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Effect of Storage Temperature and Storage Time on Free Fatty Acid (FFA) of Crude Palm Oil (CPO)

Zakiyyah Afifah Nahda, Selfina Gala*

Chemical Engineering Department, Universitas Fajar, Makassar, Indonesia
***Corresponding author**: selfinagala@unifa.ac.id

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Abstract
This study evaluated the effects of storage temperature and storage time on the Free Fatty Acid (FFA) content of crude palm oil (CPO). A factorial Completely Randomized Design was applied using three storage temperatures (25, 28, and 30 °C) and four storage times (1, 3, 5, and 7 days), with two replications for each treatment combination. FFA was determined by titration using standardized sodium hydroxide. Two-way factorial Analysis of Variance (ANOVA) showed significant effects of storage temperature, storage time, and the temperature × time interaction on FFA. Mean FFA increased from 3.837% on day 1 to 5.175% on day 3, 6.330% on day 5, and 6.665% on day 7. The highest FFA was observed at 25 °C for 7 days (6.970%), while the lowest was observed at 30 °C for 1 day (3.645%). These results indicate that storage duration is an important factor in the deterioration of CPO quality as reflected by the increase in FFA.
Keywords: *crude palm oil; free fatty acid; storage temperature; storage time; CPO quality*

Abstrak
Penelitian ini mengevaluasi pengaruh suhu dan lama penyimpanan terhadap kadar Free Fatty Acid (FFA) pada crude palm oil (CPO). Penelitian menggunakan Rancangan Acak Lengkap faktorial dengan tiga suhu penyimpanan, yaitu 25, 28, dan 30 °C, serta empat lama penyimpanan, yaitu 1, 3, 5, dan 7 hari, dengan dua ulangan pada setiap kombinasi perlakuan. Kadar FFA ditentukan melalui metode titrasi menggunakan natrium hidroksida yang telah distandarisasi. Analisis ragam faktorial dua arah menunjukkan bahwa suhu penyimpanan, lama penyimpanan, dan interaksi suhu × waktu berpengaruh signifikan terhadap FFA. Rataan FFA meningkat dari 3,837% pada hari ke-1 menjadi 5,175% pada hari ke-3, 6,330% pada hari ke-5, dan 6,665% pada hari ke-7. Nilai FFA tertinggi diperoleh pada suhu 25 °C selama 7 hari sebesar 6,970%, sedangkan nilai terendah diperoleh pada suhu 30 °C selama 1 hari sebesar 3,645%. Hasil tersebut menunjukkan bahwa lama penyimpanan merupakan faktor penting terhadap penurunan mutu CPO yang ditunjukkan oleh peningkatan kadar FFA.
Kata kunci: *minyak sawit mentah; asam lemak bebas; suhu penyimpanan; lama penyimpanan; mutu CPO*

1. Introduction

Crude Palm Oil (CPO) is one of the most important products of the palm-oil industry and serves as a major raw material for the production of various food and non-food products. The quality of CPO is an important factor that determines its suitability for further processing and its economic value. Several parameters are commonly used to evaluate the quality of palm oil, including free fatty acids (FFA), moisture content, impurities, color, and oxidation characteristics. Among these parameters, acidity and FFA are important indicators for evaluating oil quality because increasing acidity can be associated with deterioration during handling and storage [1], [2].

FFA formation in CPO is closely associated with the hydrolysis of triglycerides, which are the major components of palm oil. During hydrolysis, triglycerides react with water to produce glycerol and free fatty acids. The occurrence of this reaction can be influenced by the availability of water and environmental conditions during storage. Therefore, CPO that is exposed to conditions that promote hydrolysis may experience an increase in FFA concentration over time [2], [3].

Moisture or water availability is an important factor in the hydrolysis of triglycerides because water participates directly in the hydrolysis reaction. The presence of moisture in oil or its surrounding environment can increase the possibility of triglyceride hydrolysis and consequently contribute to the formation of FFA. In addition to moisture, the initial quality of the CPO and storage conditions may

influence the extent to which hydrolytic deterioration occurs. Consequently, controlling moisture exposure is an important consideration in maintaining CPO quality during storage [2], [3].

Temperature is another factor that can influence the chemical stability of palm oil. Changes in temperature can affect the rate of chemical and biochemical reactions occurring in the oil. Recent research on palm oil has demonstrated that controlled temperature–time conditions can significantly influence changes in FFA and other indicators of oil quality. This indicates that temperature and exposure duration should be considered together when evaluating changes in palm oil characteristics [3].

