Quality control of palm oil crude (CPO) using six sigma method in PT Karya Tanah Subur West Aceh regency

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Abstract. The rapid world demand for palm oil shows an increasing tendency towards product consumption in palm oil raw materials. PT. Karya Tanah Subur is a company engaged in processing fresh fruit bunches that produce palm oil and palm kernel. Six Sigma is a method used to provide solutions and find the cause of product defects by providing a proposed improvement in several stages. The results showed that the causes of CPO oil quality discrepancies were obtained in the cause-and-effect diagram analysis, namely factors of workers, production machinery, work methods, materials. While the defect per million opportunities in free fatty acid levels is 35,528, impurities content is 18,899 and water content is 14,719. Based on the value of the average sigma level for free fatty acid levels that is equal to 3.38, the level of impurities sigma value of 3.57 and the water content of the sigma value of 3.68 sigma. Proposed improvement of product defects mismatch with the 5W + 1H method, namely in free fatty acid levels, work system improvements in the sorting of fresh fruit bunches, provide training to operators in the selection of appropriate fruits while impurities by monitoring oil purification operators, machine maintenance cleaning periodically at the sorting station, periodic checking every hour, while the moisture content of the corrective action that must be taken is to supervise the sterilizer operator.

1. Introduction
Indonesia is one of the largest producers and exporters of palm oil. The rapid world demand for palm oil shows an increase in line with the world population from year to year increasing due to the increasing consumption of products with basic raw materials crude palm oil [5].

According to [3] of the rapid world demand for palm oil consumption at this time, Indonesia is the largest producer of palm oil in the world. According to data from the United States Department of Agriculture (USDA) that domestic consumption of palm oil in 2019 is estimated to reach 12.75 million tons or around 17% of total world consumption which reaches 74.48 million tons. While the second largest country is India, reaching 10.19 million tons or 13.68% of total world consumption. Furthermore, the third largest was China, with 7.22 million tons or around 9.7%.
Figure 1. Ten countries with the world largest crude palm oil consumption.

2. Literature Review

Therefore, the high demand in the palm oil industry for the types of processed raw materials for palm oil is increasingly rapid and competition is also increasingly competitive. Companies also have to compete to survive by showing the superiority of the products produced. Quality control is a company’s tactics and strategy to achieve market excellence, competitive advantage by having the character to be able to satisfy the needs of consumers [5]. Therefore, if a product produced does not meet a need in accordance with the wishes of consumers, there will be problems with quality. An issue can be controlled by measuring the performance of the industrial system according to the strategy [7].

Palm oil parameter standards in the company based on company operational standard specifications that have been determined through the government BSN (National Standard Agency) have set the standardization of CPO palm oil contained in SNI-01-2901-2006 is the level of ALB (Free Fatty Acid) (2.5-3.0%), impurities content (0.01-0.02%) and water content (0.1-0.2%) [9].

PT. Karya Tanah Subur is engaged in processing fresh fruit bunches that produce palm oil and crude palm oil. The parameters that determine the quality of palm oil are free fatty acid content, water content, and impurities. The current situation shows that in processing palm oil, the quality produced turns out that some still do not meet the standard specifications set by the company. Efforts to reduce defects in palm oil products are by controlling the quality of palm oil.

Based on the types of parameters of palm oil shows that there are still types of defects in the three parameters, namely the levels of ALB in July-December 2018 shows that there are still many data that are above the standard limits that have been set and in 2019 ALB levels that exceed the standard limit is at in June, while for the level of impurities that is data that exceeds the disability limit occurs in September-November 2018 and for 2019 occurred from March-June which exceeds the established standard limits, while the water content that is not according to the standards set by the company namely in May-June 2019.

In their research [12] with the title "Analysis of Quality Control of CPO (Crude Palm Oil) Using Six Sigma in the CPO Processing Plant of PT. Gunajaya Karya Gumilang, Kedawangan District, Ketapang Regency. The results of his research showed that free fatty acid quality remained at the level of 1.3 sigma with a DPMO value of 317,500 products that did not meet the requirements specified by SNI. Water content is at level 3 and impurities are approaching level 4 sigma.

Based on the description in the background of this research, it is necessary to analyze the efforts to control the quality of palm oil in PT. Karya Tanah Subur with the aim to determine the factors that cause
CPO palm oil quality mismatch, determine the sigma level in the process of controlling palm oil quality and provide suggestions for improvement of product defects with 5W+1H method.

