

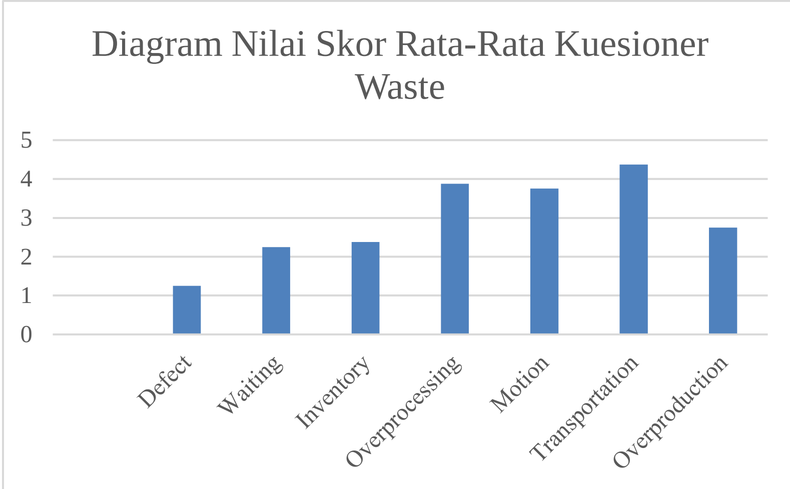
The questionnaire that has been distributed will be pasted, scored, and ranked based on the type of waste identified from the respondents' answers. The results of the packing, calculation, and the evaluation of the questionnaire on waste in tapioca flour production are as follows:

Table 2.
Results of the Waste Questionnaire Calculation

No	Waste	Respondents								Average Score	Ranking
		1	2	3	4	5	6	7	8		
1	Defect	2	1	2	1	1	1	1	1	1,25	7
2	Waiting	2	3	2	2	2	3	1	3	2,25	6
3	Unnecessary Inventory	2	3	2	2	2	3	2	3	2,38	5
4	Overprocessing	5	4	4	3	3	4	4	4	3,88	2
5	Unnecessary Motion	4	3	4	4	4	4	3	4	3,75	3
6	Transportation	5	5	4	5	5	4	3	4	4,38	1
7	Overproduction	3	2	3	3	4	2	2	3	2,75	4

Figure 2.

Diagram of the Average Score of Waste Qualitative Results



Value Stream Analysis Tools (VALSAT)

At this stage, the Matrix analysis of VALSAT the result will be processed by multiplying the questionaire's average core with the VALSAT matrix column values.

Table 3.
VALSAT Score Computation

No	Waste	Weight	VALSAT						
			PAM	SCRM	PVF	QFM	DAM	DPA	PS
1	Defect	1,25	1,25	-	-	11,25	-	-	-
2	Waiting	2,25	20,25	20,25	2,25	-	6,75	6,75	-
3	Unnecessary Inventory	2,38	7,13	2,38	7,13	-	21,38	7,13	2,38
4	Overprocessing	3,88	34,88	-	11,63	3,88	-	-	-
5	Unnecessary Motion	3,75	33,75	33,75	-	-	-	-	-
6	Transportation	4,38	39,38	-	-	-	-	-	4,38
7	Overproduction	2,75	2,75	8,25	-	2,75	8,25	8,25	-
Total Weight		**20,63**	**139,38**	**64,63**	**21,00**	**17,88**	**36,38**	**22,13**	**6,75**

Table 4.
VALSAT Tool Selection

No	VALSAT	Weight	Ranking
1	Process Activity Mapping (PAM)	139,38	1
2	Supply Chain Response Matrix (SCRM)	64,63	2
3	Quality Filter Mapping (QFM)	21,00	5
4	Decision Point Analysis (DPA)	17,88	6
5	Product Variety Funnel (PVF)	36,38	3
6	Demand Amplification (DAM)	22,13	4

No	VALSAT	Weight	Ranking
7	Physical Structure (PS)	6,75	7

Based on the selected VALSAT tool, namely Process Activity Mapping (PAM), used to identify and reduce waste in physical and material flows. This method aims to eliminate non-value-added activities, simplify processes, and design workflows more efficiently.

