

Investigation on the Optimal Harvesting Time of Oil Palm Fruit

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ABSTRACT

The selection of the right timing for the harvest of oil palm fresh fruit bunch (FFB) can affect the outcome of the palm fruit quality, which can further imply the quality of crude palm oil (CPO). Truly ripen fruits can boost the yield and quality of crude palm oil. The determination of fruit ripeness is done with an approach to estimating the time of the harvest cycle and the approximate number of palm oil fruits that are detached from their bunches (loose-fruit). The study aimed to investigate the exact harvesting time with variations in the number of palm oil fruits that loose at each additional day after the occurrence of one or two fruitlets detach. The parameters used to test the quality of palm oil fruit harvested were the level of free fatty acids (FFA) and the yield of crude palm oil. The variation used was based on two factors: the number of days after the discovery of the fruit loose released from its bunch and the planting plant. The results of Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) showed that the quality of oil palm fruit corresponded to the percentage of the number of palm oil fruits detached from their bunch and the age of the plant. Based on the results obtained, the optimal harvest time can be carried out until the sixth day after the first time of detached fruits for all planting ages.

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1. INTRODUCTION

Currently, Indonesia is listed as the largest palm oil producing country in the world. Palm oil has become a national strategic commodity for Indonesia. The palm oil plays a great role in Indonesia's national economic growth. According to the Indonesian Statistics Agency in 2021 Indonesia manages 14.6 million hectares of oil palm plantations with a total production of 45.1 million tons of crude palm oil (CPO) (BPS, 2022). Success in managing oil palm will have a positive impact on the national economy. Therefore, strengthening studies in an effort to increase the yield and quality of palm oil production is currently the government's focus.

Oil palm begins to bear fruit at the age of 3 to 4 years, and in the 8 to 11 years of age it can produce 20 ton/ha of fresh fruit bunches (FFB) annually (Dianto *et al.*, 2017). Ripe palm fruit has the potential to produce higher oil yields (Islamiah *et al.*, 2021; Okoye *et al.*,

2009; Sitio *et al.*, 2022; Sujudi *et al.*, 2016). Ripe fruit is characterized by the occurrence of loose fruits from its bunch (Hasibuan, 2020; Lai *et al.*, 2023; Purba, 2017) and changes in color (Fitrya *et al.*, 2018; Herman *et al.*, 2020; Ibrahim *et al.*, 2018; Makky & Soni, 2014; Sari *et al.*, 2019). However, under ripe fruit conditions it has the potential to increase free fatty acids (FFA) levels and yield of palm oil (Sitio *et al.*, 2022). For this reason, it is necessary to determine the right time to harvest oil palm fruit in order to get optimum ripe fruit so that it can have a positive impact on increasing the yield of palm oil.

The quality of palm oil is generally determined based on the content of FFA. This is in line with the yield pattern of palm oil production, where if harvested at the right time, the FFA content produced will be low (Susanti & Lestari, 2021). Conversely, fruits that are harvested over ripe has the potential to contain a higher FFB (Sitio *et al.*, 2021). Harvesting oil palm fresh fruit bunch (FFB) under immature (sub-optimal ripe) conditions has an oil yield of less than 20% which is much lower when compared to optimal ripe conditions which can reach 24% - 26% (Rangkuti, 2018).

Mature FFB is characterized by the release of 10–50% loose fruits per bunch. The over ripe FFB is characterized by the release of loose fruits around 50–90% of the fruit bunch (Murgianto *et al.*, 2021). Meanwhile, FFB with immature (sub-optimal) conditions is usually characterized by the presence of one to nine loose nuts (Islamiah *et al.*, 2021). The quality of palm oil is determined based on the quality and quantity aspects. Good fresh fruits will produce crude palm oil (CPO) yield of 23.2–27.4% (Pahan, 2006) and contain FFA <3% (Semangun & Mangoensoekarjo, 2003). Commercially the FFA content that is commonly used as a quality requirement for CPO is 5% (Lionny *et al.*, 2015).

To get the best yield and quality, proper harvesting of optimal ripe FFB is needed. Therefore, the ability of harvesters in determining the fruit to be harvested is an important factor to note. This study aims to investigate the right harvest time based on the parameters of the number of fruit that is loose in each additional day after the occurrence of one or two fruit that is loose for the first time.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

The materials used in this study include oil palm fruit obtained from smallholder oil palm plantations in Kait-Kait Village (-3.6015976 S, 114.7747343 E), Bati-Bati District, Tanah Laut Regency, South Kalimantan Province. The oil palm was of Tenera variety. The chemicals used were hexane, 96% ethanol, phenolphthalein indicator, and 0.1 N NaOH.

