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Challenges and Strategies in Crude Palm Oil Quality Control: A Practical Approach from an Indonesian Palm Oil Mill

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ABSTRACT

This study analyzes the implementation of the Crude Palm Oil (CPO) quality control system at an Indonesian palm oil mill, focusing on procedures, methods, and technologies used, as well as the challenges in maintaining product quality according to company standards. A qualitative approach was employed, utilizing participatory observation, in-depth interviews, and document analysis. Data were analyzed thematically and through Juran's Trilogy framework, encompassing quality planning, quality control, and quality improvement. The quality control system involves the implementation of Standard Operating Procedures (SOPs), manual sorting, Statistical Quality Control (SQC), manual testing, Foss NIRS technology, and data reporting via paper-based forms, WhatsApp, Excel, SAP, and the WD application. Identified challenges include inconsistent adherence to SOPs, delayed reporting, limited technological use, and weak interdepartmental coordination. The analysis indicates that while quality planning and control are adequately implemented, quality improvement remains suboptimal. Recommendations include staff training, SOP simplification, real-time reporting systems, enhanced cross-divisional coordination, and supplier development. Gradual implementation of these strategies is expected to enhance system effectiveness and support long-term sustainability.

INTRODUCTION

The palm oil industry plays a crucial role in Indonesia's economy, contributing significantly to exports, employment, and government revenue (Sibhatu, 2023). One of its primary products, Crude Palm Oil (CPO), is widely used in various sectors including food, cosmetics, renewable energy, and pharmaceuticals (Rauf et al., 2023). Based on data from GAPKI (2024), Indonesia produces approximately 51 million tons of CPO annually, making it the largest global producer and exporter.

Despite this strategic position, the industry continues to face challenges concerning product quality, operational efficiency, and sustainable production. These challenges are particularly evident in efforts to comply with international certification standards such as ISPO (Indonesian Sustainable Palm Oil) and RSPO (Roundtable on Sustainable Palm Oil) (Srisawasdi et al., 2023).

To maintain CPO quality, palm oil mills implement various quality control systems, including Standard Operating Procedures (SOPs), Statistical Quality Control (SQC) methods, Foss NIRS (Near-Infrared Spectroscopy) technology, and digital data recording through platforms such as SAP and the Warehouse Data (WD) system. Additional quality assurance practices include laboratory testing, sorting and grading of Fresh Fruit Bunches (FFB), and material balance calculations to control key parameters such as free fatty acid (FFA), moisture, and impurities (Syaputa & Sofiyanurriyanti, 2022; Nanda et al., 2024).

While these systems are well-designed, their implementation in practice often encounters obstacles. These include inconsistent compliance with SOPs, delayed data entry, underutilization of digital technologies, and poor interdepartmental coordination (Budiastra et al., 2024; Filz et al., 2024). Manual reporting via Excel and WhatsApp, for instance, still dominates, posing risks to accuracy and timeliness (Wada et al., 2023).

Moreover, the current use of SQC lacks advanced tools such as control charts or trend analysis for early detection of quality deviations (Wang et al., 2023). Although Foss NIRS is employed to measure parameters like FFA, moisture, and impurity levels, real-time integration with operational decisions remains limited (Nanda et al., 2024).

In the context of ISPO certification, companies must ensure not only well-documented systems but also their consistent and verifiable implementation. According to Indonesia's Ministry of Agriculture Regulation No. 38 of 2020 and Circular No. 286/KB.410/E/03/2024, quality control is a critical indicator of ISPO compliance (Komarudin & Siregar, 2024).

Prior research has largely emphasized technical system design or the application of statistical tools, yet few studies have examined the practical realities of quality control implementation on-site. In fact, the success of these systems is highly dependent on non-technical factors such as employee discipline, consistency in data recording, and effective communication between departments (Wilda et al., 2023). Without adequate human resource capacity and adherence to procedures, even sophisticated tools such as SAP, Foss NIRS, and WD will be underutilized.

Therefore, this study aims to investigate the practical implementation of CPO quality control systems, focusing on SOP compliance, SQC practices, manual and digital testing, and the use of supporting technologies. It also seeks to identify operational barriers and propose improvement strategies aligned with industry sustainability standards.

LITERATURE REVIEW

The theoretical framework in this study provides a conceptual foundation for understanding the implementation of Crude Palm Oil (CPO) quality control systems. It integrates technical, procedural, and digital perspectives while guiding continuous improvement strategies contextualized to field-level realities.

