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Harvesting standard operating procedures and fresh fruit bunch quality in oil palm: literature review

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ABSTRACT

The quality of fresh fruit bunches (FFB) is one of the key factors affecting the productivity and efficiency of the palm oil industry. Improper harvesting practices may lead to increased losses, reduced oil extraction rates, and deterioration of fruit quality. Therefore, the implementation of harvesting Standard Operating Procedures (SOPs) is essential to ensure that harvesting activities are carried out effectively and consistently. This study aimed to examine the role of harvesting SOPs in maintaining the quality of oil palm fresh fruit bunches through a literature review approach. Literature data were collected from scientific publications indexed in Sinta and Scopus databases using the keywords oil palm harvesting, fresh fruit bunch quality, harvest losses, free fatty acid, harvesting SOP, and post-harvest handling. A total of 25 articles published between 2018 and 2025 were selected based on predetermined inclusion criteria. The collected literature was analyzed descriptively through comparison and synthesis of findings from previous studies. The review indicates that the implementation of harvesting SOPs is associated with improved compliance with fruit maturity standards, reduced harvest losses, lower risk of free fatty acid formation, and improved maintenance of fruit quality. The literature also highlights the importance of worker competence, supervision, transportation management, and adherence to harvesting schedules in supporting effective SOP implementation. Conversely, inadequate harvesting practices may negatively affect fruit quality and plantation performance. In conclusion, harvesting SOPs play an important role in maintaining the quality of oil palm fresh fruit bunches and supporting sustainable plantation management. Continuous training, monitoring, and evaluation are recommended to strengthen SOP implementation and improve harvesting performance.

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1. INTRODUCTION

The The oil palm industry plays an important role in supporting economic growth and contributing to national export revenues in many producing countries, including Indonesia. The productivity and quality of palm oil products are highly dependent on the quality of fresh fruit

bunches (FFB) delivered to processing mills. High-quality FFB can improve oil extraction rates and reduce processing losses, whereas poor-quality fruit may increase free fatty acid (FFA) content and reduce crude palm oil (CPO) quality. Therefore, maintaining FFB quality throughout harvesting and post-harvest operations is essential for ensuring sustainable plantation performance and maximizing economic returns (Hudori, 2018).

Harvesting is one of the most critical operational activities in oil palm plantations because it directly determines the quality of harvested fruit. Proper harvesting practices involve harvesting fruit at the appropriate maturity stage, collecting loose fruits, minimizing fruit damage, and ensuring timely transportation to processing facilities. However, non-compliance with harvesting procedures may result in harvest losses, lower oil extraction rates, and deterioration of fruit quality (Nugroho et al., 2023). Consequently, the implementation of Standard Operating Procedures (SOPs) has become an important management tool for maintaining operational consistency and product quality.

Previous studies have identified several factors affecting FFB quality during harvesting operations. Harvest maturity has been recognized as a major determinant of oil content and processing efficiency, while improper harvesting practices may increase harvest losses and reduce overall plantation productivity. Advances in technology have also supported harvesting management through fruit ripeness detection systems and image-based quality assessment techniques, enabling more accurate harvesting decisions (Syafiuddin et al., 2020; Ahmad Mansour et al., 2023). In addition, transportation management and grading systems play important roles in maintaining fruit quality and reducing quality deterioration before processing.

Although numerous studies have discussed fruit maturity assessment, harvest losses, grading systems, free fatty acid (FFA) formation, and post-harvest handling in oil palm plantations, these topics have generally been examined separately. As a result, the findings remain fragmented across different research areas, making it difficult to obtain a comprehensive understanding of how harvesting practices collectively influence FFB quality.

Unlike previous studies that focused on individual aspects of harvesting operations, this review integrates fruit maturity management, harvest loss reduction, FFA control, transportation management, grading practices, and post-harvest handling within the framework of harvesting SOP implementation. By synthesizing findings from relevant national and international studies, this review provides a more comprehensive understanding of the mechanisms through which harvesting SOPs influence FFB quality and plantation performance. This integrated perspective represents the main contribution of the present review.

Therefore, this study aims to review and synthesize previous research regarding the implementation of harvesting Standard Operating Procedures (SOPs) and their role in maintaining the quality of oil palm fresh fruit bunches. The findings are expected to provide useful insights for plantation managers, researchers, and practitioners in improving harvesting effectiveness, reducing losses, maintaining fruit quality, and supporting sustainable palm oil production.

2. METHOD

This study employed a literature review approach to examine the role of harvesting Standard Operating Procedures (SOPs) in maintaining the quality of oil palm fresh fruit bunches (FFB). The literature review method was selected because it enables the synthesis and evaluation of findings from previous studies related to harvesting practices, fruit quality standards, harvest losses, free fatty acid (FFA) formation, and post-harvest handling in oil palm plantations (Snyder, 2019).

