Vol. 13, No. 4 (2024): 1432 – 1441 http://dx.doi.org/10.23960/jtep-l.v13i4.1432-1441

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

The Use of Gamal Leaves (*Gliricidia sepium*) to Accelerate Fresh Fruit Bunch Detachment and Improve the Quality of Crude Palm Oil

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Article History:

Received : 30 September 2024
Revised : 31 October 2024
Accepted : 29 November 2024

Keywords:

Bunch detachment,
CPO quality,
Ethylene,
Gliricidia sepium,
Ripening.

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ABSTRACT

Acceleration of processing for fresh fruit bunches (FFB) is crucial to increase profitability and business opportunities for oil palm farmers. This research aims to evaluate the effect of using gamal (Gliricidia sepium) leaves and the duration of ripening on the percentage of FFB processing as well as the quality of crude palm oil. This study employed a factorial completely randomized design (CRD). The data were analyzed using ANOVA with Duncan's Multiple Range Test at a significance level of 5%. The results of the analysis showed that the best treatment was S3T2 (40% gamal leaves, 20 h of ripening) with a natural processing percentage of 45.87% of the FFB weight and 60.34% of the total bunch weight. The use of gamal leaves and the duration of ripening significantly affected the quality parameters of the oil, especially the free fatty acid content. Treatment S1T1 (20% gamal leaves, 10 h of ripening) showed the best results with a free fatty acid value of 1.30%, meeting the quality standard (<5%). However, the moisture content still exceeded the quality standard (<0.5%), although treatment S3T2 yielded the best result at 0.63%. While, the impurity content quality met the quality standard (<0.5%), with the best value achieved by treatment S1T1 at 0.15%.

1. INTRODUCTION

Threshing or stripping fresh fruit bunches (FFB) of oil palm is an important step during crude palm oil extraction process. The stripping process aims to separate the fruit nuts from the bunch, producing cleaner nuts called "brondolan". Stripping fresh fruit bunches has several objectives, including reduce impurities such as impurity and fiber which can contaminate oil (Amelia *et al*., 2021), improve the quality of palm oil by separating ripe fruit from immature ones, contributes to increase processing efficiency by reducing the volume of bunches that need to be processed, saving time, energy and costs, and making fruit transportation easier (Sukarman *et al*., 2024).

The threshing of FFB has a number of issues that need to be considered. One of them is the potential for fruit loss, especially if the process is carried out manually. Rough threshing can also damage to the fruit, which can reduce the quality of the oil produced. Apart from that, the stripping process also requires additional costs for equipment and labor. However, there are also several advantages resulting from the stripping process, including improving the quality of palm oil, efficiency in processing, and transportation of the fruit (Sukarman *et al*., 2024).

There are five methods in the stripping process of FFB. The first is mechanical stripping, which uses a machine with a rotating drum and blades to separate the fruit from the bunch. Although efficient and fast, mechanical stripping can damage to the fruit if done carelessly (Sukarman *et al*., 2024). The second is biological stripping, using microorganisms to separate the fruit by eating the fibers connecting fruit nuts to the bunch. Third, chemical stripping using ethylene, a plant hormone that can trigger fruit ripening (Giyanto *et al*., 2021). Ethylene gas can be applied to FFB in various ways, such as spraying, injection or fumigation. Although environmentally friendly, this process tends to be slow and requires higher costs. Physical stripping involves human effort to separate the fruit with hands or simple tools such as knives (Pernando *et al*., 2018). Although cheap and easy to do, physical stripping tends to be slow and less efficient than other methods. Finally, thermal and mechanical stripping involve the use of steam followed by mechanical thressing. The last is the most practically adopted by most palm oil mills.

Accelerating FFB stripping after harvesting of oil palm fruit bunches is an important factor that can increase profits and business opportunities for oil palm farmers. Fast stripping process refers to the process of collecting and delivering FFB from plantations to palm oil mills within a short time after harvesting. By speeding up stripping after harvesting, farmers can optimize their profit potential. Faster delivery of FFB to the factory allows for increasing quality and selling value of the fruit. Fresh fruit that is immediately processed results in higher quality of crude palm oil, so it can be traded at a more profitable price on the market (Sukarman *et al*., 2024).