Table 5.
Percentage of Frequency and Time of Each Activity

No	Activity	Frequency	Percentage	Time (Minutes)	Prcentage
1	Operation	15	51,72%	961	67,25%
2	Transportation	7	24,14%	328	22,95%
3	Inspection	4	13,79%	60	4,20%
4	Storage	1	3,45%	20	1,40%
5	Delay	2	6,90%	60	4,20%
	Total	**29**	**100%**	**1429**	**100%**

Figure 3.
Percentage of Frequency and Time of Each Activity

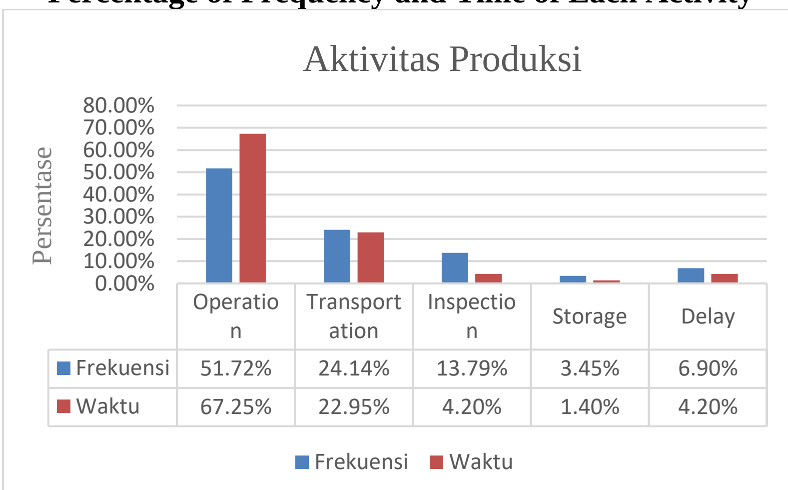


Table 5 and Figure 3 show the frequency and time distribution for each activity in tapioca flour production: operation (51.72%, 67.25%), transportation (24.14%, 22.95%), inspection (13.79%, 4.20%), storage (3.45%, 1.40%), and delay (6.90%, 4.20%)

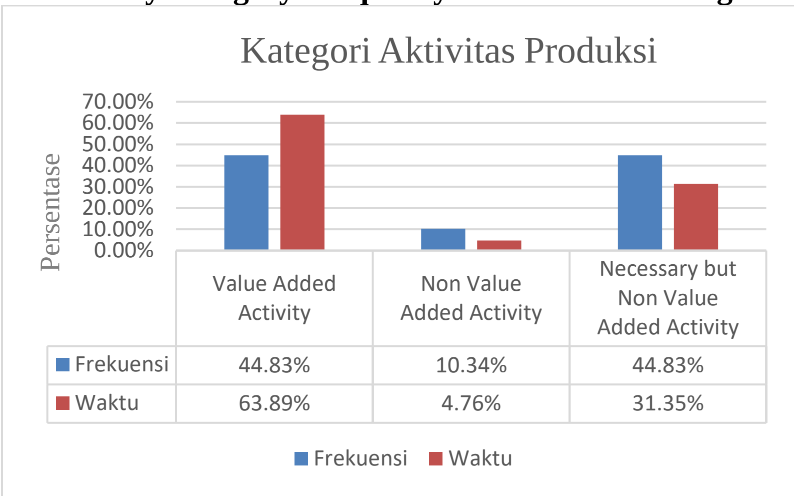
After knowing the number and duration of each activity, the next thing is to group it into three categories, value-added, non-value-added, and necessary but non-value-added.

Table 6.
Activity Category Frequency and Time Percentage

No	Activity	Frequency	Percentage	Time (Minutes)	Prcentage
1	Value Added Activity	13	44,83%	913	63,89%
2	Non-Value-Added Activity	3	10,34%	68	4,76%

3	Necessary but Non-Value-Added Activity	13	44,33%	448	31,35%
	Total	**29**	**100%**	**1429**	**100%**

Figure 4.
Activity Category Frequency and Time Percentage



Based on the results shown in Table 6 and Figure 4. the percentages for each type of activity are as follows: the frequency of value added accounts for 44.83% with 63.89% of the time, while non-value added occurs 10.34% of the time at 4.76%, and necessary but non-value added makes up 44.83% with 31.35% of the time. These findings highlight the need to minimize non-value-added activities.

