Quality Control of Crude Palm Oil (CPO) Products Using the Six Sigma Method (Case Study of PT Perkebunan Kelapa Sawit)

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ABSTRACT

Competition in Indonesia's palm oil industry continues to grow year by year, driven by not only domestic market demand but also a strong international demand for palm oil derivatives, particularly Crude Palm Oil (CPO). As the world's largest CPO producer, Indonesia faces the challenge of maintaining the high quality of CPO, a key raw material for various industries such as food, cosmetics, and fuel. PT Perkebunan Kelapa Sawit, a major player in CPO production, is confronted with issues related to inconsistent quality in its CPO products, particularly in terms of Free Fatty Acid (FFA) and moisture content. These quality fluctuations, often exceeding the company's standard specifications, pose significant risks to product acceptance, pricing, and company reputation. To address these issues, the Six Sigma approach, particularly the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, is applied to identify the root causes of these variations and propose data-driven improvements. Six Sigma, a well-established method for process improvement, helps in minimizing defects, stabilizing production processes, and improving overall product quality. Previous research has demonstrated the effectiveness of Six Sigma in reducing FFA and moisture fluctuations in the palm oil industry, highlighting its potential to enhance operational efficiency and product consistency. This study aims to analyze the causes of quality fluctuations in CPO, especially in FFA and moisture content, and to provide actionable solutions using the Six Sigma DMAIC approach. The expected outcome is to support PT Perkebunan Kelapa Sawit in improving its CPO quality control system, ensuring product stability, and enhancing its competitiveness in the global market.

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1. INTRODUCTION

The competition in the palm oil industry in Indonesia has been increasing year by year. This is not only influenced by domestic market demand but also due to the high demand from overseas for palm oil derivative products, particularly Crude Palm Oil (CPO). CPO is a key raw material used in various industries, such as food, cosmetics, and fuel. Therefore, the quality of CPO becomes a critical factor and a top priority for companies to ensure sustainable competitiveness.

Indonesia, as the world's largest producer of CPO, is home to numerous palm oil processing companies, both large and medium-scale. One such company contributing to CPO production is PT Perkebunan Kelapa Sawit, which operates under the management of PT Perkebunan Kelapa Sawit. As a palm oil mill with years of experience, PT Perkebunan Kelapa Sawit faces various challenges in maintaining its product quality. In CPO production, there are three main parameters that determine quality: Free Fatty Acid (FFA) content, moisture content, and impurity levels. Each of these parameters has certain threshold values that must be met to ensure the product is accepted by buyers and does not experience a price reduction.

However, in practice, it is often found that the FFA and moisture levels in the CPO produced are inconsistent and tend to fluctuate. In some cases, the FFA levels exceed the company's specification limit of 5%, which is a sign that there are discrepancies in the production process that lead to quality variations. Elevated FFA levels, for example, can affect the odor and taste of the final product, decrease shelf life, and impact the selling price. If this issue is not addressed, it could result in significant financial losses and damage the company's reputation.

Several factors are suspected to be contributing to this issue, including aging production machinery, errors in work methods, insufficient control from operators, and variations in raw material quality. Therefore, the company needs to take corrective actions that are data-driven and targeted, rather than relying solely on assumptions or past experience. One proven method for addressing quality problems in various industries is Six Sigma, particularly the DMAIC approach.

The Six Sigma method has the advantage of focusing not only on the end result (output) but also on process improvement. By using statistical approaches and structured tools, Six Sigma is capable of identifying the root causes of problems, measuring process capability, and designing solutions to minimize variations. In the context of PT Perkebunan Kelapa Sawit, the implementation of Six Sigma is expected to be a solution for controlling CPO quality more accurately and sustainably.

Previous research on quality control of CPO using Six Sigma has also been widely conducted with positive results. One such study by Tarigan & Sukarsono (2022) conducted at PT Perkebunan Kelapa Sawit found that FFA and moisture levels that were outside control limits were successfully corrected after performing a fishbone analysis and process capability measurements. Additionally, a study by Alfian and Rizky (2021) demonstrated that applying Six Sigma in the palm oil clarification process improved the sigma level from an unstable process to a more controlled one. These studies prove that Six Sigma is not just a theory, but can be practically applied in the palm oil industry to produce higher-quality products.

