



Manufacturing Processes and Manufacturing Systems

Analysis Quality for Kernel Production with Seven Tools Method

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A B S T R A C T

In today's era of rapid industrial advancement, the palm oil industry in Indonesia has experienced significant growth, intensified competition and prompting companies to enhance production quality to remain competitive. Predominantly acting as raw material suppliers, many palm oil companies, including those in Southeast Sulawesi, are required to meet stringent quality standards set by their domestic and international partners. One such company processes oil palm into crude palm oil (CPO), palm kernel, fibre, and kernel shell, with CPO and kernel being distributed to partner companies under strict quality agreements. A breach of these agreements, particularly in kernel quality, has led to penalties and potential termination of partnerships. Palm kernel oil (PKO), a high-value derivative, must meet quality criteria such as free fatty acid content, moisture, dirt content, and kernel integrity. Observations revealed recurring deviations from these standards, notably in excessive dirt content. This study aims to identify root causes of quality issues using the Seven Quality Control Tools method, supported by primary data including production outputs and interviews with workers. The analysis identified key contributing factors: inadequate adherence to machine efficiency guidelines by operators, sorting errors in raw materials, and mismatched or poorly maintained machinery. Corrective actions were proposed using 5W+1H analysis, emphasizing the need for operator compliance with efficiency protocols, improved raw material handling, and appropriate machine usage and maintenance to ensure consistent kernel quality aligned with agreed standards.

1. INTRODUCTION

In the current era of rapid advancement, competition across various industries has become increasingly intense. Accordingly, each company continually seeks to enhance its capacity and capabilities to maintain competitiveness within its respective industry. The palm oil industry in Indonesia has shown significant and accelerating growth in recent years [9]. This development has inevitably impacted competition within the palm oil industry [2]. The majority of palm oil companies in Indonesia primarily process palm oil into semi-finished products, which are then delivered to partner companies both domestically and internationally for further processing into final products ready for distribution to end customers [1]. Essentially, the Indonesian palm oil industry tends to play the role of a primary raw material supplier for various finished goods. Current market competition continues to drive many palm oil

companies, as raw material suppliers, to enhance their services and ensure consistent production quality in order to remain a preferred choice among manufacturers [3]. The quality of raw materials will significantly affect the final outcome of the product. In this context, for products derived from palm oil, the outcome is not solely about product quality. It also relates to the quantity of the final product.

Southeast Sulawesi is one of the provinces in Indonesia experiencing significant growth in the palm oil industry [4]. One of the palm oil companies in Southeast Sulawesi is actively engaged in processing palm oil into several products, including crude palm oil (CPO), palm kernel, fibre, and kernel shell. Two of these products, fibre and kernel shell are utilized internally by the company as fuel for its own power generation. The other two products are distributed to partner companies, both domestically and internationally, in accordance with specific criteria. Before establishing a partnership, these partner companies typically acting as manufacturers generally provide detailed information

regarding the criteria they seek in selecting raw material suppliers. This information is communicated to the palm oil company as the prospective supplier. Consequently, both parties negotiate and establish a cooperation agreement based on mutually accepted terms concerning quality, quantity, service, and other relevant criteria. Any violation of these agreements typically results in sanctions for the supplier, ranging from formal warnings to, in more serious cases, termination of the partnership.

In general, the palm oil industry produces two types of palm oil: crude palm oil (CPO) and palm kernel oil (PKO) [5]. Crude palm oil (CPO) is obtained through the boiling and pressing of oil palm fruit, whereas palm kernel oil (PKO) is derived from the seed or kernel of the palm fruit [6]. In the production process of 100 kg of oil palm fruit, the proportion of palm kernel oil (PKO) obtained is approximately 20% of the total palm oil output [7]. Meanwhile, crude palm oil (CPO) yields a higher percentage of the total output. However, the selling price of palm kernel oil (PKO) is higher compared to that of CPO. Due to its premium price, the quality of PKO must adhere to strict standards that require careful attention. These quality standards can be assessed early on by examining the palm kernel seeds produced. The quality of PKO is determined by factors such as free fatty acid (FFA) content, moisture level, and dirt content [8]. Additionally, the presence of broken kernels can affect the three aforementioned quality parameters. One of the palm oil companies in Southeast Sulawesi has reached an agreement with its partner company regarding the standardization of these four kernel quality aspects. The following data outlines the standards as documented in the company's Standard Operating Procedure (SOP):

Table 1. Kernel quality standards

Kernel Quality Standards	
Moisture	≤ 7%
Dirt	≤ 6%
Broken Kernel	≤ 15%
FFA	≤ 2%

(Source : SOP Company)

