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Quality Evaluation and Causal Analysis of Crude Palm Oil Based on Critical Quality Parameters: Free Fatty Acids, Moisture, and Impurities

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ABSTRACT

Crude Palm Oil (CPO) is a vital commodity derived from the processing of sterilized oil palm mesocarp extracted from Fresh Fruit Bunches (FFB), serving as a primary raw material in the edible oil industry. The quality of CPO is critically influenced by parameters such as Free Fatty Acid (FFA), moisture content, and impurities, which directly affect its stability, shelf life, and market value. Despite established quality standards, many CPO production facilities continue to face inconsistencies in these parameters due to variations in harvesting practices, post-harvest handling, and processing conditions, yet few studies have explored plant-specific root causes. This study aimed to evaluate the quality of CPO at XYZ Co. in Barito Kuala Regency by analyzing FFA levels, moisture content, and impurity content through a qualitative-descriptive approach, including field observations, staff interviews, and analysis using bar charts and fishbone diagrams, with data collected from October 2023 to January 2024. Results showed that FFA levels remained within the company's standard of 5%, ranging from 3.9% to 4.06%; moisture content varied between 0.25% and 0.35%, with some values exceeding the limit; while impurity levels surpassed the 0.030% threshold in two observation periods. Fishbone diagram analysis identified human error, substandard raw materials, poor machine maintenance, and non-compliance with standard operating procedures as key contributing factors. The study recommends improvements in supervision, operator training, equipment maintenance, and SOP implementation to enhance and maintain consistent CPO quality.

Keywords: free fatty acid, moisture, impurity, crude palm oil

INTRODUCTION

Crude Palm Oil (CPO) is derived from the processing of sterilized oil palm mesocarp extracted from Fresh Fruit Bunches (FFB). Free fatty acids (FFA) are formed as a result of the hydrolysis of triglycerides in palm oil. Although palm oil contains various types of fatty acids, the determination of FFA content typically uses palmitic acid as a reference. CPO is the primary product obtained from oil palm plantations and serves as a key raw material for cooking oil production. It is rich in carotenoids, tocopherols, and

tocotrienols, and also contains non-glyceride components such as water, free fatty acids (FFA), and trace metals, all of which influence its oxidative stability. A high concentration of FFA in CPO is undesirable, as it reduces oil quality and shelf life. Elevated FFA levels are indicative of hydrolytic degradation, which negatively impacts the refined product (Lukito & Sudradjat, 2017; Morcillo et al., 2013; Nanda et al., 2016; Sampaio et al., 2017; Tan et al., 2023).

The quality of CPO production is closely associated with the quality of the harvested fruit. FFBs of optimum ripeness can yield CPO with an oil extraction rate ranging from 23.2% to 27.4%, and an FFA content of around 5%. Higher oil yields are typically achieved when processing ripe fruits, which have a greater oil content compared to unripe ones. Therefore, proper harvesting techniques play a critical role in determining the efficiency and quality of CPO extraction (Akbar et al., 2023; Lukito & Sudradjat, 2017).

Inconsistent harvesting practices and post-harvest handling can result in variations in CPO quality, particularly in FFA levels, which tend to remain in the range of 4% to 5%. These elevated FFA values are considered high and may cause undesirable sensory attributes such as off-flavors and odors. In general, the higher the FFA content, the lower the quality of the CPO (Lukito & Sudradjat, 2017; Nanda et al., 2016).

This research was aimed to analyze the quality of Crude Palm Oil (CPO) produced from the processing of Fresh Fruit Bunches (FFB) at XYZ Co., Barito Kuala Regency, focusing on the parameters of Free Fatty Acid (FFA), moisture content, and impurities (dirty).

RESEARCH METHODOLOGY

Material and Equipments

The materials used in this study included crude palm oil (CPO) samples, 0.1 N sodium hydroxide (NaOH), 1% phenolphthalein, 95% ethanol, diethyl ether, distilled water, and Whatman No. 42 filter paper. All chemicals were of analytical grade.