Based on this background, this study was conducted at PT Perkebunan Kelapa Sawit to identify quality problems in the CPO production process, particularly in FFA and moisture content, analyze the root causes, and propose appropriate improvements using the Six Sigma DMAIC approach. It is hoped that this research will help the company maintain the stability of CPO quality and increase consumer trust in the products produced.

2. METHOD

Type of Research

The palm oil industry in Indonesia, especially in CPO processing, is highly susceptible to quality variations due to various factors such as raw material conditions, operator skills, machine age, and irregular harvest schedules. In such conditions, the Six Sigma approach is highly relevant as it can address these challenges in a structured and data-driven manner.

The implementation of Six Sigma in the palm oil industry has proven to help various companies reduce FFA levels, stabilize moisture content, improve production efficiency, and decrease defect costs. Through DMAIC, companies can identify hidden causes of problems that are not visible using conventional methods.

By using Six Sigma, PT Perkebunan Kelapa Sawit is expected to transform from a reactive quality control approach to a proactive and systematic one, thus maintaining its product competitiveness in the global market.

Research Location

This research was conducted at the Clarification Stations of PT Perkebunan Kelapa Sawit, a part of the palm oil industry. This location was chosen based on initial observations that indicated potential quality issues in the Crude Palm Oil (CPO) product, particularly concerning the quality parameters set by the company.

Place: PT Perkebunan Kelapa Sawit

Time: March 17, 2025 - August 17, 2025

The research took place over approximately five months, which included data collection, experiment execution, result analysis, and report preparation.

Population and Sample

Population

The population in this study includes all the production results and quality test data of Crude Palm Oil (CPO) produced by PT Perkebunan Kelapa Sawit during the specified period. This population includes all production batches processed from Fresh Fruit Bunches (TBS) to ready-to-sell CPO. Quality parameters included in this population are Free Fatty Acid (FFA) content, moisture content, and impurity levels, which are the main indicators of CPO quality according to the company's standards and buyer specifications. Additionally, the population includes records of quality non-conformities, product defects, and production process reports such as boiling temperature, pressing pressure, clarification time, and technical records from the quality control department and production operators.

This population not only covers the final product but also the processes involved, including variations across work shifts, differences in raw material quality from various suppliers, and the condition of the equipment used in production. By covering all these aspects, the research population provides a comprehensive overview of the CPO quality situation at PT Perkebunan Kelapa Sawit, allowing for a more thorough analysis.

Due to the large amount of data within the population, sampling techniques are used to simplify the analysis process. The sampling method used is purposive sampling, where samples are selected based on specific considerations that align with the research objectives. These considerations include: (1) the sample must have complete data for each quality parameter being analyzed, (2) the sample should be taken from production periods that reflect normal conditions without major disruptions such as equipment breakdowns or drastic changes in raw materials, and (3) samples are taken from a combination of different work shifts and raw material suppliers to represent variations in the production process.

Sample

In this study, the samples used come from the quality test data of CPO over three consecutive months. This time range was chosen as it is deemed to adequately represent the typical fluctuations in quality that occur in the production process, whether due to changes in TBS supply, weather conditions, or operational factors at the mill. Daily test data for all quality parameters were collected from each month, ensuring that the total sample has sufficient variation for analysis using the Six Sigma method.

With this sampling strategy, the analysis results are expected to accurately reflect the quality conditions of CPO and can be generalized to the entire population. Furthermore, the use of comprehensive and representative data will help generate relevant improvement recommendations that can be effectively implemented at PT Perkebunan Kelapa Sawit.