To ensure that the kernel quality consistently meets the agreed standards, the company conducts tests on production outputs at specific intervals, depending on the kernel production volume. Within a two-month period, the company can perform up to 24 quality tests. These results are documented in the following checklist:

Table 2. Kernel quality for May - June 2020

Checksheet					
Division	: Kernel	Observation count	: 24 Days		
Department	: Production	Data recorder	: Sri Wahyu Nensi		
Product	: Kernel	Periode	: 2 May 2020 – 30 June 2020		
No	Date	FFA (%)	Moist (%)	Dirt (%)	Total Production (Kg)
1	02/05/2020	1,05	5,58	7,20	9007
2	04/05/2020	1,08	5,60	7,70	7367
3	05/05/2020	1,13	5,62	7,65	8261
4	07/05/2020	1,12	5,64	7,85	8871
5	08/05/2020	1,06	5,88	7,59	6441
6	09/05/2020	1,11	5,80	7,95	5383
7	12/05/2020	1,13	5,72	7,60	8136
8	14/05/2020	1,10	5,76	7,70	6986
9	15/05/2020	1,16	5,67	7,50	6551
10	18/05/2020	1,35	5,20	8,02	6770

11	19/05/2020	1,28	5,68	7,86	5739
12	30/05/2020	1,06	5,57	7,60	6218
13	02/06/2020	1,08	5,65	7,50	5388
14	03/06/2020	1,24	5,52	8,00	10397
15	05/06/2020	1,05	5,48	8,10	8819
16	06/06/2020	1,15	5,57	7,80	5705
17	08/06/2020	1,17	5,51	8,00	8509
18	09/06/2020	1,10	5,58	8,15	7209
19	10/06/2020	1,07	5,76	8,10	5886
20	12/06/2020	1,10	5,63	8,25	7582
21	13/06/2020	1,15	5,68	8,20	6725
22	15/06/2020	1,26	5,65	8,10	6316
23	17/06/2020	1,20	5,71	8,00	6237
24	30/06/2020	1,19	5,65	8,20	4347

(Source : Observation data)

Observation data reveals that the dirt content in the kernels exceeds the standard limits outlined in the company's SOP. The frequency of data dirt exceeding the limit set in the SOP is 100%.. This has tangible consequences for the palm oil industry involved, as it must pay penalty fees to its partner company in accordance with the agreed terms. If such violations persist, the palm oil company may face more severe sanctions, including termination of the partnership by the partner company. The complex kernel production process necessitates a specialized approach to identifying the root causes of quality deviations from established standards. To address this, the researcher employs the Seven Quality Control Tools method to find solutions for quality control of the production output, specifically the palm kernel seeds.

The object of the author's previous research had never been touched by outside researchers due to its remote location. Therefore, the researcher saw an opportunity to solve the existing problems using the seven tools method, which is often effective in finding solutions to related problems.

2. STUDY LITERATURE

Seven Tools is an instrument that aims to assess quality standards that can help companies overcome various issues and improve their processes. The seven tools method can also be used to identify inconsistencies in a production process and understand the causes behind errors that arise during production. Basically, Seven Tools consists of seven control tools, namely flow charts, check sheets, histograms, Pareto diagrams, control charts, scatter diagrams, and fishbone diagrams.

1. Flowcharts are tools used in organizations to illustrate their operational processes, making them easier to understand based on the sequence from one stage to the next.
2. Checklists are documents that contain information grouped in a simple, structured, and organized manner within a process.
3. A Histogram is a collection of information that aims to present an easy-to-analyze summary of data, and the data is displayed graphically for elements in the process that frequently appear.
4. A Pareto Chart is a type of chart that identifies the causes of problems based on relative frequency and the order of an issue, so that important problems can be resolved.
5. A Scatter Diagram is a type of diagram used to assess the relationship between various factors relevant to the cause and effect of a quality.
6. A Control Chart is used to monitor data or materials that are outside the specified limits. The creation of a control chart is influenced by variable data and attribute data, each variable having its own control chart. To establish a control chart, there are elements consisting of:

3. RESEARCH METHODOLOGY

This study was conducted using types of data collection methods: primary data. The primary data consisted of quality standards and production output, and observation with interviews the workers. In the data processing stage, the researcher employed several formulas as follows:

$$\text{Range} = \text{Max} - \text{Min} \quad \text{Eq. 1}$$

$$\text{Class interval} = \text{Range/Class width} \quad \text{Eq. 2}$$

$$\begin{aligned} \text{Lower class limit of the first class} \\ = \text{Minimum value} - 0,005 \quad \text{Eq. 3} \end{aligned}$$

$$\begin{aligned} \text{Upper class limit of the first class} \\ = \text{Lower class limit of the first class} + \text{class interval} \quad \text{Eq. 4} \end{aligned}$$