Fishbone Diagram

Figure 5.
Fishbone Waste Defect

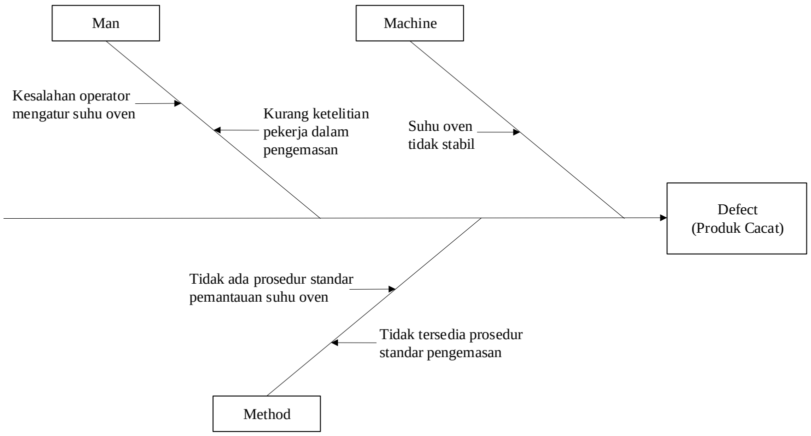


Figure 6.
Fishbone Waste Waiting

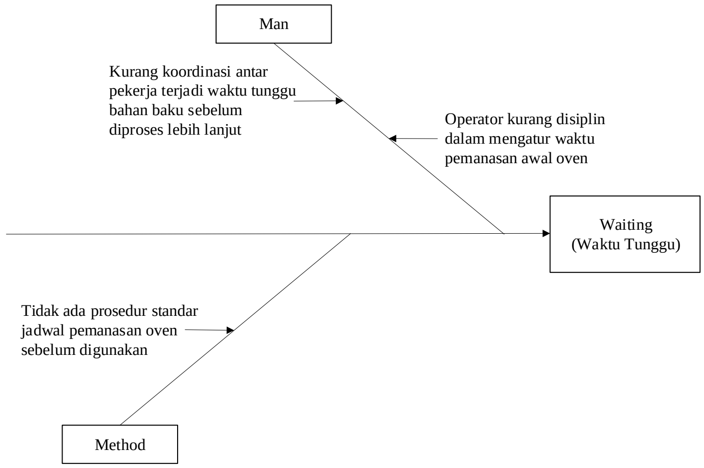


Figure 7.
Fishbone Waste Unnecessary Inventory

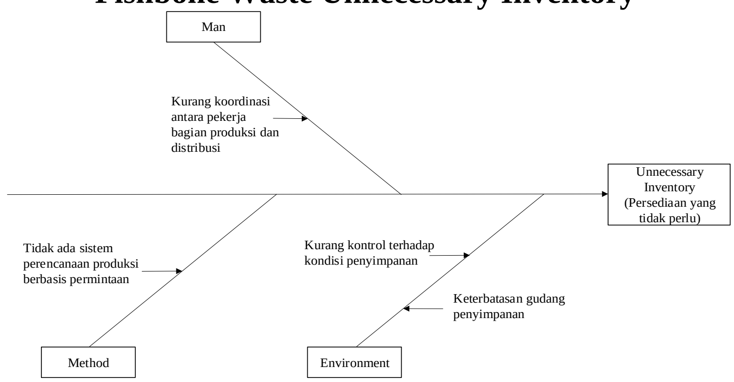


Figure 8.
Fishbone Waste Overprocessing

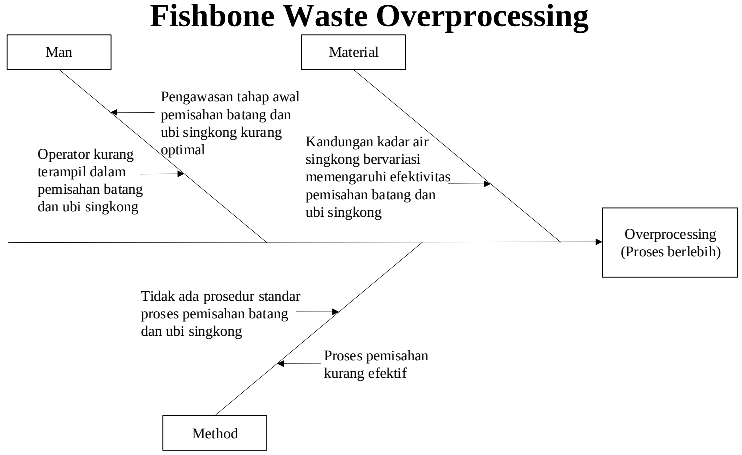


Figure 9.
Fishbone Waste Unnecessary Motion

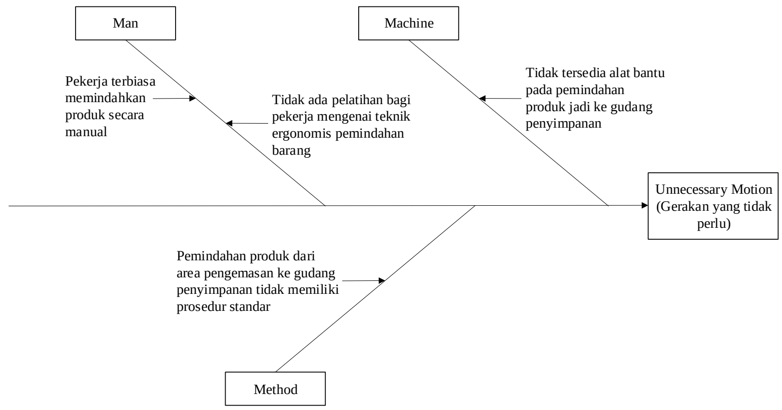


Figure 10.