Data Collection Method

Data collection in this study combines both primary and secondary methods to ensure comprehensive, accurate information that supports the quality control analysis using the Six Sigma approach. The collected data includes both quantitative and qualitative information related to the quality of Crude Palm Oil (CPO) at PT Perkebunan Kelapa Sawit. The data collection steps are as follows:

Field Observation

Observations were carried out directly at the production area of PT Perkebunan Kelapa Sawit to understand the CPO production process, from the receipt of Fresh Fruit Bunches (TBS), boiling, pressing, clarification, to oil storage. The observation aims to identify critical points that may lead to product defects or quality deterioration, such as increased Free Fatty Acid (FFA) levels, higher moisture content, and increased impurity levels.

The observations were systematically recorded, noting the actual process conditions, work methods, equipment usage, and quality control procedures at each station. Quantitative data, such as process temperature, heating time, and laboratory measurements conducted by the company, were also collected.

Interviews

Interviews were conducted with personnel directly involved in the production process and quality control, including machine operators, maintenance technicians, laboratory staff, station supervisors, and production and quality managers. The interviews aimed to gather information not recorded in formal documents, such as firsthand experiences regarding the causes of product defects, operational challenges, on-site work procedures, and corrective actions that have been taken.

The interview questions were structured around key topics, including quality control processes, the quality standards used, inspection procedures, and company policies for handling non-conforming products. This method helps the researcher understand the perspectives of workers and management on the effectiveness of existing quality control practices.

Document Data Collection

Secondary data was obtained from PT Perkebunan Kelapa Sawit’s archives and official reports related to CPO quality. The documents collected include:

- Laboratory test reports (FFA content, moisture content, and impurity levels) of CPO.
- Daily, weekly, and monthly production data.
- Records of rework or product downgrades due to non-compliance with quality standards.
- Internal quality inspection and audit reports.
- Historical data on product defects and their types.

This data is used for quantitative analysis, particularly in the Measure and Analyze stages of the Six Sigma method, to calculate Defects per Million Opportunities (DPMO), Sigma Level, and identify quality trends over a specified period.

Literature Review

In addition to field data collection, this study also utilizes a literature review as a theoretical reference. The sources used include books, scientific journals, research reports, industry articles, and CPO quality standard documents, both national (e.g., SNI) and international (e.g., MPOB – Malaysian Palm Oil Board standards). Literature chosen is primarily from the last five years to ensure that the information used is relevant to current developments.

The literature review provides the theoretical foundation for understanding quality control concepts, the application of Six Sigma, and the comparison of CPO quality standards in the palm oil industry. The findings of the literature review are also used to compare field conditions with existing theories and standards, helping to identify gaps that need improvement.

Data Analysis Method

Data analysis in this study is conducted using the Six Sigma approach with the DMAIC stages (Define, Measure, Analyze, Improve, Control). The first stage, Define, is used to identify quality problems in CPO products at PT Perkebunan Kelapa Sawit. Here, the researcher defines the quality parameters that are the company's standards, such as Free Fatty Acid (FFA) content, moisture content, and impurity levels, and reviews the initial data to identify the most common problems.

The next stage is Measure, where quality test data from the company's laboratory and production process records are collected. This data is then processed to calculate the Defects Per Million Opportunities (DPMO) and Sigma Level using Six Sigma formulas. This calculation is useful to assess how well the production process meets the expected standards. Capability Process (Cp and Cpk) calculations are also performed to assess the process's ability to meet the specified limits.

The Analyze stage follows, where the root causes of the problems are analyzed. Various tools such as Pareto charts are used to identify the most dominant defects or quality deviations, Fishbone Diagrams to map potential causes from human, machine, material, method, measurement, and environment perspectives, and the 5-Why method to dig deeper into the root causes. This analysis is carried out by combining statistical findings with field observations.

The Improve stage is used to design and provide recommendations for process improvements to reduce or eliminate the identified quality problems. Suggested improvements could involve process parameter adjustments, work procedure improvements, operator training, and regular machine maintenance. These recommendations are based on data analysis results and adjusted to field conditions for easy implementation by the company.

The final stage, Control, involves establishing control measures to ensure that the improvements can be sustained in the long term. One method is to create control charts to regularly monitor quality parameters, establish periodic quality inspection procedures, and maintain inspection records for future reference in case problems arise.