Storage time is also an important factor in determining changes in oil quality. The longer CPO is exposed to storage conditions, the greater the opportunity for chemical and biochemical reactions to occur. Prolonged exposure can therefore result in changes in FFA and other quality parameters, depending on the storage environment. The effect of storage duration is particularly relevant when the oil is maintained at temperatures that can accelerate degradation reactions [3], [4].

The combined effect of storage temperature and storage time is particularly important because these factors may interact in influencing the rate of oil deterioration. An increase in temperature can alter the reaction rate, while a longer storage period provides more time for the reaction to proceed. Consequently, evaluating temperature and storage time simultaneously can provide a more comprehensive understanding of the changes occurring in CPO during storage [3].

Changes in FFA concentration during storage are also important from an industrial perspective. FFA is closely related to the acidity of vegetable oils, and acidity is recognized as one of the quality characteristics considered in international standards for fats and oils. The Codex Standard for Named Vegetable Oils provides quality criteria related to acidity and recognizes FFA as a relevant quality characteristic for certain palm-derived oils [1], [2]. Therefore, monitoring FFA during storage is important for assessing whether CPO maintains an acceptable quality before entering subsequent processing stages.

Proper storage conditions are consequently required to minimize the deterioration of CPO. Temperature control, protection from excessive moisture exposure, appropriate storage facilities, and management of storage duration can help maintain oil quality. Understanding the relationship between these factors and FFA formation can provide useful information for determining storage practices that minimize undesirable changes in CPO quality [1], [3].

Previous research has shown that temperature and exposure duration can influence changes in palm-oil quality, while moisture availability is closely related to hydrolytic reactions that produce free fatty acids [2], [3]. However, the magnitude and direction of these effects may vary depending on the characteristics of the oil, initial quality, experimental conditions, temperature range, and storage duration. Therefore, controlled experimental studies are still important to determine how specific combinations of storage temperature and storage time affect FFA under defined experimental conditions.

Based on these considerations, FFA can be used as an important response parameter for evaluating changes in CPO quality during storage. This study specifically investigates the effect of storage temperature and storage time on FFA formation in CPO. In addition to evaluating the individual effects of these two factors, this study also examines their interaction under the tested experimental conditions. The analysis is expected to determine whether variations in storage temperature and duration significantly affect FFA concentration and whether the effect of one factor changes depending on the level of the other factor [3].

The results of this study are expected to provide a better understanding of the behavior of FFA in CPO during storage. The findings may also provide a basis for identifying storage conditions that can minimize undesirable increases in FFA and maintain CPO quality before further processing. Furthermore, the results may contribute to the development of more appropriate storage practices in the palm-oil industry, particularly in relation to temperature and storage duration management.

2. Materials and Methods

2.1 Materials and equipment

The research material was crude palm oil (CPO). The main reagents and materials used for FFA analysis were neutral hot alcohol, phenolphthalein indicator, and standardized NaOH solution. The equipment included an analytical balance, Erlenmeyer flask, burette, hotplate, thermometer, and other supporting laboratory equipment.

2.2 Experimental design

A factorial Completely Randomized Design was used with two factors. The first factor was storage temperature: 25, 28, and 30 °C. The second factor was storage time: 1, 3, 5, and 7 days. Each of the 12 treatment combinations was replicated twice, resulting in 24 experimental units.

2.3 FFA analysis

The homogenized CPO sample was weighed and transferred into an Erlenmeyer flask. Neutral hot alcohol and phenolphthalein indicator were added. The mixture was titrated with standardized NaOH until a persistent pink endpoint was obtained. The FFA content was calculated from the volume and concentration of NaOH used in the titration and the mass of the CPO sample.

2.4 Data analysis

FFA data were summarized as treatment means and analyzed using two-way factorial Analysis of Variance (ANOVA) at a 95% confidence level to evaluate the effects of storage temperature, storage time, and their interaction. The reported experiment used two replications per treatment combination. Because the original report noted limitations in normality and homogeneity assumptions, ANOVA results were interpreted together with the treatment means and graphical trends.

3. Results and Discussion

3.1 Effect of storage temperature on FFA

The mean FFA at 25, 28, and 30 °C was 5.719%, 5.436%, and 5.350%, respectively. ANOVA showed that storage temperature significantly affected FFA ($F(2,12)=2,976.292$; $p<0.001$). The descriptive trend showed a decrease in mean FFA from 25 to 30 °C within the overall dataset. However, the temperature effect should be interpreted together with storage time because the temperature × time interaction was also significant.

