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RESEARCH ARTICLE

IMPROVING THE QUALITY AND PRODUCTIVITY OF PALM OIL THROUGH MECHANISATION IN PALM OIL COMPANIES

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ABSTRACT - The purpose of this study is to enhance palm oil productivity and quality through mechanisation by identifying palm oil production processes and recommending appropriate mechanisation strategies to increase palm oil productivity and quality. The data was gathered via semi-structured interviews with employees from YP Plantation Holdings Sdn Bhd. The findings hope to offer recommendations for YPPH to optimise the production process, improve palm oil quality, and increase productivity. This will not only uphold YPPH's market competitiveness but also promote better farmer welfare, expand the agricultural industry, and influence policy and decision-making. The study also offers a conclusion and discussion, research recommendations, identification of literary gaps, and best practices for future development. Implementing the proposed solutions can lead to improved palm oil quality, higher output, and overall growth for YPPH and the agricultural sector, notably the palm oil industry. This will help YPPH to improve palm oil quality while increasing output and overall development, solidifying its position as a vital player in the palm oil market.

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1. INTRODUCTION

The palm oil sector is the backbone of Malaysian agriculture, providing food and fuel to an expanding worldwide population. The rapid growth of local oil palm stemmed from Malaysia's attempt to diversify its agriculture from mainly rubbers in the 1960s (Basiron, 2007). Malaysia and Indonesia are among the world's largest palm oil producers and are responsible for the great bulk of palm oil production worldwide. Peninsular Malaysia accounts for more than 12% of global output and generates over 50% of Malaysia's palm oil. According to the FFTC Agricultural Policy Platform (FFTC-AP), more than 4.9 million hectares of land were planted with oil palm, generating 17.73 million tonnes of palm oil and 2.13 million tonnes of palm kernel oil by 2020. Malaysia has benefited greatly from the palm oil sector as it has helped to create jobs, generate foreign cash, and boost economic growth. Furthermore, palm oil exports have been a significant source of foreign cash for Malaysia, adding to the country's economic strength and trade balance. Therefore, promoting high and efficient productivity is crucial to ensure the long-term production of excellent oil palm.

The Organisation for Economic Co-operation and Development (OECD) defines productivity as the ratio of total output to total input. Productivity measures how production inputs, such as capital and labour, are efficiently used in the economy to create the desired output. Improved productivity allows the economy to generate more products and services with the same number of inputs, or with fewer inputs to achieve the same amount of output. Long-term economic growth can only be achieved through increased productivity. According to Indiastuti (2016), productivity increase is related to the ratio of inputs to outputs. Increased productivity demonstrates how well resources are managed in production, which leads to a rise in output (Chukwulozie et al., 2018). Malaysia is the world's biggest palm oil producer, with output increasing year after year due to rising market demand. Variances in the capacity to arrange economic resources will result in variances in output levels. Such component will stem from social, economic, and institutional access as well as farmers' inability to use their output. Increased productivity will have a positive impact on the nation, companies, or people in the form of more earnings or income, a better reputation, and less resource waste.

Quality has been acknowledged as a key business in today's global marketplace. The American Society for Quality (2010) defines quality as the total of a product or service's features and attributes that impact its ability to fulfil explicit or implied demands. The importance of quality in any organisation cannot be overstated since price and quality are two critical factors in every purchasing choice (Stevenson, 2009). The definition of quality can be interpreted from two perspectives: consumer and producer. According to the producer, good quality is when the product produced by the company meets its specifications; whereas, good quality for consumers is when the products meet their expectations, have benefits that match their needs, and are equivalent to the amount of money they paid for the products (Fatimah et al., 2018). However, the idea of quality is commonly seen as conformance or the general features of a product expected by the consumer. In the Malaysian palm oil sector, Malaysia Sustainable Palm Oil (MSPO) was formed in 2014 with the goal of improving the nation's palm oil global competitiveness and implementing stricter environmental laws. All palm

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oil producers in Malaysia are encouraged to obtain MSPO certification; while MSPO is not internationally acknowledged, its certification standards reflect the quality and safety of palm oil-produced goods.

The palm oil industry ultimately emerges as Malaysia's primary agricultural sector. Over time, local oil palm farms have become increasingly reliant on foreign labour to conduct everyday operations. Mechanisation is the implementation of tools with mechanised components to assist the user in doing certain tasks (Ahmarofi et al., 2024). The adoption of mechanisation tools in the palm oil sector is believed to increase the production and quality of palm oil. All harvested palm oil fresh fruit bunch (FFB) must be evacuated from the plantation field to the nearby processing mill in an undamaged condition within 24 hours (Ahmarofi et al., 2024). Any delay can reduce the quality of harvested FFB due to the increase in free fatty acid (FFA) content in the oil within the bunch (Rankine & Fairhurst, 1998). Moreover, delays in harvest processing will have a significant impact on the palm oil sector as the corporations will experience a significant loss in its oil palm operations. Therefore, mechanisation is an important factor in the Malaysian oil palm industry since it reduces reliance on manual labour and increases the land labour ratio from 10:1 to 15:1 (Mohd Khalid et al., 2023).