The equipment consisted of an analytical balance, burette, Erlenmeyer flask, hot plate with magnetic stirrer, oven (105°C), desiccator, pipettes, beakers, thermometer, and stopwatch.

Research design

This study employed a qualitative-descriptive approach to analyze the quality of Crude Palm Oil (CPO) derived from the processing of Fresh Fruit Bunches (FFB) at XYZ

Co., Barito Kuala Regency, Indonesia. The analysis focused on three key quality parameters: Free Fatty Acid (FFA), moisture content, and impurities. The analytical tools utilized included bar charts and fishbone diagrams to identify and visualize potential causal factors affecting these quality indicators.

Primary data were collected through direct observation of the CPO quality analysis process conducted on-site at XYZ Co. The data collection period spanned from October 2023 to January 2024. In addition, in-depth interviews were conducted with key informants who possess expertise and technical knowledge relevant to CPO processing and quality control.

Qualitative data were analyzed descriptively. The analytical procedure included measuring the levels of FFA, moisture, and impurities in CPO samples, followed by visual representation using bar charts for comparative purposes and fishbone diagrams for root cause analysis. The conclusions were drawn based on data obtained during the month of December 2023.

Analysis of CPO's Quality Paramters

a. Free Fatty Acid

FFA content in crude palm oil (CPO) was determined by acid-base titration. Samples were collected from the storage tank, and each analysis was performed in triplicate. About 5 g of CPO was dissolved in a warm mixture of 95% ethanol and diethyl ether (1:1 v/v), followed by the addition of phenolphthalein indicator. The solution was titrated with 0.1 N NaOH until a stable pink color appeared. FFA content was calculated as a percentage of palmitic acid based on the volume of NaOH used (AOCS, 1998; Che Man et al., 1999; Kristono, Rahardja, & Darmawan, 2020).

b. Moisture

Moisture content in crude palm oil (CPO) was measured using the oven drying method. Approximately 5 g of well-mixed CPO was placed in a pre-weighed aluminum dish and heated in an oven at 105°C for 1.5 hours. After drying, the sample was cooled in a desiccator and reweighed. Moisture content was calculated from the weight loss and expressed as a percentage of the initial sample weight. Each sample was analyzed in triplicate (Badan Standarisasi Nasional, 2006; Kristono, Rahardja, & Darmawan, 2020).

c. Impurity

Impurities in crude palm oil (CPO) were measured by filtering 10 g of warm oil through pre-weighed Whatman No. 42 filter paper. The residue was dried at 105°C, cooled

in a desiccator, and weighed. Impurities were calculated as a percentage of the initial sample. Each test was conducted in triplicate (Kristono, Rahardja, & Darmawan, 2020).

Fishbone Diagram Analysis

To further identify the root causes of quality deviations in Crude Palm Oil (CPO) production at XYZ Co., a Fishbone Diagram (Ishikawa diagram) was employed as a structured analytical tool. This method categorizes potential causes of elevated Free Fatty Acid (FFA) levels, moisture content, and impurities into four main dimensions: human, material, machine, and method (Basuki et al., 2023).

RESULTS AND DISCUSSION

This section presents the results of the analysis on the quality of Crude Palm Oil (CPO) obtained from the processing of Fresh Fruit Bunches (FFB) at XYZ Co., Barito Kuala Regency. The results from the measurement of FFA levels, moisture content, and impurities will be comprehensively analyzed to identify the factors affecting CPO quality. Additionally, the results will be compared with established quality standards, and the impact of variations in these parameters on the stability and quality of the oil will be discussed. The discussion will also explore potential steps to improve CPO quality through the control of these parameters during the production process.

Quality Paramters of Crude Palm Oil (CPO)

a. Free Fatty Acid (FFA) Content

Based on the bar chart above, the average FFA value of the CPO oil in the first 10 days is 4.06%, in the second 10 days is 3.96%, and in the last 10 days is 3.9%. These FFA values meet the company’s standard, where the maximum allowable FFA value for CPO oil is 5% (Figure 1).