Quality

This study adopts Juran's Quality Trilogy as the main theoretical lens, which defines quality as conformance to customer requirements achieved through systematic planning and control (Juran & De Feo, 2017). The trilogy comprises three key functions: quality planning, quality control, and quality improvement, together forming a sustainable quality management cycle.

Quality is viewed not as a coincidence, but as the result of deliberate managerial processes (Shidiq et al., 2022).

In In manufacturing contexts, quality is often assessed through measurable technical indicators such as product stability, dimensional accuracy, and material purity (Heizer et al., 2020; Rauf et al., 2023). Common quality problems stem from inconsistent raw materials, procedural deviations, lack of standardization, and weak internal oversight (Monteiro et al., 2023).

Moreover, human and organizational factors significantly influence quality outcomes. Consistent SOP implementation, staff discipline, and interdepartmental communication are key to maintaining quality standards (Wilda et al., 2023; Pacana & Czerwińska, 2023). Therefore, quality must be understood as both a technical and socio-organizational construct.

Quality Control Methods

Quality control ensures that production processes meet pre-defined standards through monitoring, deviation detection, and corrective action (Juran & De Feo, 2017). This function should extend beyond end-product inspection to encompass upstream processes, in line with Total Quality Management (TQM) principles (Heizer et al., 2020).

Statistical Quality Control (SQC) is a widely used method involving sampling, control charts, and process variation analysis (Febrina & Fitriana, 2022). It enables early detection of quality issues while minimizing inspection costs (Monteiro et al., 2023). Effective quality control also depends on reliable documentation, which supports audits and evidence-based decision-making (Liu et al., 2024).

Standard Operating Procedures (SOPs)

SOPs provide formalized instructions that standardize work procedures and minimize process variability (Rahmawati & Suryana, 2024). They are critical to ensuring consistency, compliance, and accountability within quality systems (Budiastra et al., 2024). Well-developed SOPs also serve as tools for quality evaluation and root cause analysis (Ly & Kieu Viet, 2022), and must be regularly reviewed to remain aligned with operational dynamics and technological advances. However, effectiveness depends heavily on personnel compliance and understanding (Febrina & Fitriana, 2022).

Digitization in Quality Control

Digitization enables real-time data access, automation, and cross-functional integration—essential components of modern quality control (Efraim et al., 2014; Duraivelu, 2022). Technologies such as NIRS, ERP systems, and IoT devices help reduce human error and improve process visibility (Shidiq et al., 2022). For example, Near-Infrared Reflectance Spectroscopy (NIRS) rapidly measures parameters like FFA, moisture, and impurities with minimal sample preparation (Nanda et al., 2025). However, its effectiveness depends on consistent usage, technical training, and integration with decision-making systems (Budiastra et al., 2024).

METHODS

This study employed a qualitative approach to examine the implementation of the Crude Palm Oil (CPO) quality control system. A qualitative design was chosen to explore real-world operational dynamics and uncover the contextual meaning behind practices not easily quantified. The primary aim was to capture field-level realities from the perspectives of actors involved in the system. Data collection was conducted through participatory observation, in-depth interviews, and document analysis. Thematic and inductive analysis was used to identify patterns of system implementation and barriers encountered (Sugiyono, 2015).

Unit of Analysis

The study focused on two divisions within the Palm Oil Mill: the Sorting Division and the Laboratory Division. The Sorting Division handles the classification of Fresh Fruit Bunches (FFB), while the Laboratory Division is responsible for testing raw materials, in-process, and final CPO products. Both units are central to maintaining product quality and implementing quality control procedures.

Data Sources and Collection Techniques

Primary data were obtained through field observations and interviews with ten key informants holding operational roles. Secondary data were gathered from internal documents and relevant scientific literature. Triangulation was applied to enhance data validity by cross-verifying sources (Sugiyono, 2015)

Data Analysis

Data were analyzed using thematic analysis, involving coding, categorization, and interpretation of emerging themes. All transcripts were coded manually to preserve contextual meaning and maintain analytical depth throughout the process. The analysis proceeded through four stages:

1. Data coding and initial grouping;
2. Identification of key themes based on field data;
3. Contextual analysis of each theme;
4. Organization of findings into a descriptive and interconnected framework.