Some types of leaves emits ethylene that can be used to accelerate ripening process for fruits. For example, the use of gamal leaves (*Gliricidia sepium*) to accelerate the ripening of yellow kepok bananas showed a significant effect on fruit maturity. The use of gamal leaves was able to speed up the ripening time of yellow kepok bananas with optimal results (Widyasanti *et al*., 2019). Other research also shows that gamal leaves can speed up the ripening process of white ambon banana fruit, with a hourly respiration rate of 92.86 mg CO_2/kg (Ulva & Daesusi, 2021).

Based on the above explanation, this research aims to examine the potential for using gamal leaves in accelerating the stripping of oil palm FFB. This innovation was carried out by varying the weight of gamal leaves against the weight of FFB which had been grouped based on maturity fractions. This research also aims to analyze the quality of the crude palm oil (CPO) produced. Specifically, this research wants to know the effect of using gamal leaves and the length of ripening on the percentage of stripped fruit and the quality of the obtained CPO.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

This research was carried out from September to December 2023 at the Quality Laboratory of the Plantation Cultivation Study Program, the Process Laboratory of the Plantation Product Processing Technology Study Program of the Indonesian Palm Oil Technology Institute (ITSI) Medan, and the PT. PP Lonsum Turangie Palm Oil Mill Lab.

The materials used in this research were oil palm FFB of the Tenera species with a stripped fruit (berondolan) categorized as fraction I (12.5–25% of the outer fruit has stripped), gamal leaves, Whatmann GF/B, and CPO filter paper. The chemicals used in this research were 0.1 N NaOH, n-Hexane, PP indicator, 96% ethanol, isopropyl, and distilled water. The main equipment included electric oven, stirring hot plate, analytical balance, digital balance with capacity 30 kg, fermentation box (50cm x 50 cm x 50 cm), hydraulic press with capacity 16 ton, and glassware.

2.2. Research methods

This research used a factorial completely randomized design (CRD) with the first factor influencing the weight of gamal leaves at three levels, namely S1 20%, S2 30%, and S3 40% of the FFB weight, corresponding to respectively 2 kg, 3 kg, and 4 kg. The second factor was the period of fermentation including 10 h (T1) and 20 h (T2). Each treatment combination was carried out using around 10 kg FFB and was repeated 3 times, resulting a total of 18 samples. The data obtained was analyzed statistically using the analysis of variance (ANOVA) test followed by the Duncan's Multiple Range Test (DMRT) at the 5% level.

2.3. Fermentation and Extraction Process

Fresh fruit bunches (FFB) were harvested and weighed about 10 kg. Gamal leaves were added according to the treatment, namely 20% (2 kg), 30% (3 kg), and 40% (4 kg). The FFB and the gamal leaves were introduced into fermentation box sizing of 50cm x 50 cm x 50 cm for ripening process. The ripening process was carried out with two levels, namely for 10 h and 20 h. After going through the ripening process, the FFB was removed from the ripening box, and the fruit nuts that detached naturally were collected in a plastic container and weighed (NS). The fruits that were still attached in the spikelet were smashed manually, and the stripped fruits were collected and weighed (MS). The unstripped fruits remaining in the bunch were picked manually, collected in a container, and weighed (US).

The stripped fruits were then sterilized by boiling it for 30 min at a temperature of 100 ºC. After that, the fruit flesh was separated from the seeds to facilitate the extraction process using a manual hydraulic press with a maximum pressure of 16 ton. The extracted oil was then stored in a labeled bottles. The final stage was analyzing the quality of crude palm oil (CPO) produced from the extraction process.

2.4. Observations and Measurements

2.4.1. Stripped Fruit Nuts

The percentage of naturally stripped fruits (%NS), mechanically stripped fruits (%MS), and unstripped fruits (US) over the processed FFB and the whole fruits were calculated according to the following equations.

$$\%\ NS = \frac{NS}{FFB} \times 100 \quad (1)$$

$$\%\ NS = \frac{NS}{NS+MS+US} \times 100 \quad (2)$$

$$\%\ MS = \frac{MS}{FFB} \times 100 \quad (3)$$

$$\%\ MS = \frac{MS}{NS+MS+US} \times 100 \quad (4)$$

$$\%\ US = \frac{US}{FFB}\ x\ 100 \quad (5)$$

$$\%\ US = \frac{US}{NS+MS+US} \times 100 \quad (6)$$

2.4.3. Empty Fruit Bunch

Empty fruit bunch (EFB) is bunch without any fruit attached. The percentage of EFB was calculated as follows.