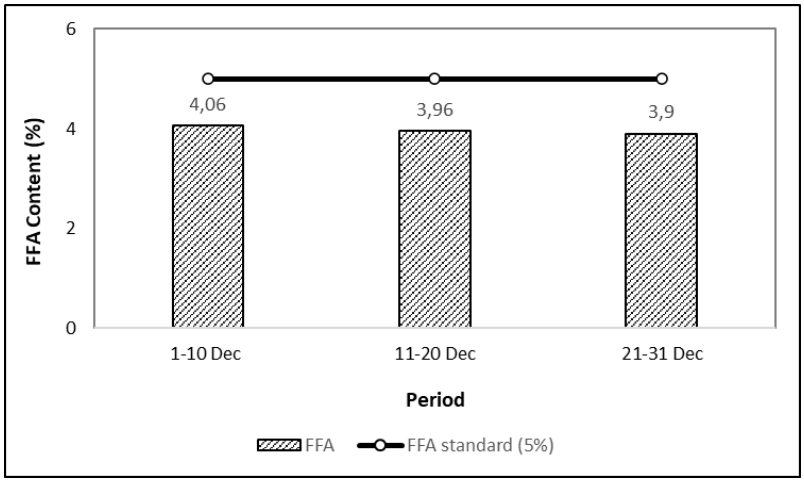

Figure 1. Free fatty acid result analysis

b. Moisture

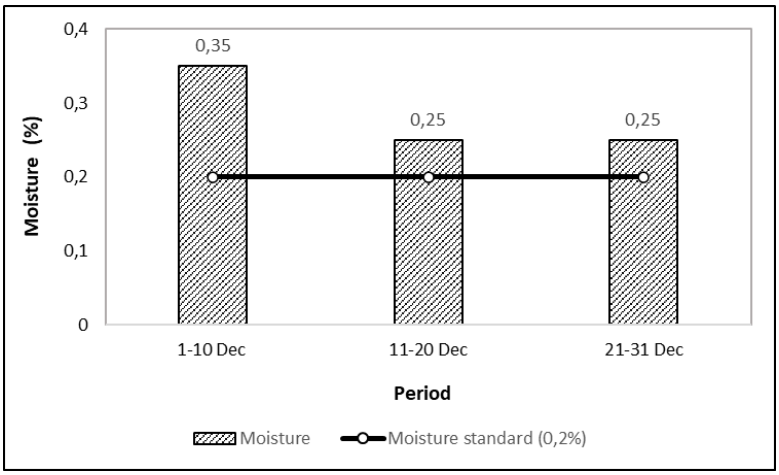

Figure 2. Impurity result analysis

Based on the bar chart, the moisture content during the first 10 days of December was recorded at 0.35%, which complies with the company's standard for moisture level in Crude Palm Oil. In the subsequent 10-day period, the moisture content decreased to 0.25%, a value that falls below the acceptable threshold. Interestingly, the same moisture level of 0.25% was also observed during the final 10 days of the month; however, this value is considered to meet the standard set by the company (Figure 2).

c. Impurity

Based on the Figure 3, it can be assumed that the impurities content in the first 10 days of December was 0.034%, which meets the standard for impurities content. In the second 10 days, the impurities content was 0.035%, which does not meet the standard for

impurities content, and in the last 10 days, it was 0.035%, which also does not meet the standard for impurities content set by the company.