1.1 Research Problem

The purpose of this study is to explore the major factors affecting palm oil productivity and quality in Malaysia and the absence of mechanisation in plantation palm oil production within the local palm oil industry. Low palm oil production and the lack of mechanisation can negatively impact oil palm companies, particularly during harvesting, and jeopardise palm oil's quality. Workers will also be affected by the high human labour rate and long working hours, leading to deteriorating health and safety. Such issue will eventually cause labour shortage, which can have adverse effects on palm oil production and quality. Therefore, understanding and tackling these problems is critical for building a long-term collaboration that benefits both the company and the workers, especially those who are tasked to handle mechanisation during the production process like harvesting, cutting, in-field collecting, as well as internal and external transportation. This hopes to facilitate the production of high-quality palm oil, ultimately leading towards maximised profitability, minimised human labour, and fulfilling consumer demand in the palm oil sector.

1.2 Research Gap

Mechanisation has been propounded as a critical component for increasing productivity and quality in palm oil production. To facilitate its actual on-site implementation, there is a need for extensive research that qualitatively examines how mechanisation instruments directly influence palm oil productivity and quality in terms of texture, colour, scent, and production. The availability of such investigation will add to the understanding of mechanisation usage and subsequent improvement in palm oil output and quality. Furthermore, analysing factors like appropriate mechanisation, the productive period of mechanisation, and the cost-effectiveness of process optimisation can offer important insight into the possible return on investment. It also sheds light on the specific challenges that palm oil companies may face in introducing mechanisation, which can affect productivity and palm oil quality. This will facilitate stakeholders in devising potential solutions to such constraints.

1.3 Research Questions

a) What are the specific steps and stages involved in the manufacturing process of palm oil in YP Plantation Holdings Sdn Bhd?

b) What are the potential areas in mechanisation to improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd?

c) What are the best practices in mechanisation that can be used to improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd?

1.4 Research Objectives

a) To identify the production process of palm oil in YP Plantation Holdings Sdn Bhd.

b) To improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd.

c) To suggest the best practices in mechanisation that can be used to improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd.

1.5 Scope of Study

This study explores the use of mechanisation for increasing palm oil output and quality alongside possible difficulties in its implementation. The scope of this study is limited to the plantations owned by YP Plantation Holdings Sdn Bhd (hereinafter known as YPPH) and their operations. The projected timescale for performing this study was determined by the availability of data and the use of interview as the data collection method. The findings are presented through a thorough report and hope to assist YPPH in improving palm oil quality and successfully resolving mechanisation-related challenges.

1.6 Significance of the Study

This research offers substantial advantages, particularly for increasing the production and quality of palm oil in the local industry. Mechanisation will enable YPPH to produce high yield of quality palm oil. This can have a direct influence on the company's reputation and market competitiveness, resulting in greater profitability and customer satisfaction. Furthermore, the research intends to increase workers' well-being by introducing mechanisation to reduce the amount of human labour utilisation at the workplace while considering the perspectives of both YPPH and the workers. Observational facts and practical insights generated from the research can also help to advance the superior agriculture industry. This will assist other palm oil companies by providing a successful experience in productivity and quality as well as the usage of mechanisation, which will lead to an improvement in the palm oil business. Moreover, this research can inspire higher quality and more efficient output through mechanisation in the agricultural economy. It also serves as a significant learning tool for various stakeholders who are interested in the efficacy of mechanisation in increasing palm oil productivity and quality.

1.7 The Case Company

YP Plantation Holdings Sdn Bhd is a palm oil plantation firm founded in 1985 and stands as a subsidiary of Yayasan Pahang. The company has been investing in palm oil plantation since 1994 by opening its first 1,171 acre plantation and continues to develop and expand such business on lands held by the parent corporation upon recognising the long-term importance of the plantation sector as Yayasan Pahang's primary source of revenue. Gambang's mechanised plantation includes activities like harvesting, poisoning, and fertilisation. To date, YPPH employs 253 labour workers, comprising 74% immigrant and 26% local workers. The company has 2,210 hectares of palm oil land, of which 1907 hectares are mature and 303 hectares are still maturing. It also has a five-year crop of palm oil in 1996, 1997, 2003, 2002, and 2018, including other plants like coconut, pineapple, and banana. As an 'investment arm' for Yayasan Pahang, YPPH aspires to maximise revenues and generate steady and continuous income through efficient and cost-effective management. The company has received several accolades, including MSPO and ABMS accreditation as well as the AIGA Award. However, manual labour remains prominent across most YPPH palm oil plantations, particularly in FFB harvesting, transporting, and cutting. Based on these issues, the purpose of this research is to analyse and suggest mechanisation enhancements that can reduce human labour, ultimately boosting palm oil productivity and quality.