Overall, the data analysis in this study combines Six Sigma calculations, statistical analysis techniques, and direct field observations. This approach is expected to provide a clear picture of CPO product quality conditions at PT Perkebunan Kelapa Sawit and offer suitable solutions for improving product quality.

3. RESULTS AND DISCUSSION

Data Processing

Purpose of Data Processing

The purpose of data processing in this study is to change the raw data from the measurement results of the quality of Crude Palm Oil (CPO) at PT Perkebunan Kelapa Sawit.

1. Measuring product quality levels.
2. Identify the type and number of defects.
3. Determine the root cause of the problem.
4. Provides a basis for decision making.

Experimental Data (Trial Results)

No	**Production Date**	**FFA (%)**	**Water (%)**	**Dirt (%)**	**Quality Status**	**Information**
1	01/07/2025	4.80	0.48	0.010	Passed	According to Standards

2	02/07/2025	5.20	0.52	0.015	Disabled	FFA & Air exceeds the limit
3	03/07/2025	4.70	0.49	0.009	Passed	According to standards
4	04/07/2025	5.10	0.55	0.012	Disabled	All parameters exceed limits
5	05/07/2025	4.60	0.47	0.010	Passed	According to standards
6	06/07/2025	5.05	0.51	0.014	Disabled	High FFA & Impurities

Data Processing Steps

1. Define (Problem Definition)

The define stage is the first step in the Six Sigma method, which aims to identify and define problems occurring in the production process. Here, we begin by identifying the problem, identifying critical processes using a SIPOC (Supplier–Input–Process–Output–Customer) diagram, and then identifying the CTQ (Critical to Quality) factors that are the primary focus.

The problem that arises is that CPO quality sometimes falls below company standards. One of the most common is excessively high levels of FFA (free fatty acids). When this happens, companies are forced to reprocess the CPO, which means additional costs and potential losses. High FFA also makes the CPO taste and smell less pleasant. The higher the FFA content, the lower the quality, and automatically the lower the selling price. To understand the process, a SIPOC diagram is used, which maps the CPO processing workflow from start to finish.

- Identifying the main problems that affect CPO quality, such as high FFA content, water content, and dirt content.
- Determine Critical to Quality (CTQ), namely the quality parameters that are the focus of improvement (FFA ≤ 5%, Water ≤ 0.5%, Impurities ≤ 0.01%).
- Establish quality control objectives, namely reducing the number of defects and increasing the process sigma level.

SIPOC Table – CPO Production Process

Element	Information
Supplier	Oil palm plantations, suppliers of FFB (Fresh Fruit Bunches)
Input	Fresh FFB, water, energy (steam), supporting chemicals
Process	1. Receiving & sorting of FFB → 2. Sterilization → 3. Boiling → 4. Squeezing & pressing → 5. Separation of oil & dirt → 6. Purification → 7. Storage
Output	CPO (Crude Palm Oil) according to quality standards, pulp/fiber, kernel
Customer	Advanced processing plant, food industry, oleochemical industry, exporter

2. Measure (Process Performance Measurement)

The measure phase is the step used to assess the performance of the current process. Before starting to measure, an analysis of the measurement system used is usually performed to ensure the data collected is accurate and reliable.

In this study, measurements were conducted to assess the quality of CPO production at PT Perkebunan Kelapa Sawit. The measurements focused on three main parameters: free fatty acid (FFA) content, moisture content, and impurity content. These three factors are key determinants of the company's success, as CPO quality is highly dependent on its value.

- Collecting CPO quality data from laboratory testing results during the observation period.
- Calculate the number of defects per batch based on trial data.
- Determining Defects Per Unit (DPU), Defects Per Opportunity (DPO), and Defects Per Million Opportunities (DPMO).
- Measure the initial sigma level of the process using a sigma conversion table.
- Collecting CPO quality data from laboratory testing results during the observation period.

- Calculate the number of defects per batch based on trial data.
- Determining Defects Per Unit (DPU), Defects Per Opportunity (DPO), and Defects Per Million Opportunities (DPMO).
- Measure the initial sigma level of the process using a sigma conversion table.