$$\%\ EFB = \frac{EFB}{FFB} \times 100 \quad (7)$$

Information: TK = Empty bunch, and TBS = Fresh fruit bunches

2.4.4. Free Fatty Acid Content

Free fatty acids (FFA) in the CPO was analyzed according to SNI 2901-2021 (BSN, 2021). A 100 ml Erlenmeyer flask was weighed. A CPO sample of ±5 g was weighed (W) and introduced into the Erlenmeyer. The oil sample was added with 15 ml of N-hexane and 10 ml of alcohol, and 5 drops of phenolphthalein (PP) indicator. Next, the sample was titrated using 0.1 N NaOH solution until the color changed to reddish orange. The volume of NaOH solution (V) used to reach the end point of the titration was recorded. The FFA content was calculated using the following formula:

$$\%\ FFA = \frac{25{,}6 \times V \times N}{W} \quad (8)$$

where N is the normality of NaOH, and 25.6 is a constant to calculate FFA as palmitic acid.

2.4.5. Water Content

A sample of ±5 g of CPO was weighed using an analytical balance (A). Then put it in a digital oven for 5 min. The sample was cooled in a desiccator for 5 min then weighed the final result (B). Water content can be calculated using the following formula:

$$\%\ Water\ content = \frac{A-B}{A} \times 100 \quad (9)$$

2.4.6. Impurity Content

A CPO sample of ±5 g was weighed and dissolved it in a beaker with 100 ml of n-Hexane until it boiled. Turn on the vacuum pump and place the crucible glass in a container to rinse using n-hexane until clean. Put the crucible glass together with the filter paper Whatman GF/B into a digital oven for 3 min. Next, cool in a desiccator and weigh the sample and crucible cup after being placed in the oven, then record the results. Impurity levels can be calculated using the following formula:

$$\%\ \text{Impurity Level} = \frac{X-Y}{Z} \times 100 \tag{10}$$

where X is weight of filter paper before oven, Y is weight of filter paper after oven, and Z is sample weight.

3. RESULTS AND DISCUSSION

3.1. Stripping Performance

3.1.1. Naturally Stripped Fruits

Table 1 and 2 present the effect of treatment on the percentage of naturally detached fruit (NS), respectively relative to FFB and total fruit nuts. Based on analysis of variance, single factor ripening time and amount of gamal leaves significantly affect the NS. The interaction of both factors, however, is not significant. Table 1 clearly shows that increasing amount of gamal leaves caused improvement of NS from 21.14% to 24.97% and to 29.97% with gamal leaves of respectively 20%, 30%, and 40%. This means increase in gamal leaves from 20% to 30% improve the NS by 18.12% based on FFB. Similarly, doubling gamal leaves from 20% to 40% has caused an improvement of 41.80% for NS. Based on total fruit nuts (Table 2) an improvement of 43.82% for NS can be realized as a response of doubling gamal leaves amount. Specifically, the NS is 27.66% with gamal leaves 20% and increase to 39.77% using 40% gamal leaves. An increase in the percentage of gamal leaf weight given to FFB implies that the fruit will ripe quickly. This is caused by the presence of ethylene gas in gamal leaves (Suanda *et al*., 2010). Ethylene is a natural hormone that influences plant growth and development, including the regulation of flowering, fruit ripening, and leaf fall. Using the right amount of gamal leaves can help regulate these processes in plants (Suanda *et al*, 2010). Ethylene gas can speed up the ripening process of oil palm fruit and affect the process of separating the fruit from the bunch. Ethylene gas acts as a ripening hormone and can accelerate fruit maturity, so that fruit exposed to ethylene gas tends to ripen more easily (Giyanto *et al*., 2021).

Table 1. The effect of treatment on the percentage of naturally stripped fruit relative to the weight of FFB

Fermentation time	**Gamal leaf weight**			**Average (%)**	**Improvement (%)**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**		
T1 (10 h)	15.66	18.91	24.74	19.77 a	--
T2 (20 h)	26.61	31.03	35.20	30.95 b	56.55
Average (%)	21.14 A	24.97 B	29.97 C		
Improvement (%)	--	18.12	41.80		

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

Table 2. The effect of treatment on the percentage of naturally stripped fruit relative to the total fruit nuts

Fermentation time	**Gamal leaf amount**			**Average**	**Improvement (%)**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**		
T1 (10 h)	20.19	25.54	33.26	26.33 a	--
T2 (20 h)	35.12	40.24	46.29	40.55 b	56.53
Average	27.66 A	32.89 B	39.77 C		
Improvement (%)	--	18.92	43.78		