Fishbone Waste Transportation

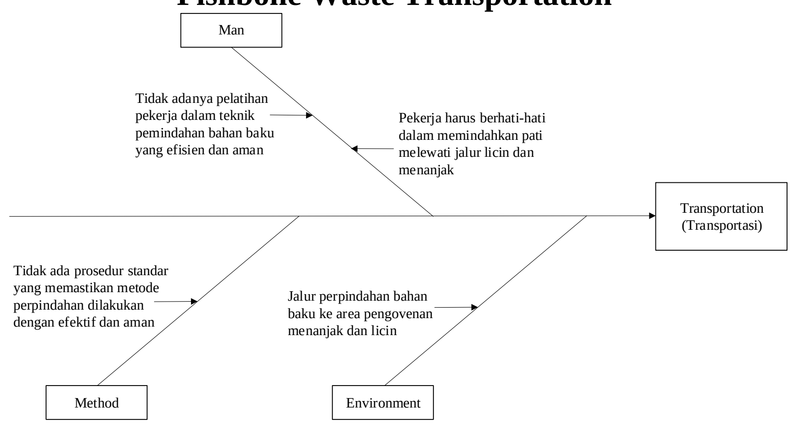
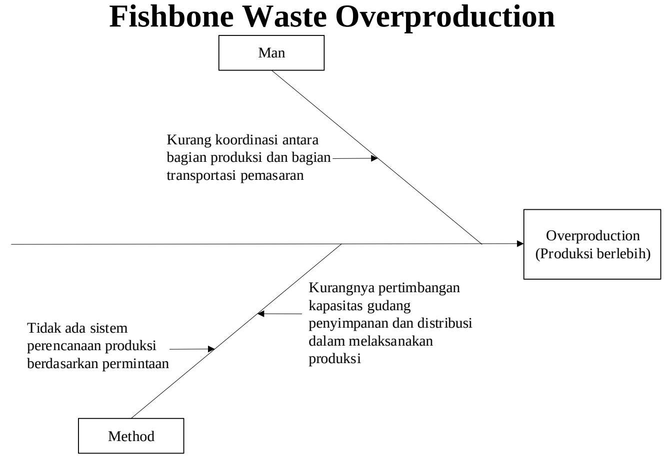


Figure 11.
Fishbone Waste Overproduction



Kaizen

a. Plan

The planning stage starts by identifying PT XYZ's issues and developing a strategy to eliminate seven wastes using root cause analysis with fishbone diagrams.

b. Do

5S was implemented as planned to enhance tapioca flour production efficiency through cause and effect analysis.