To facilitate the calculation and data visualization processes in this study, the researcher utilized Microsoft Excel. Technically, this study employed the Seven Tools method. The following is the flowchart of this research:

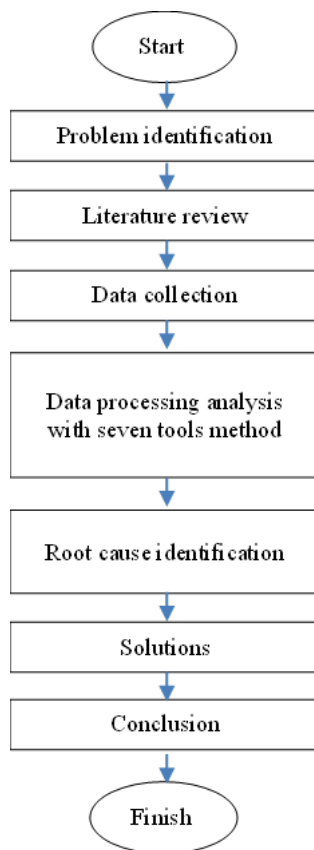


Figure 1. Flowchart

4. RESULT AND DISCUSSION

1. Check Sheet

A Check Sheet is a simple inspection form designed to contain a list of necessary items for recording production data, allowing the data to be organized systematically and orderly as it is collected at the site. In Table.1, the data represents the results of kernel product quality observations using the check sheet for the period of May to June 2020 at the company.

2. Stratification

To identify the specific defects present in the kernel products, the data was categorized and grouped into smaller

subcategories, a process known as stratification. Based on data obtained from PT. Sultra Prima Lestari, the types of defects identified are FFA, Moisture, and Dirt. The following table presents the results of the stratification:

Table 3. Stratification

Stratification					
Division	: Kernel	Observation count	: 24 Days		
Department	: Production	Data recorder	: Sri Wahyu Nensi		
Product	: Kernel	Periode	: 2 May 2020 – 30 June 2020		
Observation	Date	Total production	Type of standart		
			FFA (%)	Moist (%)	Dirt (%)
1	02/05/2020	9007	1,05	5,58	7,20
2	04/05/2020	7367	1,08	5,60	7,70
3	05/05/2020	8261	1,13	5,62	7,65
4	07/05/2020	8871	1,12	5,64	7,85
5	08/05/2020	6441	1,06	5,88	7,59
6	09/05/2020	5383	1,11	5,80	7,95
7	12/05/2020	8136	1,13	5,72	7,60
8	14/05/2020	6986	1,10	5,76	7,70
9	15/05/2020	6551	1,16	5,67	7,50
10	18/05/2020	6770	1,35	5,20	8,02
11	19/05/2020	5739	1,28	5,68	7,86
12	30/05/2020	6218	1,06	5,57	7,60
13	02/06/2020	5388	1,08	5,65	7,50
14	03/06/2020	10397	1,24	5,52	8,00
15	05/06/2020	8819	1,05	5,48	8,10
16	06/06/2020	5705	1,15	5,57	7,80
17	08/06/2020	8509	1,17	5,51	8,00
18	09/06/2020	7209	1,10	5,58	8,15
19	10/06/2020	5886	1,07	5,76	8,10
20	12/06/2020	7582	1,10	5,63	8,25
21	13/06/2020	6725	1,15	5,68	8,20
22	15/06/2020	6316	1,26	5,65	8,10
23	17/06/2020	6237	1,20	5,71	8,00
24	30/06/2020	4347	1,19	5,65	8,20

(Source : Data Processing)

3. Histogram

A histogram is used to show the frequency distribution of how often different values occur based on the available data.

a) FFA

Table 4. FFA Data

FFA data (%)					
1,05	1,08	1,13	1,12	1,06	1,11
1,13	1,10	1,16	1,35	1,20	1,06
1,08	1,24	1,05	1,15	1,17	1,10
1,07	1,10	1,15	1,26	1,20	1,19

(Source : Data Processing)

Minimum value : 1,05

Maximum value : 1,35

Range : Max – Min
1,35 – 1,05 = 0,3 Eq. 1

Class width : 6

Class interval : Range/Class width
0,3/6 = 0,5 Eq. 2

Table 5. Class interval FFA data

FFA				
No	Interval class		Range	Frequency
1	1,045	1,095	1,07	7
2	1,095	1,145	1,12	7
3	1,145	1,195	1,17	5

4	1,195	1,245	1,22	3
5	1,245	1,295	1,27	1
6	1,295	1,350	1,32	1

(Source: Data Processing)

Example calculation :