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

Increasing ripening time has also resulted in the significant increase of naturally detached fruit, namely from 19.77% at ripening time 10 h to 30.95% at 20 h ripening time. This means an improvement of 56.55% based on FFB weight (Table 1). Based on total fruit nuts, the improvement of NS is 56.53%. Longer ripening time (20 h) with high amount of gamal leaves (40%) has resulted in highest amount of fruit nuts that detaching naturally (35.20% based on FFB, or 46.29% based on total fruit nuts). The cause of the increase in the naturally stripped fruits in the treatment with ripening time 20 h was due to an increase in the FFA in palm fruit after a longer ripening treatment (Simatupang *et al*., 2021). However, FFA levels after FFB are harvested will increase naturally by 0.1% every 24 h, such that if the ripening time is longer there are concerns that it will affect the quality (Krisdiarto *et al*., 2017).

Some fruit nuts in the FFB are still attached strongly in the spikelet. These fruits were stripped mechanically using rotated drum. Table 3 and 4 summarizes the effect of treatment on the percentage of mechanically detached fruit (MS), respectively relative to FFB and total fruit nuts. Based on analysis of variance, single factor ripening time and amount of gamal leaves significantly affect the MS. The interaction of both factors, however, is not significant.

Table 3. The effect of treatment on the percentage of mechanically stripped fruit relative to the FFB

Fermentation time	**Gamal leaf amount**			**Average**	**Improvement (%)**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**		
T1 (10 h)	6.10	7.53	7.92	7.19 a	--
T2 (20 h)	7.36	12.44	10.67	10.15 b	41.32
Average	6.73	9.99	9.30		
Improvement (%)	--	48.37	38.11		

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

Table 4. The effect of treatment on the percentage of mechanically stripped fruit relative to the total fruit nuts

Fermentation time	**Gamal leaf amount**			**Average**	**Improvement (%)**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**		
T1 (10 h)	7.77	10.17	10.74	9.56 a	
T2 (20 h)	9.70	16.16	14.05	40.55 b	39.12
Average	8.74 A	13.17 B	12.40 B		
Improvement (%)	--	50.75	41.90		

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

During ripening process, a high respiration rate will cause significant changes in the physical or chemical properties of the fruit. There are various factors that influence the rate of respiration in climacteric fruit. The environment where the fruit is stored will influence the speed of the respiration process. (Widyasanti *et al*., 2019) reported that addition of gamal leaves during ripening Ambon banana has resulted in the highest respiration rate of 92.86 mg CO_2/kg.h. The increase in naturally detached fruits due to gamal leaves during ripening of FFB indicates that respiration process of FFB has been escalated. The respiration pattern can be used as a reference for fruit producers to estimate the storage time and the length of the ripening process, so that the maximum storage time can be estimated to ensure that good quality of fruit is obtained (Kusumiyati *et al*, 2018). The results of our experiment showed that S3T2 treatment provided the highest fruits naturally stripped (NS) due to the highest dose of gamal leaves and the highest ripening time. The FFA value increases and causes the fruit nuts to detach easily.

3.1.2. Unstripped Fruit (US)

The oil palm nuts are crowded together so that the nuts in the deeper position still stick firmly, even after the mechanical threshing process is carried out. These fruits are classified as unstripped fruit (US) and is picked manually. Table 5 and 6 show effect of treatments on the unstripped fruits (US). Based on analysis of variance, single factor ripening time and amount of gamal leaves significantly affect the MS. The interaction of both factors, however, is not significant. The level of US is influenced by the amount of the gamal leaves and the length of ripening. The greater the weight of the gamal leaves and the longer the ripening time, the lower the percentage of US. The S3T2 treatment (40% gamal leaves with 20 h of ripening time) produced the lowest US (30.11%). In contrast, S1T1 (20% gamal leaves with 20 h of ripening) had the highest US (55.81%). The threshing process for FFB in palm oil mills is performed by using steam at pressure of 3 bar gauge. The unstripped bunches are defined as the empty fruit bunches (EFB) that still have at least 30% fruit (nuts) in the bunch. Oil palm mills required that the USB must be <3% (Rahardja & Sopyan, 2012).