2. LITERATURE REVIEW

2.1 Palm Oil Productivity Measure

Most manufacturers evaluate resource availability while determining production capacity. Pargar (2017) believes that resource utilisation is vital in the production process. Thus, the use of appropriate resources will result in optimal output and great profit. To achieve profits, businesses must maximise resource utilisation by establishing their degree of productivity. This can be determined by the efficacy and efficiency with which inputs are used to produce output. There are two main techniques for assessing productivity, namely (1) labour productivity, which measures output per unit of labour, and (2) total factor productivity (TFP), which measures the total productivity of all production components from increased input quality, such as technological progress, human resource management, and human capital (Ismail et al., 2022). According to the Malaysia Productivity Corporation, greater TFP contribution to economic growth is unquestionably critical for improving people's living circumstances. In general, TFP continues to contribute minimally to Malaysia's economic growth, with capital input accounting for most of the contribution (MPC, 2016). The manufacturing sector's TFP increased by 1.5 percent during the 10th Malaysia Plan compared to 1.3 percent in the 9th Malaysia Plan. Such increase is accounted for good investments in the manufacturing sector where significant investments in machinery and advanced automation were undertaken to boost the sector's worldwide competitiveness, thus producing more complex and diversified products (Sulaiman et al., 2017). Furthermore, improvements in qualified staff and collaboration with research institutes also lead to significant TFP growth. A high TFP growth rate is critical in the industrial sector, particularly in key industries that drive a country's economic growth. Palm oil-related business is therefore vital given Malaysia's position as one of the leading palm oil producers worldwide.

2.2 Issues and Challenges of Mechanisation in the Palm Oil Industry

Modernisation in many areas of life necessitates the use of technology to reduce stress and improve efficiency. Farm mechanisation in oil palm plantations has been a continuous endeavour and is supported by numerous research bodies and institutions. Various research entities and institutions have spearheaded the introduction of new palm oil plantation mechanisation, but due to funding and fabrication facility constraints, they have only been able to develop a prototype at the National Aeronautics and Space Administration (NASA) Technology Readiness Level (TRL) 5 (Ramli et al., 2022). Several research items have changed over time to accommodate different plantation types, geography, and activities. The technologies produced varied from complex items, such as the hydraulically propelled Hydraporter, to something as basic as a motorcycle trailer. Most technologies developed via research and development (R&D) have received limited acceptability due to various issues, including the low rate of technical improvement in oil palm mechanisation and automation. The criteria set by the Ministry of Science, Technology, and Innovation (MOSTI) indicates that most R&D organisations or universities can only attain technical validation, also known as Technology Readiness Level (TRL) 5. It was created based on the NASA standard to represent the technological progression from idea (TRL 1) to operational deployment (TRL 9) (Ramli et al., 2022). In line with IR4.0, Agriculture 4.0 concerns the application of technologies, such as the Internet of Things (IoT), precision farming, drone technology, artificial intelligence (AI), and big data analytics, into agriculture. Nonetheless, some large agricultural producers continue to use traditional manual labour practices. For instance, the oil palm industry is preparing for IR2.0 by adding electric-powered harvesters known as

CANTAS Electro and drone technology (Ramli et al., 2021). The industry's slow adoption of technology is mostly due to the high cost of introducing new technologies and its reliance on inexpensive foreign labour.

2.3 Quality Control of Palm Oil

Quality is one of the major concerns for many companies as it has the power to alter the dynamic between suppliers and customers while also lowering losses for the business. Throughout a company's growth phase, maintaining the quality of its services and products is highly crucial. This is because most customers consider quality as among the important considerations when deciding whether to use a product. For instance, the growing rivalry among crude palm oil (CPO) manufacturers will push them to raise the productivity and quality standard of their product. According to Stevenson (2009) and Montgomery (2000), quality control is a process that compares output to a standard and takes corrective action when it fails to meet the standard.

One of the widely utilised quality control systems for plantation is the Taguchi approach. It encompasses three basic and essential elements that provide robust performance: quality robustness, target-oriented quality, and quality loss function (Hasudungan Lubis & Aryza, 2018). Target-oriented quality aims to minimise deviations from a target, whereas quality loss function measures the system's overall losses. Meanwhile, quality robustness is connected to a product's capacity to withstand external conditions. Product quality can be increased by minimising a product's performance deviation from its goal value, which is measured by Taguchi using a quality deviation function. Greater product quality will result in less functional variance and fewer losses incurred by society. Taguchi classifies quadratic functions into three categories when determining quality attributes: nominal is the best, smaller is better, and larger is better (Hasudungan Lubis & Aryza, 2018).

According to Dale (1998) and Stevenson (2009), businesses typically use seven fundamental quality tools to monitor quality in the manufacturing or service sectors: Check Sheet, Pareto Chart, Histogram, Scatter Diagram, Flow Chart, Cause and Effect Diagram, and Control Chart. Quality control charts are often used in various sectors, including manufacturing, to monitor product quality and identify major deviations from quality objectives as well as random and non-random variability (Saravanan & Nagarajan 2013).

3. DATA AND METHODOLOGY

This study employed a qualitative research design to obtain a full grasp of the manufacturing process production, quality control processes, and proposal employing laser for automation in harvesting. The qualitative technique allows a thorough examination of these elements. Face-to-face interviews were performed with YPPH manager and workers who were selected based on their knowledge and experience in palm oil production and quality control. Assessments of the existing literature were gained through reputable interview sessions since they shared commonalities or were related to the issue. All interview sessions were recorded and thorough notes were gathered for future study.

Furthermore, this study also gathered secondary data regarding palm oil production and quality control in other countries like Indonesia and the United States. The use of lasers in agriculture was viewed as an important signal for improving production and quality control. A comprehensive analysis was conducted on both primary and secondary data to explore any emerging themes and trends related to the production process, quality control, and recommended mechanisation. Such insights hope to present a comprehensive overview of the issue.