3. Methods

3.1 Quality Control
According to [8] Quality is a key success factor for overall business growth characteristics of a product and service from marketing, maintenance, design, price and durability of product availability. If a product produced by a company is not in accordance with the standards to be set then the product is said to be a defective product group [7].

Quality in the world of manufacturing can be interpreted as an item or result to determine or decide on consumers who have bought the product/goods will not return to buy it [1].

Quality control is one of the techniques or methods that will be carried out before the end of the production process by producing the final product in accordance with established standards [10].

Steps in determining quality standards according to [6] there are four standards including:
1. Considering competition and competitor product quality
2. Considering the use of the final product
3. The selling price of the product is in accordance with the expected quality
4. Consist of several teams in the field carried out

3.2 Quality Control Aids
Quality control has seven statistical tools that are used to control quality, including Check Sheet, Stratification or Histogram, Histogram, Control Chart, Pareto Diagram, Scatter Diagram, Cause Chart (Fishbone Chart) [13].

3.3 Six Sigma
Six Sigma [4] generally consist of two words namely six meaning six, sigma means symbol or symbolic standard deviation which can be interpreted as a unit size by symbolizing a process or measure of sigma value. The Six Sigma method approach is also needed to approach science, equipment, training and measurement. The approach used in the Six Sigma method is define, measure, analyze, improve and control.

3.4 Steps of the Six Sigma Method
The steps for the Six Sigma method include:
1. Define
   Is a stage of improving quality by determining the proportion of defects to damage to production failures so you can use the SIPOC diagram to determine the process model "SIPOC (Suppliers, Inputs, Processes, Outputs, Customers).
2. Measure
   Measure is an improvement in the quality of Six Sigma, there are three things that need to be done, among others: determining the quality characteristics by determining CTQ (Critical to Quality), determining the control variable map and measuring sigma values.
3. Analyze
   Quality improvement programs that can be carried out include grouping types of disabilities, making pareto diagrams, making cause and effect.
4. Improve
   Improve is the cause of quality problems done by establishing an action plan to improve the quality of Six Sigma. In this improve phase there are stages that need to be done including determining the corrective action with the 5W+1H method, determining the action using the tree diagram method.
5. Control
Supervision is needed to be able to know the effect of the achievement process on the quality of product produced by documenting the procedures documented in the standard work guidelines.

3.5 Six Sigma Method as a Measurement Tool
Six Sigma as a measurement system uses defect per million opportunities as a unit of measurement. DPMO is a good measure for product or process quality, because it correlates directly with defects, costs and time wasted, to be able to see more clearly about sigma levels can be seen in Table 1. The relationship between Six Sigma and DPMO [1].

| Sigma    | Parts per Million       |
|----------|-------------------------|
| 6 Sigma  | 3.4 defects per million |
| 5 Sigma  | 233 defects per million |
| 4 Sigma  | 6,210 defects per million |
| 3 Sigma  | 66,807 defects per million |
| 2 Sigma  | 308,537 defects per million |
| 1 Sigma  | 690,000 defects per million |

3.6. SIPOC Diagram (Supplier, Input, Process, Output, Customer)
The SIPOC diagram is one of the Six Sigma tools used by the process improvement team to identify each element in the process improvement project before the process is run [4].

4. Results
4.1 Data Collection and Data Processing
Data collection was obtained by interviewing, documenting the company and fielding directly in the field at PT. Karya Tanah Subur located in Padang Sikabu Village, West Aceh Regency, Aceh Province. Data collection which includes data on the amount of production, causes of disability and conditions that exist in the production department. Whereas in data processing using the DMAIC method (Define, Measure, Analyze, Improve and Control).

4.2 Palm Oil Production Data (CPO)
Palm oil Production Data (CPO) in 2018-2019 can be seen in Table 2, as follows.

| Month               | Amount of Production CPO (Ton) |
|---------------------|--------------------------------|
| July 2018           | 5503                           |
| August 2018         | 5696                           |
| September 2018      | 5564                           |
| October 2018        | 5293                           |
| November 2018       | 5084                           |
| December 2018       | 5403                           |
| January 2019        | 6715                           |
| February 2019       | 6688                           |
| March 2019          | 6370                           |
| April 2019          | 6669                           |
| May 2019            | 6685                           |
| June 2019           | 6983                           |
4.3 Data on the Type of Palm Oil Damage (CPO)

Data on the type of damage to palm oil (CPO) products of PT. Karya Tanah Subur, there are three types of damage including free fatty acid (ALB), impurities content and water content, while data on the types of damage to palm oil (CPO) products in 2018-2019 can be seen in Table 3. as follows.