- Seiri
  Sort the necessary items and eliminate the ones that are not needed to reduce waste.
- Seiton
  Place equipment strategically for quick access, minimizing search time, unnecessary movement.
- Seiso
  Regularly clean the work area to ensure hygiene, spot issues, and prevent machine damage.
- Seiketsu
  Set standard procedures to sustain seiri, seiton, and seiso.
- Shitsuke
  Fostering discipline and compliance for a sustainable, efficient workplace

c. Check

The third stage of the PDCA cycle involves analyzing and assessing the stage to ensure improvements are in accordance with the objectives at the plan stage.

Table 7.
Stage Check Repair

Waste	Before Repair	After Repair with 5S
Defect	The oven temperature is unstable The packaging is not tight	Regular oven temperature control Stricter packaging method
Waiting	Cassava is left to wait before entering the next process Waiting time for the oven to heat up to the ideal temperature	Arrange the cassava according to the order of entry and arrange the production flow so that it is processed immediately Preheat the oven
Unnecessary Inventory	Finished product stock piles up in the storage warehouse without clear distribution planning	Production in accordance with request order FIFO system in storage Better Stock recording
Overprocessing	Separation of stems and cassava is done more than once	Ensure more efficient stem separation from the start
Unnecessary Motion	Workers have to manually move finished products back and forth to the storage warehouse by carrying them on their shoulders	Use a trolley to move finished products more quickly and efficiently, and prevent the risk of work accidents
Transportation	The transfer of starch to the oven area passes through wooden planks and slippery uphill paths	Improve the transfer path and use a more stable base, so it can be faster
Overproduction	Tapioca flour production exceeds demand, causing stockpiles and the risk of expiration	Customize production based on demand

d. Action

The final stage of the PDCA cycle, evaluates results against initial objectives to ensure standardization aligns with targets.

Value Stream Mapping Adjustments Improvements

Table 8.
Adjustment of Tapioca Flour Production Process Time

No	Process Description	Pre-repair processing time (minutes)	Post-repair Processing Time (minutes)
1	Raw materials are unloaded from the transport truck to the production area	30	20
2	Waiting for cassava to go into the next processing	10	0
3	Visual inspection of cassava	15	5
4	Cassava is put into the hopper using a loader	30	15
5	Manual separation of remaining humps during the transfer process by conveyor	8	0
6	The starch liquid is drained into the settling tank	20	10
7	Starch slate shoveling	60	35
8	Transport of starch chunks to the oven warehouse area by trolley	175	110
9	Wait for the oven temperature to warm up to the set temperature	50	45
10	Transfer of packaged tapioca flour to storage warehouse	35	25

Repair Remarks:

1. Raw materials are unloaded from the transport truck to the production area

Moving raw materials from the truck to the production area takes 30 minutes because it is still done manually. This time can be reduced by dividing specific tasks, such as assigning special groups to unload, transport, and organize raw materials. With a clear division of tasks, the process becomes faster, more efficient, and reduces fatigue and duplication of work.

2. Waiting for cassava to go into the next processing

After being unloaded from the truck, the cassava is left for 10 minutes before being processed to the stage of separating the stems or unnecessary parts. This delay is due to a poorly structured production flow and an untidy cassava order. Waiting time can be reduced by arranging cassava according to the order of arrival and optimizing the production flow so that it is processed directly to the next stage.

3. Visual inspection of cassava

The inspection process took 15 minutes because it was only carried out by one officer. This time can be accelerated by implementing early sorting, establishing clear eligibility criteria, and training workers to recognize defects faster, so that inspectors can work more efficiently.

4. Cassava is put into the hopper using a loader

The use of the loader takes 30 minutes due to the untidy pile of cassava, hindering transportation efficiency. This time can be reduced by arranging cassava more evenly, avoiding overcrowding, and directing operators to pick up from a more optimal area.