3.1 Research Flow

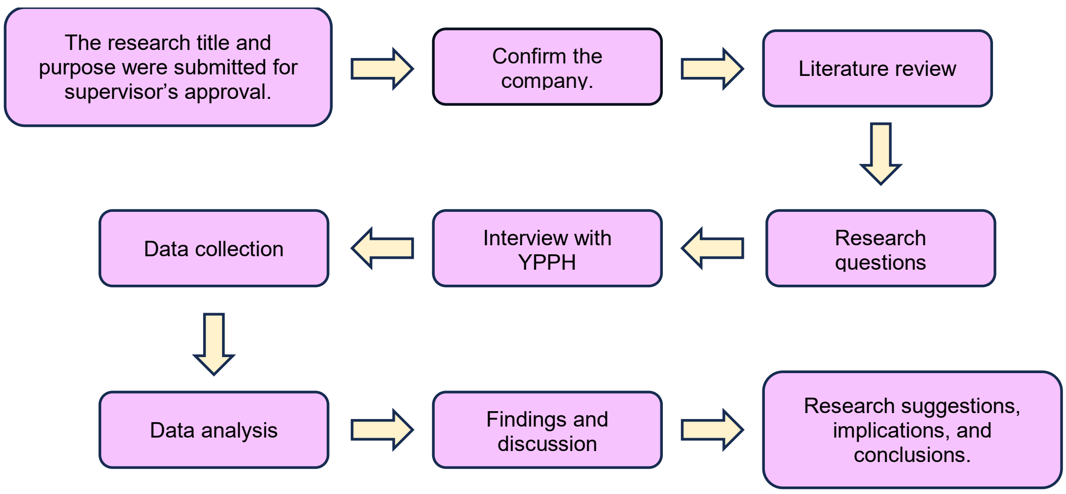

Figure 1. Research flow

4. RESULTS AND DISCUSSION

4.1 Results

The palm oil harvesting process begins with the harvesting workers' arrival early in the morning for a Master Call. It is an important step to ensure all workers are informed, equipped, and ready to begin their activities for the day. All labour workers and plantation must obtain an e-thumb print prior to commencing their work where their attendance will be recorded immediately into the system. The procedure is swift, effective, and time-saving for both employees and administrators compared to conventional techniques like manual attendance registers or swiping cards. Each employee has a unique thumbprint that cannot be imitated by others. This improves security and reduces the possibility of employees registering the attendance on behalf of others. Then, workers will be assigned several harvesting chores that must be completed on the day. Ten regions must be trimmed and each worker is required to gather a minimum of 150 to 200 FFB every day. Failing to achieve such requirement will delay the process of FFB transporting to the factory, thus affecting palm oil quality. Therefore, it is important for the harvesting process to happen smoothly without interruptions.

Following the Master Call, workers will proceed to cut ripe FFB, which can be determined through the falling of two palm kernels. YPPH workers currently utilise sickles for manual FFB cutting. According to the manager, there are several mechanisation methods that can be used for FFB cutting, such as CANTAS. Previous research reported that CANTAS can increase harvest efficiency and reduce workers' weariness, allowing them to harvest 560 to 750 FFB per day (Shuib et al., 2018.). Unfortunately, the CANTAS mechanisation can only be used to cut FFB from palm trees of less than 5 meters tall while many palm trees in YPPH's plantation are above 50 meters tall. To increase palm oil production in YPPH, laser cutting technology for palm oil harvesting is advocated. Most oil palm harvesting technologies developed in recent years use mechanical cutting techniques, such as spinning disc, circular saw, chain saw, and shear type (Ahmad et al., 2020). The types of lasers utilised for FFB cutting are classified as carbon dioxide (CO2) laser, solid state laser, and pulse fibre laser. Despite being less sophisticated than other types of lasers, fibre laser is extremely efficient at both low and high output power levels (Niyibizi et al., 2012). The rationale of using pulse laser is that it channels energy via a temporal pulse profile that differs from a continuous wave (CW) beam, resulting in frond burning owing to continuous energy being channelled (Azaman et al., 2022). Furthermore, it can cut almost any material, including textiles, biomaterials, composites, and leather (Steen & Mazumder, 2010).