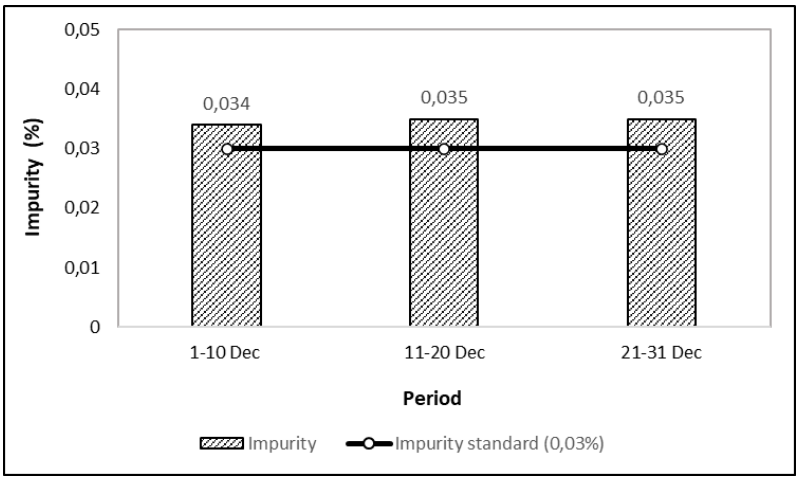

Figure 3. Impurity result analysis

Analysis of Quality Parameters using Fishbone Diagram

a. Free Fatty Acid

The fishbone diagram, also known as the Ishikawa diagram, was used to identify the root causes of elevated Free Fatty Acid (FFA) levels in Crude Palm Oil (CPO) at XYZ Co. Based on interviews with company staff, four primary factors were identified: human, material, machine, and method.

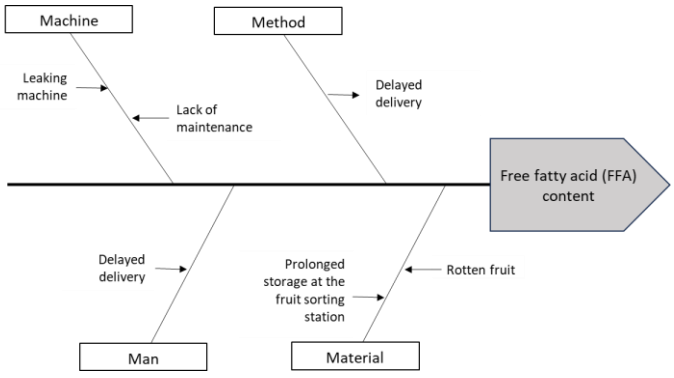

Figure 4. Fishbone Diagram FFA Results

Human factors included delayed transportation from the field and lack of supervision during the loading of Fresh Fruit Bunches (FFB), which can compromise processing timeliness. Material-related issues were linked to the use of spoiled fruit and prolonged storage at the sorting station, both of which contribute to increased FFA levels.

Machine factors involved equipment malfunction and leakage, which disrupt optimal processing conditions. Method-related issues focused on delays in FFB delivery by farmers or suppliers, allowing fruit to deteriorate before processing (Figure 4). To mitigate these issues, corrective actions were proposed: enhancing operator supervision (human), protecting raw materials from heat and rain during storage (material), maintaining machinery performance (machine), and improving the efficiency of fruit transportation from the field (method)(Lukito & Sudradjat, 2017; Tan et al., 2023).

b. Moisture

Human-related issues included inattentiveness of machine operators in monitoring sterilizer temperature, often caused by fatigue, which affects the moisture level in CPO. Material issues stemmed from substandard raw materials due to poor sorting practices and exposure to environmental elements such as sun and rain during storage on the loading ramp. In terms of machinery, malfunctioning sterilizers and lack of scheduled maintenance were key concerns, potentially disrupting production flow and affecting downstream equipment like the Continuous Settling Tank (CST) (Figure 5). Methodological issues were linked to inadequate machine setup procedures, highlighting the absence of clear operational guidelines (Falgenti & Hambali, 2022; Frank et al., 2013; Jaya et al., 2014, 2024; Marimin & Zavira, 2020; Sofiyanurriyanti et al., 2021).