This method enabled a holistic understanding of implementation practices, obstacles, and underlying dynamics, forming the basis for strategic improvement recommendations. Purposive sampling was used to select key informants based on their strategic roles in the quality control system. Data coding was performed manually using thematic analysis to identify recurring patterns and insights.

RESULTS

This study was conducted to explore the implementation of the Crude Palm Oil (CPO) quality control system at Palm Oil Mill. Data were collected through participatory observation, in-depth interviews, and document analysis, focusing on two main units: the Sorting Division and the Laboratory Division. Ten informants representing various strategic positions were interviewed directly to understand the implementation of quality control in the field.

Table 1. List of Research Informants

Informant Code	Position	Division/Unit	Role in the Quality Control System
INF1	Head Assistant	Management	Coordinates and oversees all business processes, including processing, quality control, and reporting.
INF2	Logistics & Quality Assistant	Logistics, Laboratory, and Sorting	Responsible for SOP implementation and coordination of FFB sorting, quality testing, and logistics.
INF3	Laboratory Supervisor	Laboratory	Oversees quality testing activities and documentation of laboratory results.
INF4	Production & Quality Admin	Production & Quality Administration	Prepares daily and monthly production and quality test reports.

INF5	Internal FFB Sorting Supervisor	Internal FFB Reception	Supervises sorting of FFB from company plantations before processing.
INF6	External FFB Sorting Supervisor	External FFB Reception	Oversees sorting of FFB from external suppliers and ensures compliance with quality standards.
INF7	Sampling Technician1	Laboratory	Conducts sampling, quality testing, and records test results.
INF8	Sampling Technician2	Laboratory	Conducts sampling, quality testing, and records test results.
INF9	Weighbridge Operator	Weighbridge Operations	Records the weight of incoming FFB and outgoing products as the basis for production and quality reports.
INF10	Security Officer	Security & Distribution	Controls vehicle flow in and out to ensure smooth distribution and support the quality control system.

Source: Primary data compiled by the author (2024)

The data from these informants was analyzed using a thematic approach and resulted in 13 main codes representing critical dimensions in the company's quality control system.

Table 2. List of Thematic Codes in the Quality Control System

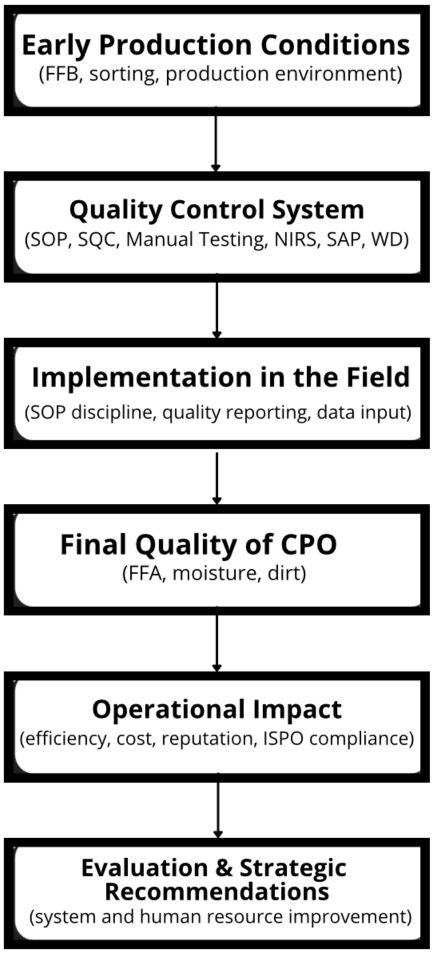
Code	Description
C_FFB_QUALITY	Quality of Fresh Fruit Bunches (FFB), including ripeness and physical condition of the fruit.
C_SORTING	Sorting procedures of FFB prior to processing.
C_SOP	Implementation of Standard Operating Procedures (SOP) as a structured work system.
C_SQC	Sampling and application of Statistical Quality Control (SQC) methods on a regular basis.
C_MANUAL_TEST	Manual quality testing using laboratory tools and visual methods such as FFB grading.
C_FOSS_NIRS	Utilization of Foss NIRS technology for automated measurement of FFA, moisture, dirt, and DOBI as clarity indicators for CPO.
C_SAP_WD	Use of SAP and WD digital systems for data recording and reporting.
C_EXECUTION	Discipline of operators in performing tasks and maintaining operational consistency.
C_REPORTING	Practices in recording and reporting operations, including both manual and digital systems.
C_SYNERGY	Cross-divisional coordination in implementing the quality control system.
C_CONSTRAINTS	Operational obstacles that hinder the effectiveness of the system.
C_SUPPORTING	Indirect factors such as infrastructure, tools, and operational environment.
C_RECOMMENDATION	Strategic recommendations for system and human resource improvements.