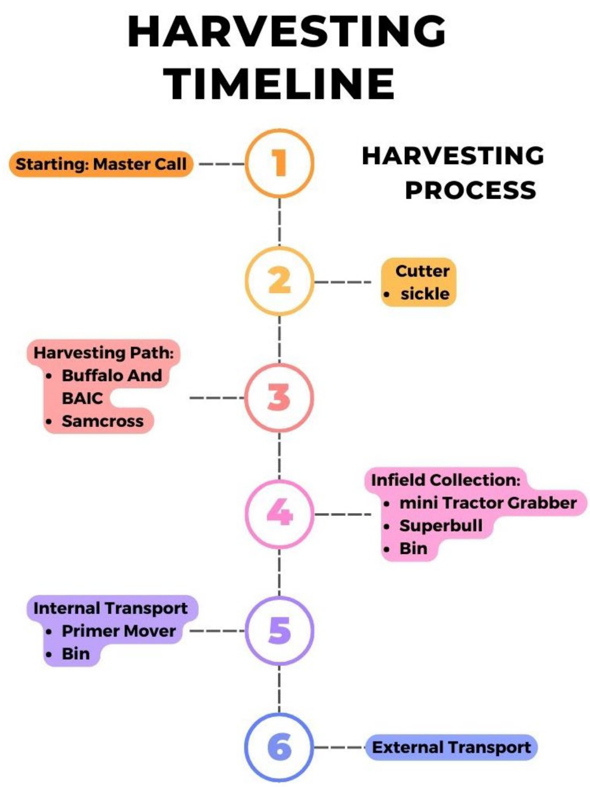

Figure 2. Harvesting timeline

Therefore, cutting using pulse fibre laser is regarded one of the most efficient and versatile cutting processes utilised in various industries (Chen et al., 2004). A technological consortium known as Kambyan Network (Malaysia) has collaborated with David Cirulli from Embry Riddle Aeronautical University in Singapore to create innovative technologies for harvesting oil palm fruits. This cooperation aims to create laser-cutting drones for palm oil plantations, which use the Autonomous SENTIENT platform ManUsIa™ to enable firms to operate autonomously. The Kambyan AleX laser-cutting drone weighs 3 kg and is approximately 70 cm in diameter. The operational model is powered by a

150-watt pulsed laser that can cut through 6 inches of plant material. In its present incarnation, the model will be piloted remotely by a drone operator to trim the fronds of oil palm trees and cut through the stems of palm oil FFB. This innovative technology can be useful for harvesting FFB from tall palm oil trees. Therefore, it is recommended for YPPH to collaborate with Kambyan Network to launch their laser cutting drone in the YPPH plantation.

Figure 3. Kambyan AleX Laser Cutting Drone

The cutting phase is followed by the harvesting path to the platform. FFB production from the harvest lane to the platform requires 350 hectares of deep peat and four BAIC units. Buffalos are used to pull the BAIC for transporting FFB to the platform. According to the manager, the manual approach is employed since mechanisation cannot reach deep peat areas due to geographical constraints, particularly the plantation's antiquated architecture. However, this manual procedure has only been utilised on 30% of TPPH palm oil plantations while the remaining 70% utilises the Samcross mechanisation. Figure 4 illustrates the differences in productivity between both methods. Mechanisation is a better option for increasing palm oil production. It is advisable for YPPH to employ 100% mechanisation during the harvesting route and to replant and reconstruct the plantation route so that mechanisation can reach the deep peat areas. Although such process can be expensive, it is necessary to boost palm oil yield and enhance profit.

Table 1. Types of machines

Type of Machine	Productivity/Mt	Hectare Coverage/Machine
Buffalo	8	350
Samcross/Maic	13	150

The next phase is in-field collection. It is an important part of the harvesting process to ensure that harvested fruit bunches are efficiently collected and transported for processing. This procedure fully utilises mechanisation, namely the mini tractor grabber (MTG), which gathers cut FFB along the harvesting path, unloads it along the roadside, and stacks the fronds. MTG will send the FFB to Bin upon reaching the capacity of 1.5 tonnes with a daily output of 20 to 22 mt/day. This mechanisation will enhance daily output in the plantation while also improving the palm oil quality. As the number of MTG units increases, productivity will rise and result in more take-home pay for workers. The productivity of both harvesters and machines is predicted to grow steadily as machine operators gain competence and familiarity with the operations and roads. YPPH also uses Superbull to improve the efficiency and convenience of in-field FFB collection. Superbull also includes output in the marshy harvest lane to Bin and improves the overall operating efficiency by significantly lowering the time to transfer FFB from the field to collecting sites.

The FFB in-field collection phase is proceeded by the internal transportation phase. It requires two main mechanisms: Bin and Prime Mover. These mechanisms are designed to survive rough and challenging conditions that are commonly seen on plantations. Each Bin is built to carry large quantities of palm oil and can store up to 10 metric tonnes of FFB every day. Prime Mover is a heavy truck that transfers bins filled with FFB to the ramps. Each Prime Mover transports 10 metric tonnes of FFB daily, with a productivity of 40 to 50 mt/day. Internal transportation becomes more efficient through the combination of Bins and Prime Movers.

The final stage of harvesting is external transportation. Once brought to the ramp, the FFB is loaded onto big transport trucks that are built to haul huge loads. Each truck has a productivity rate of 30 to 35 mt/day and can manage the size and weight of the FFB. The trucks will bring the FFB to a designated collection plant. It is crucial for FFB to be sent to the factory as soon as possible because its oil content deteriorates fast after harvesting. Efficient external conveyance aids in maintaining oil quality.

The quality of palm oil directly influences YPPH's capacity to remain profitable. However, the company's palm oil production is having difficulty to maintain quality, which may lead to lower profitability. There are several process optimisation options that can be implemented to significantly increase the quality of palm oil in YPPH. First, the fruits must be correctly appraised by a company-appointed employee who has received grading training. Immature bunches and those with lengthy stalks will surely lower extraction rates, thus reducing the supply of palm oil. However, overripe fruits have a high oil extraction rate (OER) due to their high oil content. Therefore, it is important for bunches to reach full maturity to optimise harvest rates (Mat Sharif et al., 2017). The purpose of palm oil FFB grading is to determine the quality of the FFB received, which then influences the purchase price. When the quality of oil palm FFB is high, smallholders will receive a fair payment based on premium price and quality. The FFB cutting method is also a critical element to prevent the fruits from bruising or degrading, which can lower the palm oil grade. Correct harvesting technique is important and has a substantial influence on both OER and final CPO quality. Additionally, harvesting low-quality bunches may result in high FFA levels and low OER.