Lower class limit of the first class

= Minimum value – 0,005

Eq. 3

= 1,05 – 0,005

= 1,045

Upper class limit of the first class

= Lower class limit of the first class + class interval Eq. 4

= 1,045 + 0,5

= 1,095

Lower class limit of the second class

= Upper class limit of the first class

Range = Lower class limit of the second class + Upper class limit of the second class / 2

= 1,045 + 1,095/2

= 1,07

Frequency = The frequency of data within the class interval

After constructing the frequency table, the histogram for FFA is obtained as follows:

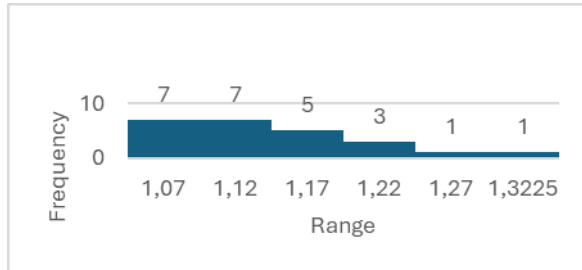


Figure 2. FFA histogram

b) Moist

Table 6. Moist data

Moist data (%)					
5,58	5,60	5,62	5,64	5,88	5,80
5,72	5,76	5,67	5,20	5,68	5,57
5,65	5,52	5,48	5,57	5,51	5,58
5,76	5,63	5,68	5,65	5,71	5,65

(Source: Data Processing)

Minimum value : 5,2

Maximum value : 5,88

Range : Max – Min
5,88 – 5,2 = 0,68

Eq. 1

Class width : 6

Class interval : Range/class width
0,68/6 = 0,11333

Eq. 2

Table 7. Class interval moist data

Moist				
No	Interval class	Range	Frequency	
1	5,195	5,308	5,251	1
2	5,308	5,421	5,365	1
3	5,421	5,535	5,478	2
4	5,535	5,648	5,591	8
5	5,648	5,761	5,705	10
6	5,761	5,880	5,820	2

(Source: Data Processing)

Example calculation :

Lower class limit of the first class

= Minimum value – 0,005

Eq. 3

= 5,2 – 0,005

= 5,195

Upper class limit of the first class

= Lower class limit of the first class + class interval Equation 4

= 5,195 + 0,11333

= 5,308

Lower class limit of the second class

= Upper class limit of the first class

Range = Lower class limit of the second class + Upper class limit of the second class / 2

= 5,195 + 5,308/2

= 5,251

Frequency

= The frequency of data within the class interval

After constructing the frequency table, the histogram for Moist is obtained as follows:

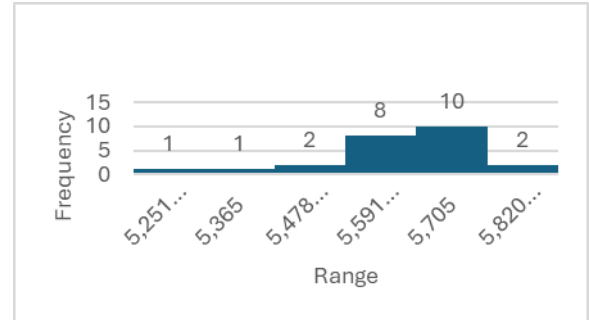


Figure 3. Moist histogram

c) Dirt

Table 8. Dirt data

Dirt data (%)					
7,20	7,70	7,65	7,85	7,59	7,95
7,60	7,70	7,50	8,02	7,86	7,60
7,50	8,00	8,10	7,80	8,00	8,15
8,10	8,25	8,20	8,10	8,00	8,20

(Source: Data Processing)

Minimum value : 7,2

Maximum value : 8,25

Range : Max – Min
8,25 – 7,2 = 1,05

Eq. 1

Class width : 6

Class interval : Range/class width
1,05/6 = 0,175

Eq. 2

Table 9. Class interval dirt data

Dirt				
No	Interval class	Range	Frequency	
1	7,195	7,370	7,282	1
2	7,370	7,545	7,457	2
3	7,545	7,720	7,632	6
4	7,720	7,895	7,807	3
5	7,895	8,070	7,982	5
6	8,070	8,250	8,160	7

(Source: Data Processing)

Example calculation :

Lower class limit of the first class

= Minimum value – 0,005

Eq. 3

= 7,20 – 0,005

= 7,195

Upper class limit of the first class

= Lower class limit of the first class + class interval Eq. 4

= 7,195 + 0,175

= 7,370

Lower class limit of the second class

= Upper class limit of the first class

Range

= Lower class limit of the second class + Upper class limit of the second class / 2
 = $7,195 + 7,37/2$
 = 7,2825
 Frequency
 = The frequency of data within the class interval

After constructing the frequency table, the histogram for Dirt is obtained as follows:

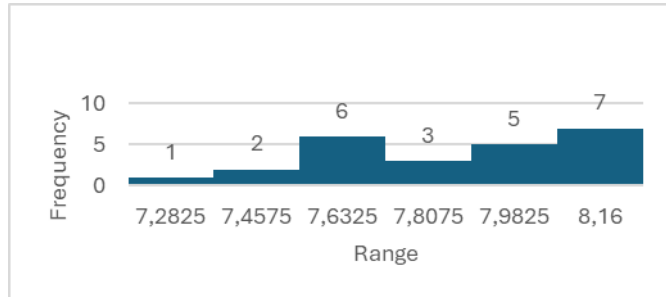


Figure 4. Dirt histogram

4. Control chart

To determine the appropriate type of control chart for this study, it is necessary to first understand the characteristics of the available data. Control charts serve to indicate whether the existing defect data remains within control limits. The following are control charts for each type of standard found in the kernel product:

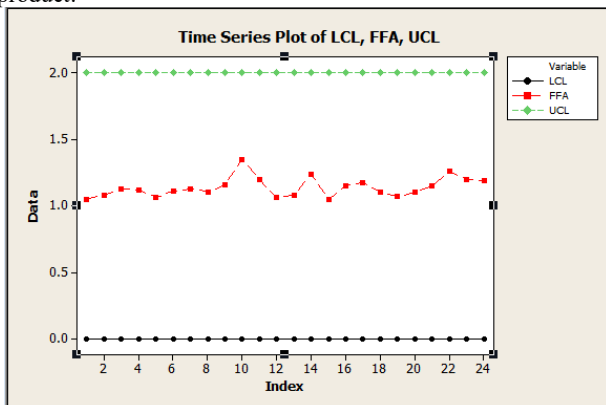


Figure 5. Control chart of FFA

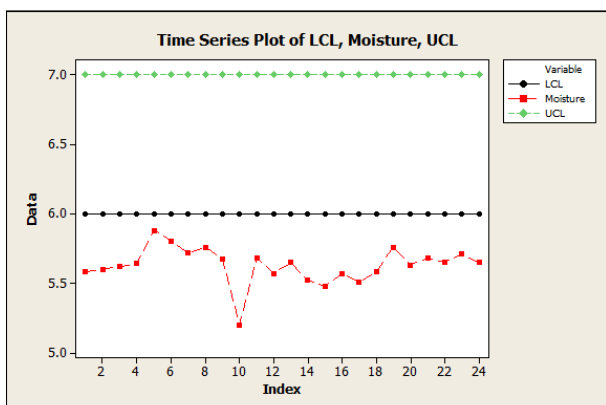


Figure 6. Control chart of moist

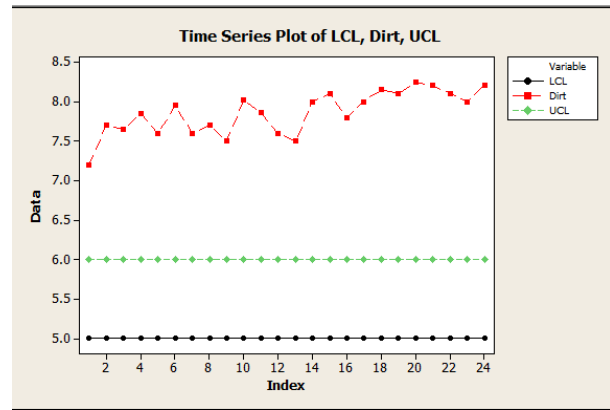


Figure 7. Control chart of dirt

5. Pareto chart

A Pareto chart is used to identify and prioritize problems that require improvement. This chart helps determine the most significant issues affecting quality improvement efforts and highlights the key problems that should be addressed first. It ranks issues from the most to the least significant based on their impact. The following table presents the data used in the Pareto chart:

Table 11. Pareto calculation

Standart	Total	Percent	Kumulative
FFA	27,31	8%	8%
Moist	135,11	38	46%
Dirt	188,62	54%	100%
Total	351,04		

(Source: Data Processing)

The following Pareto diagram illustrates the types of defects observed in kernel products during the period from May 2020 to June 2020.

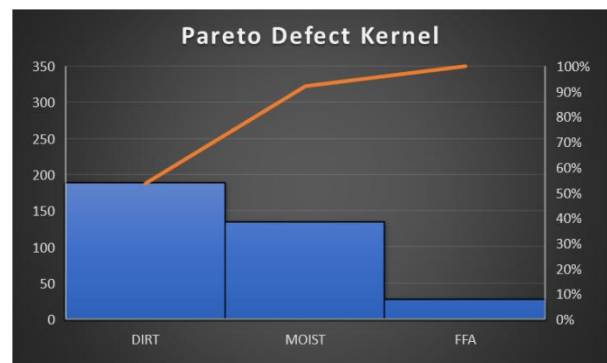


Figure 8. Pareto of defect

6. Scatter Diagram

Based on the observations conducted, several variables were identified as contributing factors to defects in the kernel products. These variables are as follows:

- Variable 1 (X1): Dirt
- Variable 2 (X2): FFA
- Variable 3 (X3): Moisture

To determine the extent of the influence of the frequency of each of the above variables on the production output (Y), data analysis was carried out using a scatter diagram.