5. Manual separation of remaining humps during the transfer process by conveyor

The process of separating the hump takes 8 minutes due to the lack of precision in the initial separation. This time can be reduced by increasing worker accuracy and providing a better understanding of the parts that must be separated so that humps can be removed faster.

6. The starch liquid is drained into the settling tank

Proses ini memakan waktu 20 menit akibat aluran yang tersumbat oleh sisa pati, serat singkong, dan lumpur. Waktu dapat dikurangi dengan rutin membersihkan saluran setelah setiap siklus produksi menggunakan sikat, sehingga aliran tetap lancar dan proses lebih cepat.

7. Starch slate shoveling

It takes 60 minutes because the wet starch sticks to the bottom and walls of the tub, making shoveling difficult. The time can be shortened by sprinkling dry starch to absorb the silt, as well as lightly stirring the top of the sediment before pipetting.

8. Transport of starch chunks to the oven warehouse area by trolley

The process took 175 minutes because the path was narrow, uphill, and slippery, requiring workers to walk slowly to keep the trolley balanced. Time can be reduced by replacing wooden boards with larger and sturdier boards, cleaning up flour deposits regularly, and adding burlap sacks on uphill paths to improve grip, so workers can move faster than they can handle.

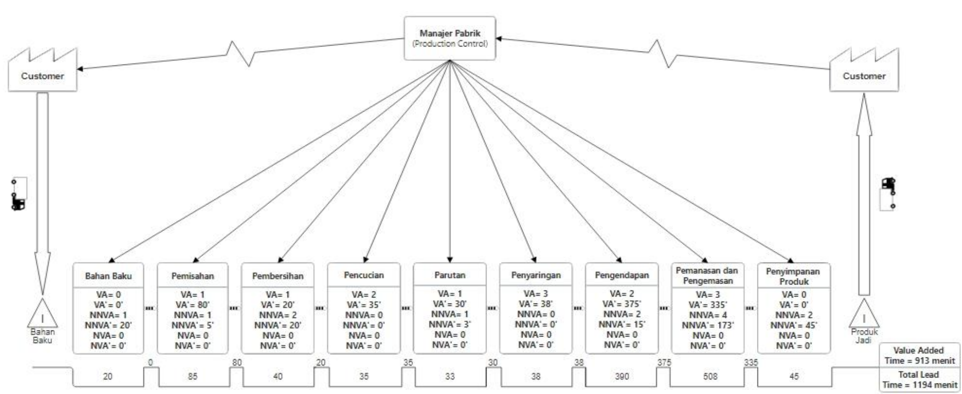
9. Wait for the oven temperature to warm up to the set temperature

Heating the oven takes 50 minutes to reach the ideal temperature. Currently the heating only starts after the starch is finished being transported, causing a waiting time. This time is eliminated by heating the oven earlier to make the process more efficient.

10. Transfer of packaged tapioca flour to storage warehouse

This process takes 35 minutes because it is still done by the pelvis, which is less efficient. The time can be shortened by using a trolley, so that the ape labor is more process-efficient, faster, and the risk of accidents is reduced.

Figure 12.
Future Value Stream Mapping



The time calculation after improvement is as follows:

a. Total Value Added = 913 minutes
b. Total Non-Value Added = 0 minutes
c. Total Necessary but Non-Value Added= 281 minutes
d. Total Production Time = 1194 minutes

Table 9.
Comparison of Total Production Time Before and After Repair

Initial Time	Time After Repair
1429 minutes	1194 minutes
23 hours 9 minutes	19 hours 54 minutes

Table 10.
Initial Activity Calculation

No	Activity	Frequency	Percentage	Time (Minutes)	Prcentage
1	Value Added Activity	13	44,83%	913	63,89%
2	Non-Value-Added Activity	3	10,34%	68	4,76%
3	Necessary but Non-Value-Added Activity	13	44,83%	448	31,35%
	Total	**29**	**100%**	**1429**	**100%**

Table 11.
Calculation of Improvement Activities

No	Activity	Frequency	Percentage	Time (Minutes)	Prcentage
1	Value Added Activity	13	50%	913	76,47%
2	Non-Value-Added Activity	0	0%	0	0,00%
3	Necessary but Non-Value-Added Activity	13	50%	281	23,53%
	Total	**26**	**100%**	**1194**	**100%**