Some equipment were needed in this research, including sample bottles, graduated glass, porcelain cups, analytical balance, Erlenmeyer, beaker glass, oven, funnel, stove, pan, filter paper, pipette, burette, desiccator, soxhlet, fat flask, volume flask, hot plate and a tool to palm fruit press.

2.2. Experimental Design

The research design used was a randomized block design with two factors. The number of delaying days after the first time oil palm fruit loose from the bunch was the first factor, and the age of the plant was the second factor. The difference in the age of planting and the number of delaying days after the occurrence of first time fruit (nut) detach from its bunch is expected to provide information on the characteristics of appropriate harvest time to obtain the best yield and quality of palm oil.

The first factor (a) is the variation in the number of delaying days of observation after it was found that there were loose fruits from the bunches, with the following levels:

- a1 : first day observation.
- a2 : second day of observation
- a3 : third day of observation
- a4 : fourth day of observation
- a5 : fifth day of observation
- a6 : sixth day of observation

Then for the second factor (b) is the variation in the age of planting oil palm trees, which is denoted as follows:

- b1 : Variation in the age of planting oil palm trees 5 years
- b2 : Variation in the age of planting oil palm trees 10 years
- b3 : Variation in the age of planting oil palm trees 15 years

Sampling was carried out within 6 days at the time of harvesting. Sampling was carried out every day from the first day the oil palm fruit started to detach from its bunch. Loose fruits that fell down on the ground was collected and packaged in plastic and then stored in a cool box, brought to the laboratory for testing FFA content and palm oil yield. The purpose of using a cool box is to reduce the rate of FFA formation in oil palm fruit during the sampling process.

The combination of observations in this study are 18 sample observations. Furthermore, each treatment combination was repeated 2 times so that a total of 36 observational data (experimental units). Observational data were tested using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) as a parametric follow-up test.

Each sample that was successfully obtained was then subjected to several treatments to obtain the yield value of crude palm oil and continued with FFA content testing. All samples received the same treatment and environmental conditions to obtain uniform yield and FFA levels of each sample.

2.3. Oil Yield Analysis

Testing for oil content was carried out based on [AOAC \(2005\)](#), using the Soxhlet method. This test was carried out in several stages. First, the fat flask was dried in an oven at 105 °C for 1 hour and cooled in a desiccator for 15 minutes, then the empty fat flask was weighed (W_1). The sample in the form of palm fruit flesh (mesocarp) was weighed as much as 5 grams (W) then mashed and wrapped using filter paper. Assemble the fat flask, soxhlet, heating mantle to the condenser. The wrapped sample was then put into a soxhlet and then added hexane solvent until it was sufficient for 1.5 cycles. Extraction was carried out for ± 6 hours until the solvent dropped back into the fat flask with a clear color. After the extraction is complete, the fat flask was removed and put into the oven at 105 °C until the solvent has completely evaporated. The extracted fat and oil flask (W_2) were cooled in a desiccator and then weighed. Oil content was calculated by the formula:

$$Oil (\%) = \frac{W_2 - W_1}{W} \times 100\% \quad (1)$$

where W is mass of oil fruit flesh (g), W_1 is mass of empty fat flask (g), and W_2 is mass of fat flask + extracted oil (g).

2.4. Analysis of FFA

Levels of FFA content was analysed based on SNI 01-2901-2006 regarding the quality of CPO, namely using the acid-base titration method. The calculated FFA content is the percentage of FFA in the CPO where the molecular weight of FFA is represented as a compound of palmitic acid. This test was carried out by heating the test sample at a temperature of 60 – 70 °C and stirring until homogeneous. After that, the sample was weighed as much as 5 grams and put into Erlenmeyer flask and added 50 ml of neutralized solvent. Then it was heated until the oil completely dissolved and 1-2 drops of phenolphthalein indicator were added. The solution was then titrated using 0.1 N NaOH solution until it reached the end point which was marked by a stable pink color change for 30 seconds. The FFA content was calculated by the following formula:

$$FFA (\%) = \frac{25.6 \times N \times V}{W} \quad (2)$$

where V is volume of NaOH solution used (ml), N is the normality of NaOH solution, W mass of CPO sample, and 25.6 is a constant to calculate FFA content as palmitate acid.