To ensure the quality of palm oil, it is also important for the machinery to be cleaned regularly to remove any residues that could have accumulated over time. According to the Malaysia Palm Oil Board (MPOB), all compartments must be marked for oil palm FFB and free of previous load residues and odours. Furthermore, oil palm FFB must be covered during transportation to protect them from rain and bird droppings (Mohd Taib et al., 2017; Mat Sharif et al., 2017). The Malaysian Standard 1784 also requires all vehicles transporting oil palm FFB to be registered, licensed, and secured and they cannot transport other hazardous items like chemicals.

Furthermore, YPPH should follow the harvesting interval whereby all ripe palm oil FFB must be harvested within 10 to 12 days to avoid overripe. It protects the palm oil quality and eliminates the risk of ripe palm oil’s market price plummeting precipitously. The Malaysian Oil Palm Growers Council (MOPGC) has established a limit of 5% FFA and 0.5% M&I. Any crude palm oil with FFA less than 5% is eligible for a fixed payment based on the percentage reduction in FFA; on the other hand, FFA percentage beyond the maximum contractual value would result in an agreed-upon penalty.

4.2 Discussion

The findings on YPPH's current concerns regarding palm oil production and quality control mainly revolve around mechanisation issues.

Objective 1: To identify the production process of palm oil in YP Plantation Holdings Sdn Bhd.

According to the results, the YPPH palm oil production process consists of many essential phases. First, all workers must attend a Master Call before they begin working in the early morning where they will be assigned with their duty for the day. They must perform and complete all assigned chores. Then, the FFB is harvested and chopped. This is a vital phase in the palm oil harvesting process. If workers make a mistake by cutting unripe palm oil, it will have an influence on the palm oil quality. Bunches with lengthy stalks and extremely immature will also limit extraction rates. On average, each worker must harvest 150 to 200 palm oil each day. Once the palm oil has been cut, the harvesting path to the platform may be used to produce FFB, which only requires a 350-hectare deep peat area and four BAIC units. The remaining 350 hectares will be used for Samcross. Workers will pile the palm oil for collection. The next phase is in-field collection, which is internal labour that involves the manufacturing of FFB with a Mini Tractor Grabber (MTG) equipped with HYVA, Superbull, and a Bin System. The MTG gathers cut FFB along the harvesting path. Each MTG has a capacity of 1.5 tonnes and it will send the FFB to the Bin. Superbull will be used for production in the swamps harvest lane to Bin. This is followed by internal transit where the Prime Mover will move 10 metric tonnes of FFB from the Bin to the ramp at a rate of 40 to 50 mt/day. The final phase is the external process where the truck will travel to the designated factory. These findings give a full insight into YPPH's palm oil producing process. Understanding these procedures will allow the analysis of each stage for potential process optimisation, resulting in increased palm oil production and quality.

Objective 2: To improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd.

Several measures can be implemented to improve the quality and productivity of palm oil at YPPH. A major area of concern is the need to reconstruct the conventional plantation design so that mechanisation can reach deep peat areas. Though hand harvesting is only needed in a few places, it affects both production and palm oil quality. Often, conventional plantation design has layouts that are inconvenient with modern mechanisation. This makes the use of machines almost impossible due to narrow roads, unusual planting patterns, and inaccessible deep peat areas. By remodelling and replanting, YPPH can develop plantations with wider and better-spacing pathways. It will also enable Samcross to be used more extensively to improve harvesting operations. Through mechanisation, YPPH can better regulate water levels, soil conditions, and palm oil health, resulting in higher palm oil yields, productivity, and quality. Mechanisation can also diminish labour intensity due to evenness in maintenance and rising plantation harvest. This will eliminate variability in palm oil quality and guarantee that the product meets the highest standard. The use of mechanisation will also facilitate better dispersion of fertilisers and pesticides alongside timely and effective harvesting, leading to high-quality palm oil.

Another significant area of process optimisation is the enhancement of FFB protection during transportation. Effective transportation techniques are critical for maintaining the quality of FFB from the time it is harvested until it reaches the processing plant. It is crucial to ensure that FFB is delivered effectively and with little damage to retain the palm oil quality. Due to enzymatic and microbiological activity, damaged FFB may result in elevated free fatty acid (FFA) levels, thus lowering the quality and market value of palm oil. Therefore, educating workers on safe loading and unloading methods can help minimise physical harm. Such training will ensure that FFB is treated carefully throughout the shipping procedure. Furthermore, FFB must be properly covered during transportation via trucks to protect them from physical damage and maintain appropriate ventilation, thus lowering the danger of spoiling. By employing these process optimisation initiatives, YPPH can enhance the overall quality of its palm oil output. This will ultimately improve customer satisfaction, increase market competitiveness, and result in greater market value for crude palm oil.