Source: Primary data compiled by the author (2024)

All interview and observation results, coded according to the 13 main themes are used to compile a systematic discussion in the Discussion section, linking Juran's quality theory and the latest scientific literature as the basis for analysis.

Based on the results of the thematic classification, this study developed a framework for the implementation of CPO quality control, which represents the system flow from upstream to downstream. This framework also maps the interrelationships between the dimensions of the system discussed further in the discussion.

Figure 1. Analytical Framework For The Implementation Of The CPO Quality Control System

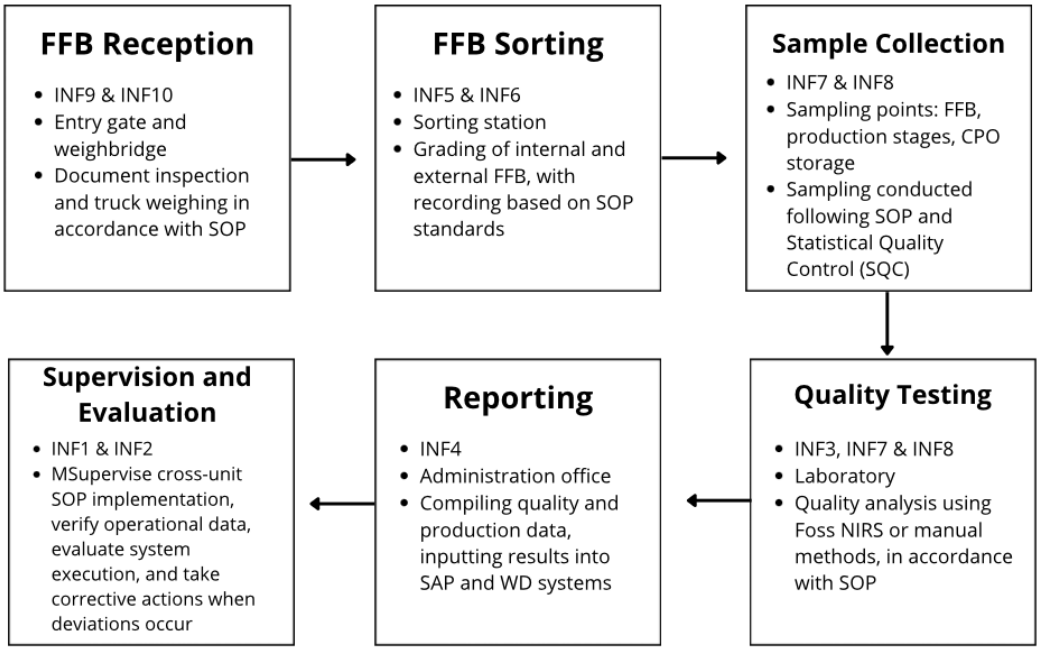


Source: Author’s illustration based on field observation (2024)

In general, the research results indicate that the quality control system has been comprehensively designed, covering FFB sorting and grading, SOP implementation, application of Statistical Quality Control (SQC) methods, manual and Foss NIRS technology-based quality testing, as well as SAP and WD-based reporting. However, the implementation of the system in the field still faces challenges, such as inconsistencies in SOP implementation, delays in data input into the system, and external FFB quality that does not meet standards. These findings provide the basis for developing practical and adaptive strategies for system improvement.

In addition to the analytical framework mapping the six main dimensions, this study also formulates a detailed implementation flow for the quality control system based on observations and informant statements. The following diagram illustrates the actual steps carried out in the field, from raw material reception to quality evaluation processes:

Figure 2. CPO Quality Control System Implementation Flow



Source: Author's illustration based on field observation (2024)

DISCUSSION

This discussion is structured around six key dimensions derived from thematic analysis, aligned with Juran's quality theory and relevant academic literature.