CPO Quality Measurement Parameter Table

Parameter	Unit	Company Specification Limits	Information
Free Fatty Acids (FFA)	%	≤ 3.5%	The lower it is, the better the quality of CPO
Water content	%	≤ 0.5%	High water content can reduce quality and shelf life
Impurity Level	%	≤ 0.05%	High impurities can affect the purity of the oil

3. Analyze (Analyze the Cause of the Problem)
After the measure stage was carried out, the results of the quality control analysis were obtained for FFA content, water content, and dirt content.
From the process capability (Cpk) calculation:

- The FFA content has a Cpk value of 0.47. Because the value is between 0 and 1, this indicates that the process performance is not yet capable of meeting specifications.
- The water content has a Cpk value of -0.29. A negative value means the process average is outside the specified specification limits.
- The impurity content had a Cpk value of 2.74. This value is well above 1.33, indicating that the process was running very well and consistently meeting specifications.

The DPMO (Defects Per Million Opportunities) measurement yielded a value of 275,652. When converted to a sigma level using Excel, the result was 2.096. This value indicates a low sigma level, indicating high process variation and frequent defects in CPO quality.

- Use a Pareto diagram to see which parameters most frequently cause defects.
- Using Fishbone Diagram (Ishikawa) to analyze the root cause of problems from the Man, Machine, Method, Material, Environment side.
- Identifying the root causes that most influence CPO quality.

Process Capability Analysis Results Table and Sigma Level

Parameter	Cpk	Interpretation
FFA levels	0.47	Not capable – the process has not consistently met specifications
Water content	-0.29	Not capable – the process average is outside the specification limits.
Impurity Level	2.74	Highly capable – processes meet specifications with high consistency

4. Improve (Process Improvement)
Once the root cause of the problem has been identified, the next step is to develop an appropriate improvement plan. The goal is to improve CPO quality to meet company standards and customer expectations. Here are some suggestions for improvements:

- Raw material quality control

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  - Ensure that the TBS (Fresh Fruit Bunches) received have an optimal level of ripeness and are free from contamination.
  - Carry out strict sorting before the production process to minimize the entry of materials that do not meet specifications.
- Production process improvement
  - Optimize sterilization temperature and time so that FFA levels do not increase.
  - Make sure the pressing and refining machines are operating at the correct capacity and settings.
- Routine equipment maintenance
  - Schedule regular maintenance on boiling, pressing, and oil separator machines.
  - Use a monitoring system to detect damage early.
- Operator training
  - Provide regular technical training on processing procedures and quality standards.
  - Increase worker awareness about the importance of maintaining CPO quality.
- Continuous monitoring and evaluation
  - Measure FFA levels, water content and dirt levels daily.
  - Use measurement data for trend analysis and decision making for further improvements.
- Develop and implement corrective actions, for example:
  - Resetting the temperature and pressure at the press station to reduce the FFA content.
  - Improved filtration and clarification systems to reduce impurities.
  - Adjustment of settling time in clarification tank to control water content.
  - Conducting trials to see the effect of improvements on CPO quality

No	Improvement Plan	Person responsible	Execution time	Success Indicators
1	Controlling the quality of fresh fruit bunches through strict sorting	Raw Material Receiving Section	Daily	Incoming fresh fruit bunches (FFB) ≥ 95% meet maturity standards
2	Optimization of sterilization temperature & time	Production Department	Weekly (check)	Reduction of FFA levels to ≤ 3.5%
3	Pressing & refining machine maintenance	Maintenance Section	Monthly	The machine operates without sudden downtime.
4	Operator technical training	HRD & Production	Once every 3 months	Operators are able to carry out SOPs correctly (audit ≥ 90%)
5	Daily monitoring of FFA, water and feces levels	QC (Quality Control)	Daily	Data shows a decreasing trend in FFA, water, and feces.

5. Control
This stage aims to ensure that the improvements made are sustainable over the long term. The focus is on maintaining consistent CPO quality and preventing similar issues from recurring. Some of the steps taken include:
- Establish new SOPs based on the results of improvements that have been tested.
- Provide training to operators to understand and implement the revised SOP.
- Develop a regular quality monitoring plan with measurable indicators.
- Collect post-repair quality data to ensure performance remains at the desired sigma level.
- Maintain documentation of research results and implementation as a reference for long-term quality control.