3. RESULTS AND DISCUSSION

The number of fruit that fell down for each sample of oil palm plant age each day is presented in Table 1. The data illustrates that the number of loose fruit increased every day for each sample with a different age of planting.

Table 1. The number of loose fruit in 6 days for each oil palm plant age

Day after the fruit detach first	Plant age		
	5-year	10-year	15-year
Day-1	4	3	2
Day-2	5	4	3
Day-3	5	4	5
Day-4	8	6	7
Day-5	7	8	8
Day-6	8	8	10
Total	37	33	35

3.1. Free Fatty Acid Levels

[Semangun & Mangoensoekardjo \(2008\)](#) explained that oil palm fruit with a high level of maturity can trigger FFA values to a high content. This increase in FFA was due to the oxidation and hydrolysis reactions of lipase enzymes in palm oil ([Purwanto & Santosa, 2016](#)). FFA content is one of the parameters for the quality of palm oil because it causes rancidity. This FFA level parameter is especially important for the use of palm oil in the food and cosmetic industries.

The data shows that the trend of FFA formation is influenced by the number of days after the fruit detach. However, the planting age did not have a consistent effect with the increase in FFA levels. The FFA levels increased with the number of days after fruit loose. The more ripe the fruit, the more FFA levels increase (see Figure 1).

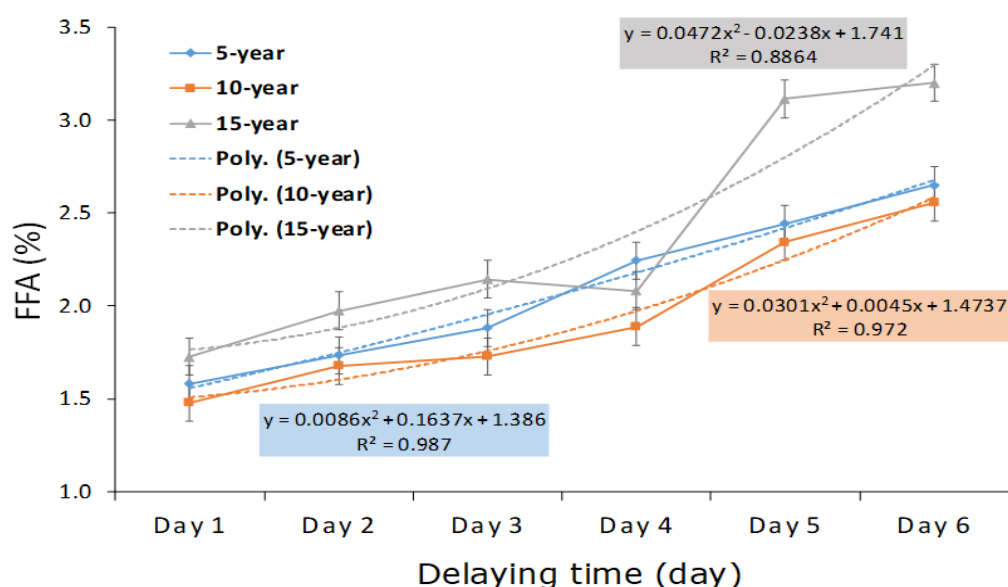


Figure 1. Trend of FFA content as affected by plant age and number of days after the fruit detaching.

The regression results for each planting age show FFA levels close to 5% occurring on different days. For 5 years of plant age, the FFA level will approach 5% on day 13 with a predicted FFA level of 4.97%. For 10 years of plant age, the FFA level will be close to 5% on the 10th day with a predicted FFA level of 4.53%. As for the 15 year old plant, the FFA level will approach 5% on the 8th day with a predicted FFA level of 4.57%.

The results of the ANOVA test showed that the day of observation had a significance value of $P = 0.001$, and the oil palm plant age factor had a significance value of $P = 0.008$. This that both factors are greatly significant on the FFA content. The interaction between the days of observation and the plant age of the oil palm showed no significant effect on the FFA level with the P value of 0.807. Then a DMRT test was carried out which was significantly different where the alpha value of 0.05 was greater than the significance value P . Table 2 presents the effect of day after fruit detach and plant age on the FFA value.