In conclusion, YPPH must optimise its production processes and increase the palm oil output and quality. By focusing on issues like replanting conventional plantation design and improving the protection of transportation, YPPH can elevate crude palm oil productivity, quality, and total value.

Objective 3: To suggest the best practices in mechanisation that can be used to improve the quality and productivity of palm oil in YP Plantation Holdings Sdn Bhd.

There are some critical aspects that must be taken into consideration when recommending best practices in mechanisation for YPPH to enhance palm oil production and quality. The aim is to develop a plan that will maintain high standards and support long-term sustainability for both YPPH and its suppliers. Mechanisation should therefore be employed to improve palm oil production and quality in YPPH with the aid of laser-cutting methods for harvesting palm oil. Laser-cutting drones are suggested as an alternative machine as they can harvest palm fruit bunches within a short time compared to other traditional methods like sickle. This will enhance productivity and allow YPPH to collect more FFB within less time. The accuracy of laser cutting also reduces the chances of damaging FFB and palm oil plants, possibly improving the overall yield and quality of palm oil. Furthermore, laser technology allows smoother cuts than traditional sickles-cutting. Neat incisions reduce damage to fruits and preserve their quality by reducing incidences of diseases or rotting. On the other hand, while fibre laser is less complex than other types of lasers, it has been proven highly efficient both at low and high output power levels (Niyibizi et al., 2014). Specifically, pulse fibre laser is known for producing improved beam quality while maintaining a high level of efficiency with little or no maintenance costs involved (Westphäling, 2010).

5. CONCLUSIONS

This study has shed light on how mechanisation in YPPH may improve the productivity and quality of palm oil. The discoveries have improved the current understanding of the research difficulties and offer practical consequences for the palm oil sector. The findings also provide theoretical and practical relevance towards stakeholders, including the plantation, farmers, and the palm oil industry. Furthermore, this study fills the gaps in the current literature by proposing mechanisation for process optimisation. Mechanisation refers to the employment of modern machinery and technology in many phases of palm oil production, particularly in the harvesting process. Mechanised instruments, like laser-cutting drones, can speed up the harvesting process while saving labour expenses and time. As a result, consistent quality is ensured while output rises, allowing the organisation to handle higher amounts of high-quality palm oil. One major challenge that YPPH needs to face for this technology development is the initial expense of obtaining and installing mechanised devices. Modern machinery often requires less regular maintenance, but when it does, the repair costs are substantial. This initial cost capital will be difficult for YPPH; however, such improved production will boost palm productivity from everyday output. As a result, the mechanisation of their plantation will have a significant influence on YPPH.

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AUTHORS CONTRIBUTION

Maisarah binti Ismail (Writing - original draft; Methodology; Data Curation; Formal Analysis)

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AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings are available on request from the corresponding author.

ETHICS STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Ahmad, M. R., Jamaludin, N., Jelani, A. R., Bakri, A., & Shuib, A. R. (2020). The Effect of Design Parameters on The Force and Energy Requirement for Cutting Oil Palm Fronds Using Magnetic Force. Jurnal Teknologi, 82(4), 141-150.

Ahmad, M. R., Mohd Bakri, M. A., Ahmad Syazwan Ramli, Mustapha, N., Daryl Jay Thadeus, Ibrahim, A. K., & M. Jusoh. (2023). Mechanisation Technology for Small-Scale Oil Palm Plantations. Advances in Agricultural and Food Research Journal, 4(2), 1-11.

Ahmarofi, A. A., Anas, A., Azani, A., Mohd, Abdul Aziz Ahmad, Zanariah Idrus, Siti Nurbaya Ismail, Hamid, S., & Mohamad Khairi Ishak. (2024). The development of a discrete event simulation (DES) model for evaluating the mechanized equipment in the Malaysia palm oil industry. AIP Conference Proceedings, 16(204).

Azaman, M. I. H. (2022). Feasibility Study of Oil Palm Harvesting Using Pulse Fibre Laser System with Different Lenses. Journal of Oil Palm Research, 3(18), 488-496.

Azaman, M. I. H., Mahdi, M. A., Ahmad, M. R., Shuib, A. R., Khalid, M. R., Bakri, M. A., Md Radzi, M. K. F., & Ramli, A. S. (2020). Optimisation of parameters laser cutting of oil palm fronds using fibre pulsed laser of 1064 Nm wavelength system. Advances in Agricultural and Food Research Journal, 1(1), 1-10.

Basiron, Y. (2007). Palm oil production through sustainable plantations. European Journal of Lipid Science and Technology, 109(4), 289–295.

Chen, Y., Nishizawa, N., Hsiung, P., Ippen, E. P., & Fujimoto, J. G. (2004). Real-time, ultrahigh-resolution, optical coherence tomography with an all-fiber, femtosecond fiber laser continuum at 15 µm. Optics Letters, 29(24), 2846.

Chukwulozie, O., Segun, O., Lekwuwa, C., & Chiagoro, U. (2018). Design of Sewage Treatment Plant for CBN Housing Estate Trans-Ekulu Enugu Nigeria. Advances in Research, 13(3), 1–18.

Dale, B., Boaden, R., Wilcox, M., & McQuater, R. (1998). The use of quality management techniques and tools: an examination of some key issues. International Journal of Technology Management, 16(4/5/6), 305.