Table 5. The effect of treatment on the percentage of unstripped fruit (US) relative to the FFB

Fermentation time	**Gamal leaf amount**			**Average**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**	
T1 (10 h)	55.81	47.61	41.47	24.15 a
T2 (20 h)	42.03	33.47	30.11	17.60 b
Average	48.92 A	40.54 B	35.79 C	

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

Table 6. The effect of treatment on the percentage of unstripped fruit (US) relative to the total fruit nuts

Fermentation time	**Gamal leaf amount**			**Average**
	S1 (20%)	**S2 (30%)**	**S3 (40%)**	
T1 (10 h)	72.06	64.28	55.98	64.11 a
T2 (20 h)	55.17	43.58	39.65	46.13 b
Average	63.62 C	53.93 B	47.81 A	

Note: numbers followed by different letters are significantly different under DMRT at 5% level (lowercases for fermentation time, uppercases for gamal leaf weight).

In our current research, the stripped fruits occurred due to ripening process using gamal leaves which is less a less optimal as compared to the use of steam in the palm oil mills. Gamal leaves trigger the production of ethylene gas, which accelerates ripening and separation of the fruit from the bunch. If the number of gamal leaves or ripening duration is insufficient, ethylene production may not be sufficient to ensure separation of the entire fruits that resulted in high portion of unstripped nuts (US). In addition, uneven distribution of ethylene during ripening can also cause the incomplete fruit release. Therefore, the effectiveness of ethylene in triggering ripening is very dependent on the weight of the gamal leaves and the duration of ripening.

3.1.3. Empty Bunches

Figure 1 present the effect of treatment on the percentage of empty bunch. Based on analysis of variance, single factor ripening time and amount of gamal leaves significantly affect the NS. In addition, the interaction of both factors is also significant. The S3T1 treatment (20% gamal leaves with 10 h of ripening) produced the lowest percentage of empty bunches (EFB), namely 13.10%, while S3T2 (40% of gamal leaves with 20 h of ripening) produced the highest EFB (21.64%). It can also be seen that the value of the empty bunches obtained is directly proportional to the material balance of the oil palm fruit. The material balance of oil palm fruit is 21% of the weight of FFB. From the data from several treatments that have been analyzed, the percentage of empty bunches is not much different from the material balance reference source.

3.2. CPO Quality

3.2.1. Free Fatty Acid

The effect of treatment on the free fatty acid (FFA) content in the resulted CPO is portrayed in Figure 2. Based on ANOVA, p-values are 0.0018 for ripening time, 0.0077 for amount of gamal leaves, and 0.0040 for the interaction of both factors. This means single factor ripening time and amount of gamal leaves as well as the interaction of both factors significantly affect the FFA. The length of ripening time and the amount of gamal leaves increases FFA content

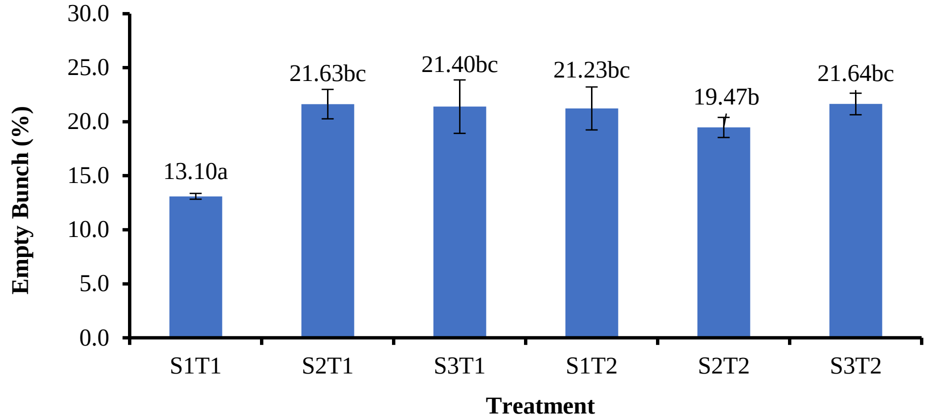

Figure 1. Effect of gamal leaf weight and ripening time on the percentage of empty bunches over the weight of FFB. (Numbers followed by different letters indicate significant differences in DMRT at the 5% level)