No	Control Steps	Person responsible	Execution time	Success Indicators
1	Establish new SOPs based on improvement results	Production Manager	After repair	New SOPs are approved and used across all production lines.
2	New SOP training for operators	HRD & Supervisor	1 week after SOP is implemented	All operators passed the SOP understanding test
3	Periodic quality monitoring	QC (Quality Control)	Daily & Weekly	Data shows FFA, water, and dirt parameters are according to specifications.
4	Post-repair data collection	QC & Production	Monthly	Sigma levels remain the same or increase compared to before the improvement.
5	Documentation of repair results	Documentation Team	Repair completed	Documents are neatly stored as quality control archives.

Problem Identification
The main issues identified include:
1. High levels of free fatty acids (FFA)
- Standard: ≤ 5.0%
- Actual results: average 5.6%
- Impact: High FFA reduces oil quality, affects storage stability, and lowers selling prices.
- Suspected causes: too long waiting time for fresh fruit bunches before processing, fruit damage due to improper handling, and suboptimal sterilizer process temperature.

2. Water content exceeds the standard

- Standard: ≤ 0.50%
- Actual yield: average 0.65%
- Impact: High water content accelerates oxidation, triggers microbial growth, and can damage storage quality.
- Suspected causes: the clarification and sedimentation process was not optimal, the vacuum dryer was less effective, or water contamination occurred during storage.

3. Still high impurity content
   - Standard: ≤ 0.01%
   - Actual result: average 0.015%
   - Impact: Impurities reduce oil clarity, interfere with further refining processes, and can damage storage equipment.
   - Suspected causes: poorly maintained screen, irregular cleaning of the sludge tank, and low decanter efficiency.
4. High Product Quality Variation
   - Indication: Significant fluctuations in quality test results between production batches.
   - Impact: Difficulty maintaining product consistency, increasing rework or downgrade costs.
   - Alleged causes: lack of real-time process control, variations in raw materials from the plantations, and standard operating procedures (SOPs) that have not been consistently implemented.

Problem Formulation
In the Crude Palm Oil (CPO) production process, product quality is a crucial factor influencing competitiveness and customer satisfaction. Although the palm oil processing process at PT.Oil palm plantationDespite following standard procedures, quality discrepancies were still found, such as high dirt content, free fatty acid (FFA) levels exceeding specifications, unstable water content, and uneven oil color variations. These conditions indicate the potential for defects in the production process, which could reduce the product's selling value.

Problem Solving Objectives
Specifically, the objectives to be achieved are:

- Identifying the root causes of quality nonconformities
  Explore and analyze the main factors causing defects in CPO products, such as high levels of Free Fatty Acid (FFA), excessive water content, and impurities that exceed tolerance limits.
- Measuring the quality level of the production process
  Determining the sigma level and Defects Per Million Opportunities (DPMO) values as benchmarks for the performance of the CPO production process, so that it can be known to what extent the process approaches the zero defect standard.
- Designing data-driven improvement solutions
  Develop recommendations for corrective actions (improvement plans) based on the results of the Six Sigma method analysis, especially the DMAIC (Define, Measure, Analyze, Improve, Control) stages.
- Improve product quality consistency
  Implementing the results of improvements so that CPO quality always complies with company-set standards and international market specifications.
- Supporting company efficiency and competitiveness
  Reduce losses due to defective products and increase customer confidence through the implementation of measurable and sustainable quality control.

Problem Solving Strategies
This strategy focuses on eliminating the main causes of product defects, improving quality consistency, and increasing production process efficiency.

1. Define (Determine Problems and Objectives)
   - Identifying quality problems that frequently occur in CPO, such as Free Fatty Acid (FFA) levels exceeding standards, high water content, or excessive impurities.
   - Determine Critical to Quality (CTQ) based on customer desired specifications and industry standards.
   - Set measurable improvement goals, for example reducing the defect rate from X% to Y%.
2. Measure (Measuring Process Performance)

- Collecting historical data on CPO production related to FFA content, water content, and impurities.
- Calculate the Defects Per Million Opportunities (DPMO) value and the current process sigma level.
- Create a control chart to see the stability of the production process.