Fatimah, Sayuti, M., & Pertiwi, E. P. (2018). Quality control of palm kernel oil using Individual Moving Range (I-MR) chart. MATEC Web of Conferences, 204(16), 01006.

Fitra Lestari, Irsan Nuari, & Devani, V. (2018). American Productivity Center Method for Measuring Productivity in Palm Oil Milling Industry. Analisis Harga Pokok Produksi Rumah Pada (UIN Syarif Hidayatullah Jakarta), 37(12).

Hasudungan Lubis, A., & Aryza, S. (2018). Implement Application of Taguchi Method for Analyzing the Quality Control of Crude Palm Oil Production. IJIRML, 4(8), 110-117.

Indiastuti, R., Setiawan, M., Indrawati, D., & Effendi, N. (2016). Technical efficiency and environmental factors of the micro, small, and medium enterprises in Bandung city: a slack-based approach. International Journal of Globalisation and Small Business, 8(1),1, 1-17.

Ismail, N. W., Kamal, S. N. M., Firdaus, M., & Hariri, N. M. (2022). Export Demand of Palm Oil in Malaysia: Analysis using ARDL Approach. Asian Journal of Agriculture and Rural Development, 12(3), 157–163.

Mat Sharif, Z. B., Mohd Taib, N. B., Bin Yusof, M. S., Bin Rahim, M. Z., Bin Mohd Tobi, A. L., & Bin Othman, M. S. (2017). Study on Handing Process and Quality Degradation of Oil Palm Fresh Fruit Bunches (FFB). IOP Conference Series: Materials Science and Engineering, 203(24), 012027.

Mogili, U. R., & Deepak, B. B. V. L. (2018). Review on Application of Drone Systems in Precision Agriculture. Procedia Computer Science, 133(54), 502–509.

Mohd Khalid, M. R., Mohd Bakri, M. A., Mohamed, A., & Daryl Jay Thadeus. (2023). The Initiative to Further Enhance Technology Adoption in the Malaysian Oil Palm Industry. Advances in Agricultural & Food Research Journal, 4(2), 1-10.

Montgomery, D. C., Carlyle, W. M., & Runger, G. C. (2000). Optimization Problems and Methods in Quality Control and Improvement. Journal of Quality Technology, 32(1), 1–17.

Muhamad, Z.-M., & Aziz, M. F. A. (2018). Mechanization in Oil Palm Harvesting. International Journal of Academic Research in Business and Social Sciences, 8(5), 246 – 255.

Niyibizi, A., Ikua, B. W., Kioni, P. N., & Kihato, P. K. (2012). Laser Material Processing in Crystalline Silicon Photovoltaics. Proceedings of Sustainable Research and Innovation Conference, 4(67), 69–74.

Pargar, F., Kauppila, O., & Kujala, J. (2017). Integrated scheduling of preventive maintenance and renewal projects for multi-unit systems with grouping and balancing. Computers & Industrial Engineering, 110(65), 43–58.

Ramli, A. S., Mohd Bakri, M. A., & Ahmad, M. R. (2022). Feature Article Enhancing Mechanisation Technology in Oil Palm Plantation. Palm Oil Engineering Bulletin, 138(11). https://palmoilis.mpob.gov.my/publications/POEB/poeb138-syazwan.pdf

Saravanan, A. & Nagarajan, P. (2013). Implementation of Quality Control Charts in Bottle Manufacturing Industry. International Journal of Engineering Science and Technology (Ijest), 5(2), 335-340.

Shuib, A. R., Radzi, M. K. F. M., Bakri, M. A. M., & Khalid, M. R. M. (2020). Development of a harvesting and transportation machine for oil palm plantations. Journal of the Saudi Society of Agricultural Sciences, 19(5), 365–373.

Steen, W. M., & Jyotiromoy Mazumder. (2010). Laser material processing. Springer, Cop.

Stevenson, & Ehlers, U. D. (2009). Web 2.0 – e-learning 2.0 – quality 2.0? Quality for new learning cultures. Quality Assurance in Education, 17(3), 296–314.

Sulaiman, N., Ismail, R., & Mohd Saukani, M. N. (2017). Globalization and Total Factor Productivity: The Case of the Manufacturing Sector in Malaysia. International Business Management, 11(2), 334-341.

Westphäling, T. (2010). Pulsed Fiber Lasers from ns to ms range and their applications. Physics Procedia, 5(18), 125–136.

APPENDICES

Semi-Structured Interview Questions with YPPH

a)	What are the most common productivity concerns at this palm oil plantation?
b)	What are the most common hurdles to maintaining the quality of palm oil?
c)	How does the farm manage and monitor palm oil productivity?
d)	What tactics do you employ to increase palm oil productivity on this farm?
e)	How do you calculate the productivity of the machines on this farm?
f)	How do you check the quality of palm oil on this farm?
g)	What quality control procedures are implemented?
h)	How do you maintain worker safety when utilising machinery on the farm?
i)	What guidelines or criteria do you use when implementing mechanisation in oil palm plantations?
j)	Which new technology do you believe will have the greatest influence on the production and quality of oil palm plantations?

Figure 4. Visit at YPPH Palm Oil Plantation

Figure 5. Ripe palm oil

Figure 6. In-field collection stage during harvesting