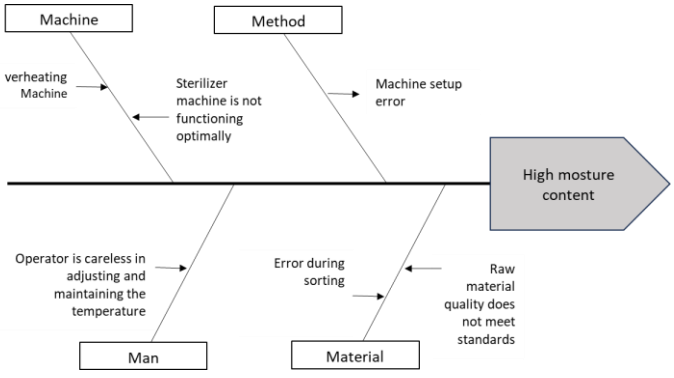

Figure 5. Fishbone Diagram of Moisture Results

Corrective actions were proposed to mitigate these challenges: for human factors, implementing operator training, structured break schedules, and strict supervision; for materials, enhancing raw material handling through protective measures, worker training, and standardized sorting protocols; for machines, enforcing regular maintenance schedules, establishing usage policies, and timely equipment repairs; and for methods, developing

comprehensive Standard Operating Procedures (SOPs), involving staff in SOP formulation, and conducting training to ensure compliance.

Fishbone Diagram of Impurity Results

Figure 6 Showed the cause-and-effect diagram or fishbone of the imputiry of Crude Palm Oil (CPO).

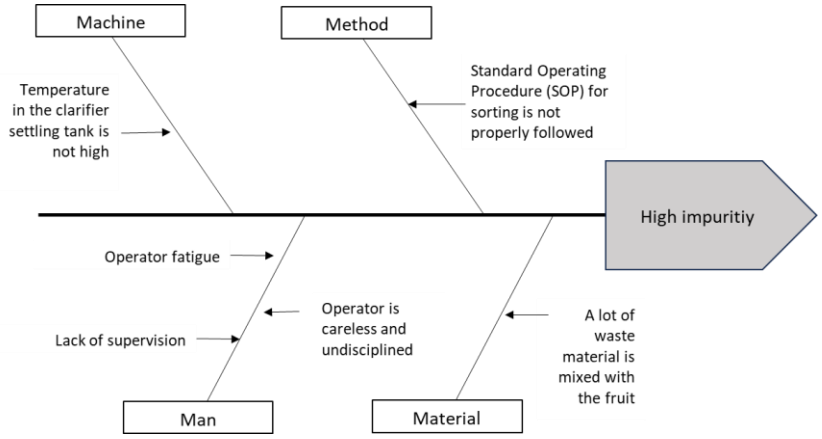

Figure 6. Fishbone Diagram of Impurity Results

Human-related factors contributing to increased impurity levels in Crude Palm Oil (CPO) include high workloads and insufficient supervision by assistants, which may lead to carelessness in the sorting of Fresh Fruit Bunches (FFB). This issue is often rooted in a lack of discipline and non-compliance with Standard Operating Procedures (SOP). To address this, it is recommended to strengthen supervisory roles and conduct briefings before production begins. Material-related issues stem from the presence of waste material within the FFB, often due to inadequate cleanliness in the production area and poorly maintained sorting machines—where fruit quality is first assessed against company standards. Machine-related problems arise from irregular maintenance schedules, particularly affecting the performance of the Clarifier Settling Tank (CST), exacerbated by lack of cleanliness in both machinery and workspaces. Methodological issues occur when operators fail to follow SOPs accurately, especially during the sorting process, where prioritizing ripe palm fruits is critical to maintain acceptable Free Fatty Acid (FFA) levels.

Based on the fishbone diagram analysis, corrective actions are proposed: for human factors, improve supervision and implement regular briefings; for material, enhance monitoring of operator compliance and cleanliness during sorting; for machinery, enforce regular maintenance schedules and cleanliness protocols; and for methods, reinforce

adherence to SOPs through supervision and pre-production instruction (Darmawan et al., 2020; Frank et al., 2013; Jaya et al., 2019, 2023; Kristono, Rahardja, & Dermawan, 2020; Sofiyanurriyanti et al., 2021; Usman et al., 2025).

CONCLUSION

Quality analysis of CPO based on FFA, moisture, and impurity content is essential in determining product quality and market value. Lower levels of FFA and moisture, along with higher purity, indicate better CPO quality. The standard values used at XYZ Co., Barito Kuala Regency, include a maximum FFA level of 5%, moisture content of 0.20%, and impurity level of 0.030%.

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