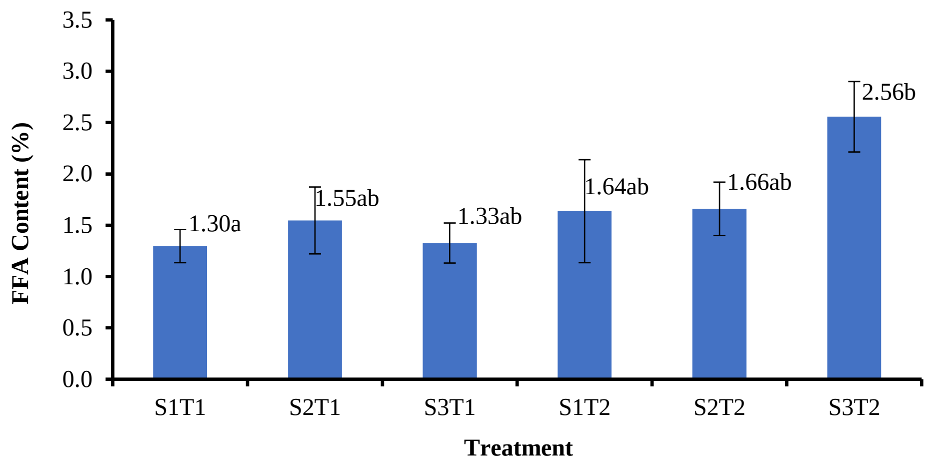

Figure 2. Effect of treatment on free fatty acids of the CPO. (Numbers followed by different letters indicate significant differences in the DMRT test at the 5% level)

with the highest (2.56%) is resulted from the S3T2 treatment (40% gamal leaves and 20 h ripening). This value is significantly different to that of S1T1 (20% gamal leaves and 10 h ripening) which resulted the lowest FFA value (1.30%). The FFA content is one of the determinants of the quality of CPO as stated in the Indonesian National Standard. The FFA level in the SNI is limited to be a maximum of 5% for premium quality and 3% for regular quality (BSN, 2021). In industrial practice, the processing of FFB to produce CPO, the FFA should be as minimal as possible. High FFA levels indicate that CPO is of poor quality (Winardi & Prasetyo, 2022). All treatments conducted in our research produced FFA that meet the standards specified in SNI 2901-2021.

Some factors can cause high levels of FFA. Too long ripening process can cause an increase in the levels of FFA in CPO, so the post-harvest production process needs to be carried out as soon as possible. Oil palm fruit bunches that are stored for too long will degenerate within at least 8-24 h after harvest. The time of harvesting the fruit and the level of ripeness greatly influence the FFA content of the fruit. The longer and over ripe the fruit is harvested, the faster the increase in FFA will be in the later storage process, and the high water content can influence the extent of hydrolysis reactions and oxidation which can increase FFA levels (Shidiq *et al*., 2022). The high levels of FFA in the CPO can be caused by the hydrolysis process which is triggered by the presence of water in the oil and the action of the lipase enzyme, both from palm fruit and microorganisms. Environmental conditions such as humid storage accelerate the increase in free fatty acid levels (Rahmawati & Utami, 2023). The increase in FFA by using gamal leaves was caused by several factors, namely the use of wet steam because in the CPO extraction process, the fruit peeling process takes a long time and oxidation occurs. In the factory, the main causes of increasing levels of FFA in CPO are human factors that are less careful in processing and analysis, machines that often experience problems due to excessive use, and FFB raw materials that are stored for too long or exposed to weather, thereby accelerating fruit damage and triggering an increase in FFA levels (Levia & Mhubaligh, 2023).

3.2.2. Water Content

Based on the ANOVA, it was found that *p*-values are 0.1276 for ripening time, 0.4755 for amount of gamal leaves, and 0.1653 for the interaction of both factors. This means that none of the factors as well as their interaction is significant to the water content of CPO, just like the effect of treaments on water content. Table 7 shows the effect of treatment combinations of gamal leaves amount and ripening time on the water content of the CPO. The S1T1 treatment produced CPO with the lowest water content of 0.68%, while the highest water content (3.29%) was resulted from S1T2 treatment. All treatments produced CPO with the water content greater than that required standard according to the SNI 2901-2021, which is maximum of 0.5% (BSN, 2021).