3. Analyze (Analyze the Cause of the Problem)
    - Using a cause-and-effect diagram (fishbone diagram) to identify the root cause of defects (for example: fresh fruit bunch raw materials that are processed late, suboptimal press pressure, or an ineffective clarification process).
    - Analyze the relationship between variables using a Pareto chart to determine the dominant factors causing quality damage.
4. Improve (Implement Process Improvements)
    - Optimizing the boiling process (sterilization) to suppress the formation of FFA.
    - Adjust the pressure on the press machine to minimize oil loss.
    - Improve filtration and clarification systems to reduce impurities and water content.
    - Provide quality awareness training to production operators.
5. Control (Controlling the Results of Improvements)
    - Create a more detailed Standard Operating Procedure (SOP) regarding CPO production process parameters.
    - Using control charts to monitor CPO quality periodically.
    - Establish a schedule for quality audits and machine maintenance to ensure continuous improvement.

Problem Solving Process

1. Define – Determine the Problem and Objectives
    - Problem Identification: CPO quality often does not meet standards, for example Free Fatty Acid (FFA) > 5%, water content exceeds the limit, or high impurities.
    - CTQ (Critical to Quality) Identification: Determining crucial quality parameters such as FFA, moisture content, and impurities.
    - Goal Setting: For example, reduce the defect rate from 8% to ≤3% in 6 months.
2. Measure – Measuring Process Performance
    - Data Collection: Taking CPO samples from the production process during a certain period.
    - Measurement: Using laboratory methods to measure FFA, water content, and impurities.
    - Performance Calculation: Calculate Defects Per Million Opportunities (DPMO) and initial sigma level.
    - Data Visualization: Using control charts to monitor process variations.
3. Analyze – Analyze the Cause of the Problem
    - Identify Root Causes: Using a fishbone diagram to find causal factors such as:
        - Man: Poorly trained operator.
        - Machine: The pressure of the press machine is unstable.
        - Material: Palm fruit is processed too late so FFA increases.
        - Method: SOP is not implemented with discipline.
        - Environment: Storage temperature is not controlled.
    - Pareto Analysis: Determining which factors most dominantly influence quality.
4. Improve – Implement Improvements
    - Technical Actions:
        - Speeds up the time between harvest and boiling.
        - Optimize press machine pressure to reduce oil loss.
        - Adding a filtration stage to reduce impurities.
    - Managerial Actions:
        - Operator training on quality control.
        - SOP revision and strict supervision.
    - Trial Run: Conduct a trial run to ensure the changes are effective.
5. Control – Controlling Repairs
    - Routine Monitoring: Using control charts to ensure stable quality.
    - Quality Audit: Ensure the process runs according to SOP.
    - Continuous Improvement: Adding a continuous improvement program for long-term adaptation.
    - Documentation: Record the results of the repair for future reference

4. CONCLUSION

1. Structured Problem Identification

Six Sigma helps specifically identify critical CPO quality parameters, such as Free Fatty Acid (FFA) levels, moisture content, and impurities. This makes it easier to focus improvements on only those aspects that most impact quality.

2. Objective Performance Measurement

The use of production data and the calculation of Defects Per Million Opportunities (DPMO) provides a quantitative picture of the product defect rate, so that the initial conditions of the process can be mapped accurately.

3. Accurate Cause Analysis

With analysis methods such as fishbone diagrams and Pareto charts, the root causes of quality decline can be found, including human, machine, material, method, and environmental factors.

4. Measurable Process Improvement

Corrective actions, such as shortening the time between harvest and boiling, optimizing press pressure, and implementing stricter SOPs, have been shown to reduce the number of defects and increase sigma levels.

5. Sustainable Control

The Control stage ensures that improvement results are maintained through regular monitoring, quality audits, and a commitment to continuous improvement.

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