Literature searching was conducted using the Sinta and Scopus databases. The search process was performed using the keywords “oil palm harvesting”, “fresh fruit bunch quality”, “harvest losses”, “free fatty acid”, “harvesting SOP”, and “post-harvest handling”. Articles published between 2018 and 2025 were considered for inclusion in this review.

A total of 45 articles were initially identified through the database search. The articles were subsequently screened based on predetermined inclusion and exclusion criteria. The inclusion criteria comprised publications discussing harvesting SOP implementation, fruit maturity standards, factors affecting FFB quality, harvest losses, transportation management, and post-harvest handling in oil palm plantations. Publications that were not directly related to harvesting operations or fruit quality management were excluded from the review. After the screening and eligibility assessment process, 20 articles were excluded because they did not specifically address the objectives of this study. Consequently, 25 articles met the inclusion criteria and were selected for further analysis.

The quality of the selected articles was evaluated based on their relevance to the research objectives, publication source, methodological clarity, and contribution to understanding the role of harvesting SOPs in maintaining FFB quality. Only articles published in reputable journals indexed in Sinta and Scopus were included in the final review.

The selected literature was analyzed using a descriptive qualitative approach. Data from each publication were reviewed, classified, compared, and synthesized to identify similarities, differences, and research trends related to harvesting SOP implementation. The analysis focused on evaluating the role of harvesting SOPs in maintaining fruit maturity standards, reducing harvest losses, minimizing free fatty acid formation, and improving overall plantation performance. The research procedure can be summarized as follows: Identification of research topic → Literature search → Article screening and selection → Data classification → Data synthesis and analysis → Interpretation of findings → Conclusion.

3. RESULTS AND DISCUSSION

3.1 Harvesting SOP and Fresh Fruit Bunch Quality

The quality of oil palm fresh fruit bunches (FFB) is strongly influenced by the effectiveness of harvesting operations. Therefore, the implementation of harvesting Standard Operating Procedures (SOPs) is essential to ensure that harvesting activities are conducted consistently and in accordance with established quality standards. Proper implementation of harvesting SOPs contributes to maintaining fruit maturity standards, minimizing harvest losses, reducing quality deterioration, and supporting overall plantation productivity.

One of the primary objectives of harvesting SOPs is to ensure that fruit bunches are harvested at the optimum maturity stage. Fruit maturity is an important determinant of oil content and processing efficiency. Harvesting immature bunches may result in lower oil extraction rates, whereas overripe bunches are more susceptible to loose fruit losses, bruising, and quality deterioration. Lai et al. (2023) emphasized that accurate fruit maturity assessment is necessary to improve harvesting effectiveness and maintain product quality. Similarly, Syafiuddin et al. (2020) reported that technological approaches for fruit maturity detection can support more accurate harvesting decisions and reduce human error during field operations.

Harvesting SOPs also contribute to reducing harvest losses through standardized harvesting and collection procedures. Improper harvesting practices may lead to uncollected loose fruits, damaged bunches, and increased field losses, which ultimately reduce plantation productivity. In addition, proper harvesting procedures facilitate better handling of harvested bunches and support effective transportation management from the field to processing facilities.

Another important aspect influenced by harvesting SOPs is the formation of free fatty acids (FFA). Delays in transporting and processing harvested bunches may accelerate enzymatic activity and increase FFA levels, thereby reducing crude palm oil quality. Compliance with harvesting schedules and post-harvest handling procedures helps minimize the time between harvesting and processing, reducing the risk of excessive FFA formation and preserving fruit quality.

Several studies have also highlighted the importance of grading systems as part of quality management practices. Grading activities allow harvested bunches to be classified according to maturity level and physical condition before processing. Judijanto (2026) reported that the implementation of grading procedures supports quality control and improves plantation productivity by reducing the risk of processing low-quality fruit bunches.

Overall, the reviewed literature indicates that harvesting SOPs provide a structured framework for maintaining FFB quality. The effectiveness of SOP implementation is influenced by several factors, including fruit maturity determination, harvest loss control, transportation management, worker competence, and field supervision. Proper implementation of these procedures supports higher FFB quality, lower FFA formation, improved crude palm oil quality, and better plantation performance.