Table 7. The effect of treatment on the water content of the CPO

Fermentation time	Gamal leaf amount			Average
	S1 (20%)	S2 (30%)	S3 (40%)	
T1 (10 h)	0.68	0.77	1.37	0.94
T2 (20 h)	3.29	1.62	0.91	1.94
Average	1.98	1.19	1.14	

Some of the causes of high water content can be caused by storing CPO for too long, CPO should be stored for at least no more than 8 h, the heating temperature is too low so that the evaporation process is not optimal, a good temperature for water content is 60°C, the condition of the fruit is damaged during the harvesting process or rotten and the processing process after harvesting is not maintained by the factory so that it can increase the water content, because the large amount of water content in it can affect the quality of CPO (Shidiq *et al*, 2022). Water content is one of important parameters to determine the quality of oil or fat and is related to its storage duration, smell and taste. Water content greatly determines the quality of the oil produced from FFB. Water content also plays a role in the oxidation and hydrolysis processes of oil which can ultimately cause rancidity. The higher the water content, the faster the oil will go rancid (Nurfiqih *et al*., 2021). High water content can cause hydrolysis of triglycerides to free fatty acids, which has a negative impact on oil quality. The ideal water content should not exceed 0.2% to meet quality standards (Renjani *et al*., 2020).

Water content is one of the determinants of the quality of CPO as stated in the national standard. The SNI 2901-2021 (BSN, 2021) requires the maximum water content in CPO is 0.5% for regular quality. From the analysis results, the treatment with the highest water content reached 2.19%, while other treatments also showed water content that was still above the expected standard. This shows that the overall water content in the CPO exceeding the quality standards set by SNI which is only 0.5%.

3.2.3. Impurity Content

Table 8 shows effect of treatment on impurity content in the CPO. Based on the results of ANOVA, it was found that the *p*-value 0.2907 for gamal leaves factor, 0.3298 for ripening time factor, and 0.2649 for the interaction of both factors. This mean that none of the factors and their interaction are significant to the impurity content. From Table 8 the S1T1 treatment (20% gamal leaves with a ripening time of 20 hours) produces the lowest percentage of impurity content of 0.14% while S3T2 (40% gamal leaves with a ripening time of 20 hours) gets the percentage the highest impurity content was 1.43%. All treatments produce CPO with impurity content within the standard quality required by SNI 2901-2021, which is 0.5% (BSN, 2021). The cause that can be concluded from the analysis carried out for each treatment is due to the inclusion of fiber during the extraction process and other impurities whose specific gravity is smaller than CPO.

Table 8. The effect of treatment on the impurity content of the CPO

Fermentation time	Gamal leaf amount			Average
	S1 (20%)	S2 (30%)	S3 (40%)	
T1 (10 h)	0.14	0.39	0.25	0.26
T2 (20 h)	0.23	0.18	1.43	0.61
Average	0.19	0.29	0.84	0.44

Impurity levels in the CPO can be caused by various factors. One of the main causes is the lack of discipline and accuracy of operators in the process of sorting FFB, the condition of production machines that do not reach the required temperature in the clarifier settling tank, and the production environment that is not kept clean (Murjana & Handayani, 2022). Some of the causes of high levels of impurity are irregular sorting, storage times that are not achieved or are too long, temperatures that are not maintained between the usual 80-85ºC, and draining that is not optimal (Shidiq *et al*., 2022). High levels of impurity can be caused by impurities such as rubbish, sand, dust and others (Sukma & Rahmi, 2023). Impurity content is one of the determinants of the quality of crude palm oil (CPO) as stated in the Indonesian National Standard SNI 2901-2021 (BSN, 2021).

4. CONCLUSION

From the research that has been carried out, it is concluded that in terms of naturally stripped fruits (NS), treatment with 40% gamal leaf and 20 h of ripening time (S3T2) produced the highest NS of 45.87%. Larger weight of gamal leaves, combined with a longer ripening time, accelerates the process of separating the fruit from the bunch. In term of quality, all treatments produced low quality CPO based on three quality parameters (FFA, water content, and impurity content). The FFA content in the CPO, all treatments produced high FFA in the range of 1.30% from the S1T1 treatment to 2.56% from the S3T2 treatment, which were lower than and comply the value determined by SNI standard of 5% for regular quality. All treatments produced CPO with water content in the range of 0.68% (S1T1) to 3.29% (S1T2), which are higher than 0.5% of SNI. The impurity content of CPO is within than the quality standard limit of <0.5% according to SNI, except for S3T2 with impurity of 1.43 which is higher than the standard. Based on this result it obvious that fruit ripening within short times is desired. Increasing gamal leaves is believed able to accelerate further ripening process. Therefore, it is interesting to investigate the quality of CPO using higher portion of gamal leaves.

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