Early Production Stage

Variations in the quality of Fresh Fruit Bunches (FFB), especially from external suppliers, remain a persistent issue in the early stage of production. INF5 stated, "Internal fruits are generally ripe and intact, but external fruits often contain defects or do not meet grading standards." INF6 emphasized the need for farmer education, saying, "Fruits from independent farmers often don't meet quality standards." These conditions reflect weaknesses in the quality planning phase of Juran's Trilogy, where controlling inputs is essential for ensuring product quality (Juran & De Feo, 2017). Although FIFO systems and grading SOPs exist, their implementation remains inconsistent across operators.

Administrative issues further disrupt early-stage quality control. INF9 reported, "Some trucks still arrive without SPB documents," while INF10 confirmed, "It creates congestion at the entry gate." These findings indicate a lack of integration between administrative and operational controls. Syaputa and Sofiyanurriyanti (2022) also noted that variability in third-party inputs undermines downstream quality. Similarly, Muangpratoom et al. (2023) highlighted that fruit ripeness and physical condition directly influence the chemical profile of CPO. Strategically, supplier development programs, intake document verification, and stricter supervision at the point of entry are needed to improve consistency from the beginning.

Quality Control Implementation

The quality control system at the mill includes SOPs, Statistical Quality Control (SQC), manual testing, and digital tools like Foss NIRS, SAP, and WD. However, execution remains uneven. INF2 explained, *"We use manual sampling and control charts, but they're not fully integrated digitally."* INF7 admitted, *"Sometimes the control forms are not completely filled out because of time constraints."* These indicate a gap in the quality control function of Juran's Trilogy, which emphasizes the importance of consistent monitoring and measurable performance (Juran & De

Feo, 2017). Heizer et al. (2020) also emphasized that effective quality control requires real-time detection and statistical analysis.

Beyond manual execution, digital integration is also lacking. INF3 revealed, *"Some results are recorded in Excel, others through WhatsApp, so there's no centralized dashboard."* This fragmentation aligns with Budiastra et al. (2024), who found that unintegrated reporting systems hinder traceability and decision-making. According to Ly and Kieu Viet (2022), digital tools are only effective when they support interconnected, data-driven decision-making. Therefore, it is essential to develop a centralized quality dashboard that unifies lab results, sampling records, and real-time alerts to enable synchronized control actions.

Field Execution

The implementation of quality control procedures in the field reveals deviations from planned protocols. INF1 remarked, *"SOPs are available, but some workers take shortcuts, especially during peak hours."* Similarly, INF4 shared, *"Reporting is sometimes delayed because the staff are either busy or unsure how to enter the data."* These findings suggest cultural and behavioral challenges that weaken the feedback loops needed for effective quality control and improvement, as emphasized by Juran & De Feo (2017). Duraivelu (2022) highlighted that weak procedural discipline often limits the success of digital and operational transformation.

Lack of coordination among divisions compounds the issue. INF5 said, *"We supervise manually, but we don't always get timely updates from the lab or receiving teams."* This misalignment hinders immediate corrective action, reducing the effectiveness of the control function. To close this gap, the mill must institutionalize daily cross-department coordination and clear reporting accountability. These actions reinforce Juran's quality control and improvement stages by ensuring that detected issues are promptly addressed and feedback is circulated throughout the organization.

Final Product Quality

The laboratory enforces strict internal quality targets for CPO, maintaining Free Fatty Acid (FFA) levels below 3.5%, moisture under 0.2%, and impurities below 0.025%. Although Foss NIRS enables faster testing, manual validation remains common practice. INF3 explained, *"We still do manual validation when there's deviation or audit, just to be safe,"* highlighting a culture of caution over speed. Sampling staff from both shifts stated, *"We follow a fixed schedule of two-hour intervals during the day and once at night,"* yet INF7 and INF8 acknowledged that this routine is hard to maintain consistently due to limited staff and high workload. Furthermore, INF4 noted, *"Inconsistencies in lab data often require clarification with sorting and weighing teams,"* revealing weak data integration across departments and limited real-time coordination.

These findings demonstrate a disconnect between advanced lab capabilities and the systemic responsiveness required for reliable quality assurance. Juran and De Feo (2017) asserted that final product quality is not merely the result of endpoint inspection, but of disciplined and connected processes across all stages. Nanda et al. (2025) highlighted that NIRS is most effective when embedded in a real-time, integrated workflow linking analytical and operational units. Febrina and Fitriana (2022) warned that traceability gaps reduce audit credibility and undermine quality consistency. While the lab excels in technical standards, performance is hindered by slow data circulation and fragmented communication, suggesting the need for a more unified digital infrastructure and stronger cross-functional data validation procedures.