Table 1. Summary of Literature Reviewed on Harvesting SOPs and FEB Quality

No	Author(s)	Year	Research Focus	Main Findings
1	Ahmad Mansour, Dembul & Yeep	2023	Non-destructive ripeness classification of oil palm FEB	Non-destructive fruit ripeness classification technology can improve the accuracy of harvest timing and the quality of fresh fruit bunches (FFB).
2	Hudori	2018	Quality performance	The quality of FFB is a key factor in processing efficiency and the quality of the crude palm oil

			measurement of oil palm FEB	(CPO) produced.
3	Kalsum et al.	2020	Factors contributing to oil losses in CPO production	Oil loss is influenced by the quality of raw materials, fruit ripeness, and postharvest management
4	Lai et al.	2023	FEB ripeness detection methods	Detecting fruit ripeness can improve harvest efficiency and the quality of the final product
5	Nanda et al.	2020	Effect of post-harvest storage on palm oil quality	Storage and delays in fruit processing increase free fatty acids (FFA) and reduce the quality of palm oil
6	Nugroho, Kurniawati & Ambarsari	2023	SOP implementation in harvesting and loading activities	Adherence to standard operating procedures (SOPs) for harvesting and loading fresh fruit bunches (FFB) helps reduce losses and maintain fruit quality
7	Syafaruddin et al.	2020	Image recognition for fruit maturity grading	Image recognition systems can improve the accuracy of fruit ripeness grading and support productivity
8	Synder	2019	Literature review methodology	Explains the systematic steps of a literature review as a research method. Used as a methodological reference
9	Akbar, Wibowo & Santoso	2023	Optimal harvesting time and fruit maturity	The optimal harvest time is up to the 6th day after the first cluster of fruit appears. Fruit ripeness affects oil yield and FFA levels
10	Samian & Rizal	2024	Harvesting practices anda FFB productivity	Proper harvest intervals, cluster picking, and FFB grading improve productivity and the Oil Extraction Rate (OER)
11	Han & Yi	2025	Deep learning for fruit maturity calssification	The CNN model can classify fruit ripeness levels with 85% accuracy, supporting more accurate harvest decisions
12	Fadhiela & Firnanda	2023	Harvesting management in oil palm plantations	A 7–8-day harvest rotation and the application of harvest ripeness criteria result in 98.6% of fruit meeting standard quality
13	Efi Said Ali et al.	2025	Harvesting maturity training and harvesting accuracy	Understanding harvest ripeness criteria can reduce losses by up to 30% and improve the quality of the oil produced
14	Putriani & Asrofillah	2025	Effect of FEB ripeness on CPO quality	Ripe fruit yields the highest oil content (24.5%) with low FFA (1.5%), while overripe fruit increases FFA (-3%) and reduces CPO quality
15	Sirtin et al.	2025	Thermal imaging for FFB grading	Thermal imaging can non-destructively predict the oil and moisture content of fresh fruit bunches (FFB), thereby supporting more objective grading
16	Pramana et al.	2021	Post-harvest losses and risks	Total post-harvest losses reached 5.21%, losses occurred at field, TPH, and mill sorting stages
17	Krisdiarto & Sutiarso	2018	Bruising during harvesting and transportation	Fruit bruising increased FFA content and reduced FFB quality, poor handling accelerated quality deterioration
18	Nurfalah et al.	2023	Harvest interval and harvest losses	Harvest intervals longer than 16 days increased harvest losses and reduced harvesting efficiency
19	Sukariyan et al.	2024	Loose fruit (brondolan) losses	Weak supervision and poor field maintenance caused losses reaching about 3.2 % of total FFB production
20	Cahyadi et al.	2025	SOP implementation among harvest workers	Good SOP compliance improved safety, harvesting efficiency, and productivity, 69% of workers complied with SOPs
21	Edyson, Murgianto, Ardiyanto, Astuti, & Ahmad	2022	Factors affecting free fatty acid (FFA) content in crude palm oil	Fruit maturity, fruit handling Pest attacks, and delayed transportation significantly increased FFA levels by 41.10 – 204%. Proper harvesting and post-harvest management are essential to maintain CPO quality

22	Asiriuwa, Ojeaburu, Imoisi, & Akpose	2025	Effect of post-harvest storage time on palm oli quality	Extended storage of fresh fruit bunches increased FFA, peroxide value, and oxidation products, resulting in significant deterioration of palm oli quality
23	Kencana & Iriani	2025	Risk analysis in oil palm harvesting operations	Inadequate SOP implementation increased operational risks,harvest delays, fruit deterioration, and transportation problems, ultimately affecting harvested fruit quality
24	Julyanda, Sembiring & Absah	2025	Optimization of FFB harvesting process using Lean Agriculture	Reducing non-value-added activities improved harvesting efficiency by 26.32-28.57%. Delays in harvesting and transportation decreased FFB freshness and OER, highlighting the importance of SOP implementation and process optimization
25	Jaya et al.	2025	CPO quality parameters	Proper harvesting and handling practices are essential to maintain low FFA levels and improve CPO quality

3.2 Factors Affecting SOP Implementation

The effectiveness of harvesting SOP implementation is influenced by several operational and managerial factors. One of the primary factors is worker competence. Harvesters are responsible for determining fruit maturity, cutting bunches correctly, collecting loose fruits, and maintaining harvesting standards in the field. Insufficient skills or lack of training may result in improper harvesting practices that negatively affect fruit quality. Therefore, continuous training programs are essential to ensure that workers understand and comply with harvesting procedures.