| Month         | Free fatty acid % | Total Reject | Dirt % | Total Reject | Moisture % | Total Reject |
|---------------|-------------------|--------------|--------|--------------|------------|--------------|
| July 2018     | 3.18              | 537          | 0.02   | 312          | 0.17       | 243          |
| August 2018   | 3.97              | 521          | 0.02   | 326          | 0.22       | 226          |
| September 2018| 3.17              | 540          | 0.03   | 372          | 0.20       | 252          |
| October 2018  | 3.13              | 541          | 0.03   | 385          | 0.25       | 265          |
| November 2018 | 3.30              | 555          | 0.03   | 314          | 0.22       | 243          |
| December 2018 | 3.31              | 552          | 0.02   | 339          | 0.19       | 248          |
| January 2019  | 2.84              | 506          | 0.02   | 348          | 0.20       | 283          |
| February 2019 | 2.52              | 576          | 0.02   | 361          | 0.22       | 261          |
| March 2019    | 2.43              | 568          | 0.03   | 389          | 0.22       | 259          |
| April 2019    | 2.60              | 592          | 0.03   | 339          | 0.29       | 245          |
| May 2019      | 2.71              | 506          | 0.03   | 336          | 0.32       | 267          |
| June 2019     | 3.48              | 581          | 0.03   | 345          | 0.30       | 259          |

4.4 Data processing

Data processing in this study uses the DMAIC (Define, Measure, Analyze, Improve and Control) approach which is a holistic approach to solve problems and improve six sigma processes. The approach will be described in stages as follows

4.4.1 Define Stage

Making the sequence of processes that occur can be done using SIPOC diagrams (Suppliers, Inputs, Processes, Outputs, Customers). At this stage, the process of processing fresh fruit bunches into CPO oil will be explained. The SIPOC diagram for the CPO oil processing is as follows:

1. Suppliers
   Suppliers of raw materials in the form of palm fruit or known as fresh fruit bunches used for the process brought in from the community and PT. Karya Tanah Subur itself.

2. Input
   Input is a raw material in the form of fresh fruit bunches that will be processed for processing palm oil imported from the community and the Oil Palm Plantations (PKS) unit of PT. Karya Tanah Subur itself.

3. Process
   It is a step or process of production activities ranging from receiving fresh fruit bunches to becoming CPO oil.

4. Results (Output)
   Output is the result obtained from the processing of fresh fruit bunches which are processed into Crude Palm Oil (CPO).

5. Customers
   Is a person or group that receives Crude Palm Oil (CPO) oil products produced by PT. Karya Tanah Subur, that sold to PT. Belawan Tangki Indonesia North Sumatra.
4.4.2 Measure Stage
Measure is the measurement phase is the second operational step in the Six Sigma method. The steps are as follows:

a. Determination of Quality Characteristics Critical to Quality (CTQ)
CPO product standards indicated the type of disability called CTQ (Critical to Quality), to further clarify the definition of the factors that affect the disability of CPO oil products.

Table 4. CTQ on crude palm oil (CPO).

| No | CTQ (Critical to Quality) | Type of CPO Oil | Specification Quality Standard CPO | Description |
|----|---------------------------|-----------------|------------------------------------|-------------|
| 1  | CTQ-1 Free Fatty Acid (ALB) | Grading Value ALB Between 2.5-3.0% | High concentrations of free fatty acids present in palm oil are very detrimental. This high free fatty acid results in lower oil yields and low oil quality, in food ingredients, fatty acids with levels greater than the weight of fat will result in unwanted and smell bad. |
| 2  | CTQ-2 Dirt | Dirt Between 0.01-0.02% | To get a better oil can be done by removing dirt, so if one is palm oil processing companies can reduce levels of dirt by level the smallest, then the oil already has the requirements to be a good oil. |
| 3  | CTQ-3 Moisture | Moisture Between 0.1-0.2% | The quality of palm oil must be maintained by removing volatile substances. Moisture in this case is one of the volatile substances when it is at temperatures above 100°C. High levels of water can cause odorous oils and reduce the quality of the palm kernel oil. |