- scatter diagram variable X1 with Y

Table 12. Total between variable X1 and Y

No	Total product	FFA (%)	No	Total product	FFA (%)
1	9,007	1,05	13	5,388	1,08

2	7,367	1,08	14	10,379	1,24
3	8,261	1,13	15	8,819	1,05
4	8,871	1,12	16	5,705	1,15
5	6,441	1,06	17	8,509	1,17
6	5,383	1,11	18	7,209	1,10
7	8,136	1,13	19	5,886	1,07
8	6,986	1,10	20	7,582	1,10
9	6,551	1,16	21	6,725	1,15
10	6,770	1,35	22	6,317	1,26
11	5,739	1,28	23	6,237	1,20
12	6,218	1,06	24	4,347	1,19

(Source: Data Processing)

Based on the above data, a scatter diagram was constructed, as shown in the figure below.

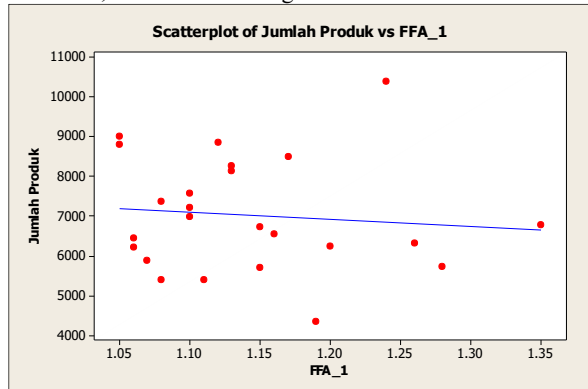


Figure 9. Scatter diagram illustrating the relationship between the number of defective products and FFA defects.

b. Scatter diagram variable X2 with Y

Table 13. Total between variable X2 and Y

No	Total product	Moist (%)	No	Total product	Moist (%)
1	9,007	5,58	13	5,388	5,65
2	7,367	5,60	14	10,379	5,52
3	8,261	5,62	15	8,819	5,48
4	8,871	5,64	16	5,705	5,57
5	6,441	5,88	17	8,509	5,51
6	5,383	5,80	18	7,209	5,58
7	8,136	5,72	19	5,886	5,76
8	6,986	5,76	20	7,582	5,63
9	6,551	5,67	21	6,725	5,68
10	6,770	5,20	22	6,317	5,65
11	5,739	5,68	23	6,237	5,71
12	6,218	5,57	24	4,347	5,65

(Source: Data Processing)

Based on the above data, the scatter diagram was created as shown below :

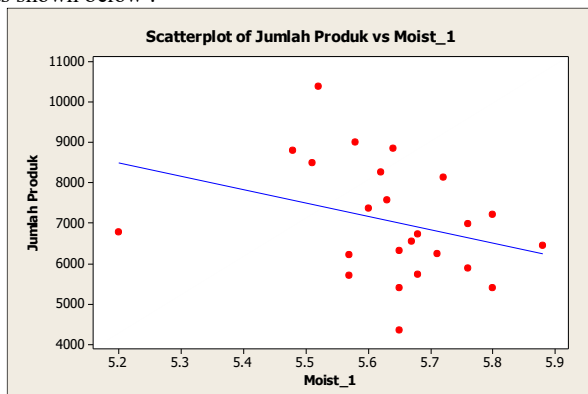


Figure 10. Scatter diagram illustrating the relationship between the number of defective products and Moist defects.

c. Scatter diagram variabel X3 with Y

Table 14. Total between variable X3 and Y

No	Total product	Dirt (%)	No	Total product	Dirt (%)
1	9,007	7,20	13	5,388	7,50
2	7,367	7,70	14	10,379	8,00
3	8,261	7,65	15	8,819	8,10
4	8,871	7,85	16	5,705	7,80
5	6,441	7,59	17	8,509	8,00
6	5,383	7,95	18	7,209	8,15
7	8,136	7,60	19	5,886	8,10
8	6,986	7,70	20	7,582	8,25
9	6,551	7,50	21	6,725	8,20
10	6,770	8,02	22	6,317	8,10
11	5,739	7,86	23	6,237	8,00
12	6,218	7,60	24	4,347	8,20

Based on the above data, the scatter diagram was constructed as shown below:

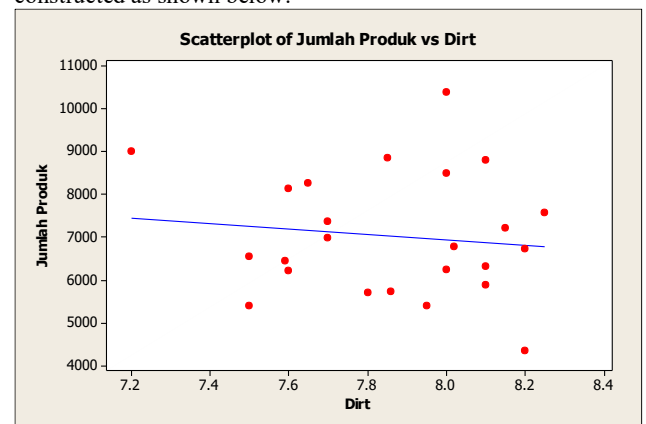


Figure 11. Scatter diagram illustrating the relationship between the number of defective products and Dirt defects.

7. Cause and Effect Diagram

Based on the results of the Pareto and scatter diagram analyses, the main issue in the palm oil industry under study was dirt defects in the kernel products. Before constructing the fishbone diagram, the author conducted interviews with the production assistant to identify the problems in the production process. The following are the findings from the researcher's interview with the informant regarding the causes of dirt defects in the kernel products of the palm oil industry under study:

Table 15. Interview results with the production department informant

No	Questions	Answers
1	Which product most frequently experiences defects during production?	The products most frequently experiencing defects are CPO and kernel, with defects characterized by quality parameters falling outside the established standard limits.
2	Which of the two products has the highest defect frequency?	The highest defect frequency was observed in the kernel products.
3	What types of defects are present in the kernel products?	The defects observed in the kernel products include FFA content, moisture, dirt, and broken kernels.
4	What are the factors that cause defects in kernel products?	The primary factors causing defects are human, material, and machine factors.

5	In kernel products, which type of defect has the highest occurrence among all existing defect types?	The most frequent type of defect in kernel products is dirt.
6	What are the causes of dirt defects in kernel products?	The most common causes are human negligence, machine conditions, and material quality.
7	What are the common issues related to human, machine, and material factors that lead to dirt defects in kernel products?	In terms of the human factor, the issue arises from insufficient operator control over the ripple mill machine and the lack of coordination between operators and the laboratory team in conducting quality checks, which are typically carried out every two hours during production. As for the machine factor, it is caused by an unstable feeding mechanism into the ripple mill and a worn-out hydrocyclone, which results in losses to the shell. Meanwhile, in the material factor, the problem is due to the processed fruits having varying nut (nud) characteristics.

(Source: Brainstorming with informant from the palm oil industry)

Based on Table 15, it can be observed that the main issue in kernel production is the dirt quality that exceeds the company's quality standards. This is frequently caused by factors related to raw materials, human error, and production machinery.

Table 16. 5W+1H Defect dirt

No	Factor	What?	Why?	Who?	Where?	When?	How?
1	Man	Operator less controls	There are not have coordination between operator and laboratory	Operator ripple mill	Nud separation area	In the nud process separation	Increase the coordination between operator and laboratory
2	Machine	Big losses	The hydrocyclone shows signs of wear, and the machine's efficiency is not optimal.	Maintenance division and operator	Nud separation area	In the nud process separation	Do a preventive maintenance and setting the efficiency
3	Material	The different of nud types	The types of fruit is not same	Grading operator	Fruit sorting area	In fruit sorting process	Sort the fruits according to their criteria.

(Source: Analysis process)

The fishbone diagram below illustrates the 'dirty' defect in kernel products, which has been identified as the most prevalent defect among all defect types.

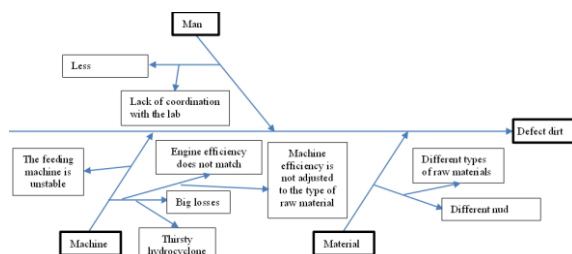


Figure 12. Fishbone defect dirt

Based on Table 3, it can be seen that kernel production during the period of May to June was carried out over 24 production days, with the highest daily production recorded on June 3, 2020. The total production during May–June amounted to 168,850 kilograms. According to Table 4, after categorizing the quality data, three types of defects were identified in the

kernel products, namely FFA, Moisture, and Dirt. Each defect type occurred in 24 quality data entries. Therefore, during May–June 2020, a total of 72 quality defect data entries were recorded, categorized into the three aforementioned types.