Supervision also plays a critical role in maintaining SOP compliance. Plantation supervisors are responsible for monitoring harvesting activities and ensuring that operational standards are consistently applied. Nugroho et al. (2023) reported that inadequate supervision often leads to harvest losses, missed loose fruits, and inconsistencies in harvesting quality. Effective supervision helps identify operational problems early and ensures corrective actions are implemented promptly. Another important factor is the availability of appropriate harvesting equipment and supporting infrastructure. Damaged tools or inadequate transportation facilities may hinder harvesting efficiency and increase the risk of fruit damage. Consequently, plantation management must ensure that operational equipment is properly maintained and available to support harvesting activities. The combination of skilled workers, effective supervision, and adequate facilities forms the foundation for successful SOP implementation.

3.3 Harvest Maturity Standards

Harvest maturity standards are fundamental components of harvesting SOPs because they directly influence oil quality and extraction rates. Oil palm fruit undergoes physiological changes during ripening, and harvesting at the correct stage ensures optimal oil accumulation. Lai et al. (2023) emphasized that maturity assessment is a critical step in harvesting management because improper maturity determination can significantly reduce processing efficiency.

Technological developments have improved maturity assessment methods in recent years. Ahmad Mansour et al. (2023) reviewed several ripeness classification techniques and concluded that image-based systems and machine learning approaches can improve harvesting accuracy. These technologies provide more objective assessments compared to conventional visual inspection methods and may contribute to more consistent harvesting decisions.

Furthermore, Syafiuddin et al. (2020) demonstrated that image recognition systems combined with fuzzy inference techniques can effectively identify fruit maturity levels. Such innovations have the potential to support plantation managers in reducing harvesting errors and improving overall fruit quality. Therefore, integrating technological approaches into harvesting SOPs may enhance operational performance and quality control.

3.4 Harvest Losses and Transportation Managemen

Harvest losses remain one of the major challenges affecting plantation productivity and fruit quality. Losses may occur due to uncollected loose fruits, damaged bunches, harvesting delays, or improper handling practices. Nugroho et al. (2023) reported that effective implementation of harvesting SOPs can significantly reduce harvest losses by improving harvesting discipline and operational consistency.

Transportation management is equally important in maintaining FFB quality after harvesting. Delays between harvesting and processing may accelerate fruit deterioration and increase free fatty acid formation. Nanda et al. (2020) reported that post-harvest handling and storage

conditions significantly affect fruit quality and oil characteristics. Therefore, harvested bunches should be transported to processing facilities as quickly as possible to minimize quality degradation.

Kalsum et al. (2020) further explained that operational inefficiencies during harvesting and transportation contribute to oil losses throughout the production process. Proper scheduling, efficient logistics, and adequate transportation facilities are therefore necessary to support quality preservation. These findings suggest that harvesting SOPs should not only focus on field harvesting activities but also include transportation and post-harvest management procedures.

3.5 Implications for Sustainable Plantation Management

The findings of this review demonstrate that harvesting SOPs contribute significantly to sustainable plantation management by improving fruit quality, reducing losses, and increasing operational efficiency. Effective harvesting practices support better utilization of plantation resources and enhance overall production performance. Moreover, maintaining high-quality FFB can improve mill efficiency and increase crude palm oil yield.

Advances in technology, particularly in fruit maturity assessment and quality monitoring, provide opportunities for further improving harvesting management. The integration of digital technologies and automated quality assessment systems can enhance decision-making processes and support more consistent implementation of harvesting standards. Such innovations are expected to strengthen quality control systems and improve competitiveness within the palm oil industry.

Overall, harvesting SOPs should be considered not only as operational guidelines but also as strategic management tools that support sustainable production. Continuous evaluation, worker training, technological adoption, and effective supervision are essential for ensuring the long-term effectiveness of harvesting SOP implementation in oil palm plantations.

4. CONCLUSION

This literature review demonstrates that harvesting Standard Operating Procedures (SOPs) play an important role in maintaining the quality of oil palm fresh fruit bunches (FFB) by ensuring proper fruit maturity, reducing harvest losses, minimizing free fatty acid (FFA) formation, and supporting effective post-harvest handling. The reviewed studies indicate that fruit maturity determination, harvest loss control, transportation management, worker competence, and field supervision are the dominant factors influencing the effectiveness of SOP implementation and FFB quality. This review contributes to the existing literature by providing an integrated understanding of the relationship between harvesting SOPs and FFB quality in oil palm plantations. Future research should focus on field-based and quantitative evaluations to assess the effectiveness of harvesting SOP implementation under different plantation conditions and management systems.

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