- Process Cycle Efficiency (PCE) Calculation

$$Process\ Cycle\ Efficiency = \frac{Value\ Added}{Total\ Lead\ Time} \times 100 = \frac{913}{1194} \times 100 = 76{,}47\%$$

Repair Recommendations

The improvement recommendations are designed based on the identification of waste that occurs, namely by making SOPs for the tapioca flour production process at PT XYZ. Standard Operating Procedures (SOPs) include work steps that workers must follow to prevent unnecessary processes. The preparation of SOPs can increase production efficiency, accelerate lead time, improve product quality, and develop worker skills. The proposed improvement recommendations are as follows:

Table 12.
Recommendations for SOP Improvement of PT XYZ

Standard Operating Procedure (SOP) Tapioca Flour Production PT XYZ
Raw Materials
• Make sure the cassava is in good condition and not rotten • Remove cassava that is rotten, damaged, or substandard • Weigh the cassava received to record the receipt of raw materials
Separation of Stem and Tuber
• Use a tool such as a machete or knife to separate the stems and cassava • Use gloves when separating the stems and cassava • Place the separated cassava in a separate section • Separate the stem/unnecessary parts in the space provided • Separate the cassava that has passed the stem separate on stage (the stem stalks and those that have not) • Check and record the results of the cassava that has been separated
Cleaning
• Make sure the roll is in good condition before use • Make sure the water flows well before using it for cleaning • Make sure there is no dirt or trash on the cassava
Washing
• Make sure the washing tub is in good condition before use • Make sure there is no skin or soil left on the cassava
Grater
• Make sure the cassava is clean from dirt such as skin and soil • Make sure the grater is in good condition before use • Make sure the grated and chopped results have a smooth texture without lumps of cassava that have not been crushed • Check the grated and chopped results
Filtering
• Clean the sieve before use to ensure there are no residues clogging it • Make sure the sieve is working properly during the filtering process • Make sure the pulp and essence have been separated properly
Sedimentation
• Make sure the sedimentation tank is clean before use • Make sure to stir so that the starch settles properly • Make sure the waste water is separated from the flour during the sedimentation process • Sedimentation time is approximately 5 – 6 hours • Make sure the starch that settles has a finer texture than at the filtering stage • Check the sedimentation results
Heating and Packing
• Make sure to clean the floor area from flour spills regularly • Preheat the oven before use

Standard Operating Procedure (SOP) Tapioca Flour Production PT XYZ
• Make sure the oven temperature is stable and check it regularly to avoid defective products • Weigh the product according to the specified packaging standards • Workers sew sacks tightly and neatly • Use clean packaging and make sure it is tightly closed to prevent contamination • Check and record the packaging results
Storage of Tapioca Flour Products
• Use the FIFO system (First In, First Out) in storage • Workers use trolleys to move finished products to the storage warehouse

CONCLUSION

This study concludes that waste levels in PT XYZ's tapioca flour production vary across categories with different average scores. Defect had an average score of 1.25, waiting 2.25, unnecessary inventory 2.38, overprocessing 3.88, unnecessary motion 3.75, transportation 4.38, and overproduction 2.75. The initial tapioca flour production lead time was 1,429 minutes with 913 value-added activities, resulting 63.89% process cycle efficiency (PCE). After improvements, the lead time decreased to 1,194 minutes, boosting PCE to 76.47%, and increase of 12.58%.

Kaizen-based waste reduction in tapioca flour production at PT XYZ uses fishbone diagram analysis, with SOPs implemented to enhance efficiency and prevent issues. For waste transportation, solutions include replacing wooden boards with sturdier ones, routine cleaning of flour deposits on the floor, and adding burlap sacks on uphill paths to make them more stable and safe, thus accelerating the movement of workers. In overcoming overprocessing, workers are increased in their precision in the initial separation and given an understanding of the parts that must be separated, thus avoiding process repetition and saving time. Meanwhile, for unnecessary motion, the use of trolleys as a tool to move products to the warehouse can speed up transportation, reduce workload, and minimize the risk of accidents.

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