b. P Full Chart (P-chart)
P control chart (P-chart) is used to determine the production process that occurs within the limits of control or not. If the process is within the control limits then it can be said that the process is stable, on the contrary if the process is outside the control limits then the process is said unstable. For making a control chart the first steps in making a control chart is as follows:
1. Check Sheet
Check Sheet method is useful to simplify the process of controlling CPO oil quality to determine the problem area based on the frequency of the type or cause and make a decision to make improvements or not. Check Sheet total oil production and type of damage CPO show in Table 5.
2. Charts of Free Fatty Acid (ALB)
The control chart of Free Fatty Acid (ALB) can be seen in the Full Control Chart Figure which is adjusted to the standards set as Figure 2:
Based on Figure 2, it can be explained that there are still points that are outside the upper control limit and the lower control limit. There are 8 points that are outside the control limit, namely at points 1, 2, 3, 4, 5, 6, 9 and 12 or 12 samples while points that are inside the control limit are 4 points including 7, 8, 10, and 11. Based on that, so that it can be said that the process is not controlled because of the point of fluctuation and irregularity this shows that the levels of Free Fatty Acid (ALB) in CPO oil products.
### Table 5. Check sheet total oil production and type of damage CPO.

| Month        | Levels ALB % | Total Reject | Levels of Dirt% | Total Reject | Levels Moisture % | Total Reject |
|--------------|--------------|--------------|-----------------|--------------|-------------------|--------------|
| July 2018    | 3.18         | 537          | 0.02            | 312          | 0.17              | 243          |
| August 2018  | 3.97         | 521          | 0.02            | 326          | 0.22              | 226          |
| September 2018 | 3.17       | 540          | 0.03            | 372          | 0.20              | 252          |
| October 2018 | 3.13         | 541          | 0.03            | 385          | 0.25              | 265          |
| November 2018| 3.30         | 555          | 0.03            | 314          | 0.22              | 243          |
| December 2018| 3.31         | 552          | 0.02            | 339          | 0.19              | 248          |
| January 2019 | 2.84         | 506          | 0.02            | 348          | 0.20              | 283          |
| February 2019| 2.52         | 576          | 0.02            | 361          | 0.22              | 261          |
| March 2019   | 2.43         | 568          | 0.03            | 389          | 0.22              | 259          |
| April 2019   | 2.60         | 592          | 0.03            | 339          | 0.29              | 245          |
| May 2019     | 2.71         | 506          | 0.03            | 336          | 0.32              | 267          |
| June 2019    | 3.48         | 581          | 0.03            | 345          | 0.30              | 259          |
| **Total Reject** | **6575**     | **4166**     |                 | **3051**     |                   |              |

**Figure 2.** Graph of free fatty acid (ALB).

3. Moisture
   The control chart for impurities from the CPO oil processing is based on the Table 4 adjusted to the standards set can be seen in Figure 3 set as follows:

**Figure 3.** Graph of moisture.
Based on Figure 3 above showed that there are still points that are outside the upper and lower control limits. There are 7 points that are outside the control limit including at the point or sample to 3, 4, 5, 9, 10, 11 and 12 while points that are inside the control limit are 5 of them at points 1, 2, 6, 7 and 8.

4. Dirt

Control chart for the water content processing is based on the Table 4 adjusted to the standards set can be seen in Figure 4 set as follow:

![Graph of Dirt](image)

**Figure 4.** Graph of dirt.

Based on Figure 4 above, showed that there are still points that are outside the control limits in accordance with the standards set by the company. There are 8 points that are outside the control limit including those at point 2, 4, 5, 8, 9, 10, 11 and 12 while points that are inside the control limit are 4 of them at point 1, 3, 6 and point 7. Based on that, so that it can be said that the process is not controlled.

4.4.3 Sigma Level

As for calculating the sigma level is used based on these calculations, then for the monthly calculations on the CPO oil processing produced by PT. Karya Tanah Subur works in the same way from each type of quality parameters can be seen in Figure 5. Level Sigma Crude Palm Oil set as follows:

![Level Sigma Crude Palm Oil (CPO)](image)

**Figure 5.** Graphs of sigma from the CPO oil processing process in PT. Karya Tanah Subur.

4.4.4 Analysis Phase

In the analysis phase, there are three stages carried out, among others, stratification, making pareto diagrams, and making causation.
4.4.5 Histogram
Based on Figure 6, showed that the highest total defect is in the level of Free Fatty Acid (ALB) with a total disability of 6,575 with a total percentage of 47.67%, the second highest disability is in the total dirt level with 4,166 with a total percentage of 30.21% and the smallest is moisture content of 3,051 with a percentage of 22.12%.