Table 2. Effect of plant age and day after fruit detach on the FFA content

Day after the fruit detach first	Plat age			Average
	5-year	10-year	15-year	
Day-1	1.581 ± 0.075	1.481 ± 0.067	1.726 ± 0.144	1.596 ± 0.101 ^a
Day-2	1.735 ± 0.584	1.678 ± 0.078	1.974 ± 0.484	1.796 ± 0.128 ^{ab}
Day-3	1.882 ± 0.079	1.729 ± 0.283	2.144 ± 0.144	1.918 ± 0.171 ^{ab}
Day-4	2.244 ± 0.002	1.889 ± 0.212	2.081 ± 0.357	2.071 ± 0.145 ^b
Day-5	2.442 ± 0.138	2.344 ± 0.294	3.199 ± 0.350	2.633 ± 0.342 ^c
Day-6	2.651 ± 0.159	2.556 ± 0.293	3.199 ± 0.792	2.802 ± 0.283 ^c
Average	2.089 ± 0.422 ^a	1.946 ± 0.417 ^a	2.373 ± 0.624 ^b	

Note: numbers followed by the same letter are significantly different under DMRT test at $\alpha = 5\%$

Table 2 shows that the FFA trend at planting age 5 years and planting age 10 years was not significantly different, while the trend in FFA levels for planting age 15 years was significantly higher from those of plants aged 5 years and 10 years old. As for the time of day after the occurrence of fruit loose, it can be inferred that the FFA level increase with time. The FFA at first, second and third days were not significantly different. For the second, third and fourth day, there was no significant difference. Furthermore, for the fifth and sixth days also showed no significant difference. However, the first day was significantly different from the fourth, fifth and sixth day, and the second, third and fourth day were significantly different from the fifth and sixth day. It can be seen that leaving the palm fruit that has detached longer will result in higher levels of FFA. The implication of the effect of the day fruit detach on FFA levels is to determine the right harvest time to reduce the risk of yielding oil palm with high FFA levels (not according to standards).

Low levels of free fatty acids can help farmers in the process of handling oil palm fruit such as the transportation process and waiting queues before entering the processing process at the factory. Choosing the right harvest time with low FFA levels can help reduce the increase in FFA levels caused by damaged/injured fruit due to material handling activities in the field.

Harvesting time measured in this study from the first day to the sixth day successively showed that FFA levels did not exceed the 2006 SNI palm oil quality standard, namely a maximum of 5%. Based on the results, the best harvest time with the lowest FFA content was shown on the 1st day of loose fruit with the number of fruit detach 25-50% due to having the lowest FFA content compared to other harvest times. The time and level of maturity of the oil palm fruit affect the increase in FFA levels. The more ripe the oil palm fruit, the more oil it has. The more fruit oil, the faster the enzymatic hydrolysis process, and the more butyric acid produced.

Formation of FFA occurs through oxidation hydrolysis and enzymatic processes during storage and processing. The oxidation process occurs as a result of the interaction of unsaturated fatty acids in the oil with oxygen and forms peroxides which cause a rancid odor in the oil, whereas oils containing a lot of saturated fatty acids hydrolyze much more easily.