Based on Figure 2, it is known that the number of data entries in the first class is 7, the second class 7, the third class 5, the fourth class 3, and both the fifth and sixth classes contain 1 data entry each, resulting in a total of 24 entries. Based on Figure 3, the number of data entries in the first class is 1, the second class 1, the third class 2, the fourth class 8, the fifth class 10, and the sixth class 2, also totaling 24 entries. Based on Figure 4, the number of data entries in the first class is 1, the second class 2, the third class 6, the fourth class 3, the fifth class 5, and the sixth class 7, with a total of 24 entries. According to Figure 5, all data related to FFA quality lie within the Upper Control Limit (UCL) and Lower Control Limit (LCL) set by the company, indicating no significant issues with the FFA quality. According to Figure 6, all data related to Moisture quality fall below the company's established LCL. Although the data fall below the LCL, this does not pose a problem. In fact, when Moisture values are below the LCL, the product's moisture quality can be considered better than the company's quality standards. According to Figure 7, all data related to Dirt quality are above the UCL set by the company. This condition may lead to customer complaints or even product returns to the factory.

The Pareto diagram shows that dirt defects in kernel products represent the most significant issue among all quality defects, accounting for 95% of the total, with approximately 188.6 data entries. According to Figure 9, the scatter diagram for FFA defects indicates no relationship (no correlation), meaning there is no tendency for specific values of variable X to occur together with specific values of variable Y. Therefore, it can be concluded that the FFA defect scatter diagram is likely uncorrelated. According to Figure 10, the scatter diagram for Moist defects shows a negative correlation, in which higher values of variable X are associated with lower values of variable Y, and vice versa. According to Figure 11, the scatter diagram for Dirt defects also shows a negative correlation, where higher values of variable X correspond with lower values of variable Y, and lower values of X correspond with higher values of Y.

The explanation of the factors contributing to dirt defects in kernel products is as follows:

1. Human Factor

Regarding the human factor, operators currently pay insufficient attention to the instructions provided by the laboratory team to monitor changes in machine efficiency, as per the laboratory's analysis, which should range between 95% and 98% and be conducted every two hours. Although the results are communicated to the operators, in practice, they do not follow the laboratory's instructions and continue using the initial machine efficiency setting of 96%. As a result, defects occurring during the production process cannot be minimized.

2. Machine Factor

Regarding the machine factor, the ripple mill machine used is not adapted to the type of raw material being processed. The raw materials consist of three types: small nuts, medium nuts, and large nuts. However, in practice, only one machine is used, which is specifically designed for large nuts. Consequently, when small and medium nuts are processed using the same machine at the same efficiency rate of 96%, it leads to significant losses, such as increased dirt levels. This occurs

because many small nuts are crushed and mixed with shell fragments and kernels. Additionally, the hydrocyclone system experiences wear and tear, which disrupts machine operation and causes shutdowns during production.

3. Material Factor

Regarding the material factor, it is known that the palm fruit processed produces nuts categorized into three types: Tenera (characterized by a thin shell), Dura, and Pisifera (characterized by a thick shell). Each type requires different ripple mill efficiency settings based on their characteristics. However, during the sorting process of the incoming palm fruit, the identification is not carried out carefully, leading to incorrect efficiency settings for the ripple mill during production. This, in turn, results in a high level of production losses.

5. CONCLUSION

Concluded that the factors causing kernel production to fall below standard include the human factor, the raw material factor, and the machine factor. From the human aspect, the machine efficiency analysis provided by the laboratory every two hours is not being followed by the operators during production. From the raw material aspect, frequent errors occur in the sorting process, resulting in improper classification of raw materials according to their respective types. From the machine aspect, only one ripple mill machine is used, which is specifically designed for large nuts. However, it is also used to process small and medium nuts without efficiency adjustments. Moreover, the efficiency changes that are supposed to be implemented every two hours are neglected by the operators, and the hydrocyclone system often experiences wear, leading to operational disruptions. To improve kernel quality, several corrective actions have been proposed through a 5W+1H analysis. In regard to the human factor, operators should carry out machine efficiency adjustments within the recommended range of 95%–98% as instructed by the laboratory, and these adjustments must be performed every two hours during production. For the raw material factor, there should be strict supervision of Loading Ram operators to ensure compliance with the raw material sorting procedures, along with a rechecking process to verify the accuracy of sorting. As for the machine factor, the ripple mill machine used must be appropriate for the specific type of raw material being processed. Additionally, operator compliance with laboratory instructions should be monitored continuously, and preventive maintenance must be conducted regularly on the hydrocyclone to avoid performance degradation.

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