![Damage Crude Of Palm (CPO)](image.png)

**Figure 6.** Histogram percentage of CPO oil damage parameter types.

4.4.6 Diagram Pareto
Based on the Figure 7, the highest total percentage is Free Fatty Acid (ALB) with a total percentage of 47.46%, for the second largest percentage, namely the amount of impurities with a percentage of 30.21% and the smallest percentage, namely the level of impurities with a total percentage of 22.12% of total production.

![Pareto Chart of Type of Damage to CPO](image.png)

**Figure 7.** Pareto chart of type damage to CPO.

4.4.7 Cause and Effect Diagrams
Analyze what factors are the causes of product damage. Factors that influence and cause product damage in general can be classified as follows:
4.4.8 Control Stage

Efforts to suppress the factors that can cause a decrease in the quality of crude palm oil (CPO) Table 6. The mechanism of controlling the processing of Crude Palm Oil can be seen in the appendix.

5 Conclusion

Based on the analysis several conclusions are obtained including:

1. Factors causing CPO oil quality discrepancies are obtained in the cause-and-effect analysis diagram, known factors causing damage in production are derived from human/worker factors, production machines, work methods, materials/raw materials.

2. Based on the average Sigma Level value for free fatty acid levels that is equal to 3.38 and the Indonesian national standard that is equal to the levels of ALB (Free Fatty Acid) (2.5-3.0%), for impurities levels of sigma value of 3.57 and standards the Indonesian national level for impurities (0.01-0.02%) and the water content of the sigma value of 3.68 sigma and the Indonesian national standard for water content (0.1-0.2%).

3. Proposed improvement of product defects mismatch with the 5W+1H method, namely the levels of Free Fatty Acid that must be improved work systems in sorting FFB fruit, provide training to operators in the selection of appropriate fruit, while for the level of impurities, the improvement is to supervise operators oil refining, periodic engine maintenance, cleaning at the sorting station, conducting periodic checks every hour, while for moisture content the corrective action that must be taken is to supervise sterilizer operators.

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Appendices A. The Mechanism of Controlling the Processing of Crude Palm Oil

| PT. KARYA TANAH SUBUR | Palm Oil Processing Procedure |
|-----------------------|-------------------------------|
| **CPO Production Process** |                               |
| **Purpose of the Procedure:** To minimize the increase and variation in Crude Palm Oil levels (CPO) to conform to specified specifications |                               |

| Aspect                          | Maintenance Plan                              | Control                                                                 |
|---------------------------------|-----------------------------------------------|-------------------------------------------------------------------------|
| Equipment Use/Boiling Machine   | Tool Checking and Machine Before Process      | Provide special time to ensure that the engine is in condition good to avoid Process errors that can result in damage to the product or work accident. Provide training to each operator about usage the right tools / machines, good for new operators, as well as old operator. Arrange the rules of work usage steps every tool / machine. Provide written information in the form of instructions regarding the steps to use the tool and placed in a location that makes it easy for the operator to know and carry out the steps and the procedure in particular in the engine temperature setting. Make instructions regarding stages of maintenance and schedule implementation of the maintenance process. The quality of raw materials is certainly very influential in quality products, therefore the selection of the right raw materials should be done starting at the time of procurement, and when sorting TBS fruits. Knowledge about material management needs to be increased, especially for operator, this can be done by providing special training on the supply of materials at the beginning of the production phase. |
| Material Utilization Raw and Sorting | Selection of Raw Materials                  | Material Handling Raw material should be placed in a closed area, away from influence. Weather conditions (rain and heat). High water content in fruit, can cause oxidation processes. |
| Management of Operators / Factors Human | Coaching and Training Upgrade HR Quality   |                                                                         |
PT. KARYA TANAH SUBUR

Palm Oil Processing Procedure

| Purpose of the Procedure: To minimize the increase and variation in Crude Palm Oil levels (CPO) to conform to specified specifications |
| --- |
| **Aspect** | **Maintenance Plan** | **Control** |
| Enhancement | Work routines can sometimes cause a decrease in concentration and the spirit of workers in carrying out activities. Therefore, the management needs to spend a little time so that the motivation of workers increases again. One of them is through togetherness activities, recreation and meetings which are more relaxed, and full of harmony. | |
| Procedure / Method | Enhancement inspection stage | Providing compensation in accordance with the workload provided |
| | | There is a specialization in work, so that mastery of the task becomes more leverage. |
| | | Perform periodic sample checks once every hour |
| | | Perform control chart calculations and calculate sigma values every period periodically. |