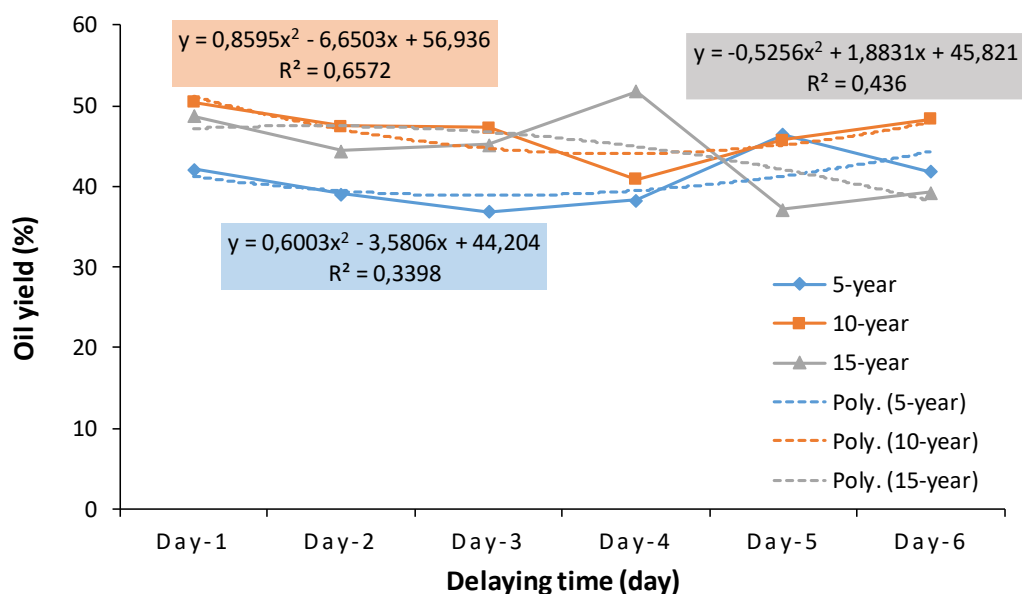
3.2. Oil Yield

The influence of the age of oil palm plantation and the number of delaying days after the first time fruit detach has been tested for significance on the yield of palm oil. The initial hypothesis developed in this study was that the age of planting and the number of delaying days had an effect on the amount of oil yield. Based on the results of the ANOVA test, it showed that the delaying days after loose fruit occurred from the first day to the sixth day had no significant effect on the oil content, so it did not require further DMRT testing at a level of 5%. The results of the oil yield test for each sample are presented in Table 3.

The oil content in the mesocarp of mature oil palm fruits with the best quality ranges from 50% - 60% (Mathews *et al.*, 2004). In the current study it was found that the oil content for all samples was close to 50%, even though there are some data showing the oil content was far below 50%. The oil content identified in this study is most likely influenced by the type of seed and cultivation management carried out by farmers.

Table 3. Effect of plant age and day after fruit detach on the oil yield (%)

Day after the fruit detach first	Plat age		
	5-year	10-year	15-year
Day-1	42.167 ± 8.357	50.449 ± 13.042	48.755 ± 7.489
Day-2	39.060 ± 12.725	47.488 ± 0.934	44.47 ± 0.213
Day-3	36.884 ± 5.064	47.286 ± 2.724	45.242 ± 1.757
Day-4	38.391 ± 8.772	40.869 ± 2.849	53.803 ± 2.874
Day-5	46.586 ± 0.187	45.101 ± 0.902	36.436 ± 0.970
Day-6	43.148 ± 2.969	49.189 ± 1.192	40.063 ± 1.099

**Figure 2.** CPO yield as affected by plant age and number of delaying days after first loose fruit

Furthermore, when viewed from the age factor of oil palm trees, it turns out to have an influence on the oil content produced, the older the age of the oil palm trees, the higher the oil content produced. Ghozali (2012) explains the coefficient of determination (R^2) is a tool for measuring the ability of a model to implement variability in the dependent variable. The coefficient of determination has a value between 0 and 1. The low value of R^2 indicates that the variation of the dependent variable which is explained by the independent variable is very limited. The independent variable means that it provides almost all of the information needed in estimating the dependent variable.

Based on the results on the graph (Figure 2) it has a value of the coefficient of determination (R^2) of 0.436 for 15-year age trees. The increase in oil content is influenced by the independent variable, namely the day of observation of loose fruit, while the rest is influenced by other factors. Whereas for trees with a planting age of 5

years, R^2 is 0.3398 and for trees 10 years R^2 is 0.6572. If it is close to 1, it causes the correlation to be strong and when it goes to 0, it causes the correlation to become weak. In this case, the correlation of the dependent and independent variables is weak because the value of R is close to 0. Through the coefficient of determination (R^2) the contribution of the independent variables can determine changes in the value of the dependent variable.

4. CONCLUSION

Delaying in harvesting time and plant age did not significantly affect the yield of palm oil. Although there is a tendency to decrease the yield of palm oil due to delays in harvest time, it is not statistically significant. Separately, delaying in harvesting time and plant age significantly affect the FFA content of palm oil. In this case the FFA content increased with increasing delaying time in harvesting after the fruit was detached for the first time. FFA levels also increase with increasing age of the plant, especially after reaching the age of 15 years. Even so, the FFA content of crude palm oil is still below 5% of the SNI standard for all combinations of plant ages and harvesting delay of up to 6 days. Based on this, delaying the harvest time until the 6th day after the first time the fruit loose from the bunch can be done without the risk of the FFA content exceeding the 5% limit.

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