Operational Impact

The performance of quality control systems directly affects operational efficiency, particularly when verification delays and digital mismatches occur. INF2 emphasized, *"Smooth operations are maintained when product quality meets internal standards."* Yet INF9 observed, *"When the system is slow, input delays occur and trucks pile up at the scale,"* while INF4 added, *"Data mismatches across SAP and WD systems often slow down reporting and require recoordination."* These lapses in system integration lead to bottlenecks, additional administrative work, and reduced agility. Such findings contradict Juran's principle that quality should facilitate, not hinder, operational flow.

Instead of enabling swift decision-making, current digital systems tend to create friction, resulting in redundancy and delays. Komarudin and Siregar (2024) underscored that ISPO compliance requires traceable and digitally synchronized reporting to avoid inconsistencies and rework. INF3 mentioned that *"validation steps sometimes delay shipment releases,"* illustrating how fragmented systems can compromise both responsiveness and reliability. Addressing these issues requires a centralized quality dashboard, streamlined digital reporting architecture, and tighter integration between quality control and logistics functions. By aligning system design with operational speed, the company can avoid duplicated efforts and reduce cycle time disruptions.

Evaluation and Recommendations

Despite the completeness of the quality control framework, field execution remains inconsistent due to behavioral variability, low interdepartmental coordination, and incomplete digital integration. INF1 emphasized, *"Quality reporting accuracy can only be achieved if the lab, admin, sorting, weighing, and security teams support and complement each other."* INF4 echoed this concern, saying, *"Data synchronization across divisions is still problematic, especially when different formats are used for reports."* INF3 added, *"Audit outcomes depend heavily on precision and the quality of supporting documentation,"* while INF7 and INF8 noted that heavy workloads and shift constraints often reduce sampling consistency. INF9 and INF10 also confirmed that missing external delivery documents routinely cause process delays and confusion during verification.

These operational weaknesses highlight a gap between system design and continuous improvement, particularly within Juran's quality improvement pillar. While the company has adopted key quality tools, the current culture is still reactive rather than preventive. Ly and Kieu Viet (2022) suggested that SOPs must be presented in visual and practical formats to ensure usability at the frontline. Komarudin and Siregar (2024) also emphasized the importance of synchronized collaboration to meet ISPO standards and maintain system responsiveness. Based on this analysis, five strategic actions are recommended: (1) provide regular technical training across departments, (2) convert SOPs into simplified visual formats, (3) establish a centralized real-time quality dashboard, (4) hold periodic cross-department coordination forums, and (5) implement structured coaching programs for external suppliers. These initiatives aim to transform a reactive, fragmented system into an integrated and continuously improving quality management environment.

CONCLUSION

This study found that the Crude Palm Oil (CPO) quality control system implemented at the observed palm oil mill has been comprehensively designed. The system encompasses fresh fruit bunch (FFB) sorting and grading, Standard Operating Procedure (SOP) implementation, Statistical Quality Control (SQC) methods, both manual and digital quality testing (using Foss NIRS), and data recording through SAP and Warehouse Data (WD) systems. These components interact to form an integrated control structure that reflects Juran's quality principles: planning, control, and improvement, ensuring product consistency from upstream to downstream processes.

However, challenges remain in actual implementation, including inconsistent SOP adherence, delayed data input, limited cross-departmental coordination, and suboptimal technology utilization. To address these issues, several improvement strategies are proposed: enhanced technical training, simplification of SOP formats into visual checklists, real-time integrated reporting systems, interdepartmental coordination forums, and structured guidance for external suppliers. The consistent and phased application of these strategies is expected to enhance the effectiveness of the quality control system and support long-term sustainability in line with ISPO certification standards.

LIMITATION

This study has several limitations. First, data collection was limited to ten informants directly involved in the quality control system, which may not capture the full perspectives of other employees or operational divisions. Second, while the qualitative approach allowed for in-depth exploration, the findings remain subjective and are influenced by each informant's individual experience and interpretation. Third, this study did not explore technical aspects such as equipment calibration, maintenance procedures, or a cost-benefit analysis of the quality control system.

Future research should involve a broader range of respondents across different departments and consider a mixed-methods approach to enhance generalizability. Additionally, comparative studies across multiple palm oil mills could provide insights into best practices and common implementation challenges in sustaining CPO quality control.

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