3.2 Effect of storage time on FFA

Storage time produced a clear increase in FFA. Mean FFA increased from 3.837% on day 1 to 5.175% on day 3, 6.330% on day 5, and 6.665% on day 7. Compared with day 1, the increase on day 7 was approximately 73.7%. ANOVA showed a significant effect of storage time ($F(3,12)=98,368.333$; $p<0.001$). The increase is consistent with progressive hydrolysis of triglycerides during storage.

3.3 Interaction between storage temperature and time on FFA

The temperature × storage time interaction significantly affected FFA ($F(6,12)=294.625$; $p<0.001$). On day 1, mean FFA was 3.935%, 3.930%, and 3.645% at 25, 28, and 30 °C, respectively. On day 3, the values increased to 5.310%, 5.115%, and 5.100%. On day 5, FFA reached 6.660%, 6.180%, and 6.150%, while on day 7 it reached 6.970%, 6.520%, and 6.505%, respectively. The highest value was therefore obtained at 25 °C for 7 days, while the lowest was obtained at 30 °C for 1 day. The changing distance among temperature treatments indicates that the effect of temperature depended on storage duration.

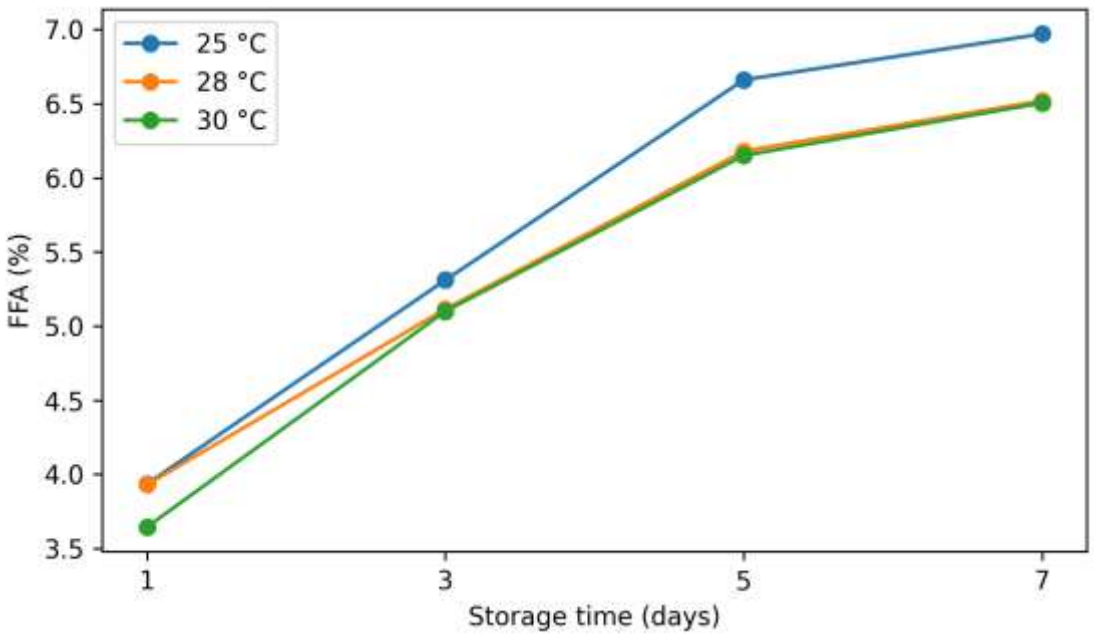


Figure 1. Effect of storage temperature and storage time on FFA of CPO.

Table 1. FFA (%) at each storage temperature and storage time

Temperature	1 day	3 days	5 days	7 days
25 °C	3.935	5.310	6.660	6.970
28 °C	3.930	5.115	6.180	6.520
30 °C	3.645	5.100	6.150	6.505

Table 2. Two-way factorial ANOVA results for FFA

Factor	F-value	p-value
Temperature	2,976.292	<0.001
Storage time	98,368.333	<0.001
Temperature × time	294.625	<0.001

The results presented in **Table 1** indicate that the free fatty acid (FFA) content increased progressively with increasing storage time at all investigated storage temperatures. At 25 °C, the FFA content increased from 3.935% after 1 day of storage to 5.310% after 3 days, 6.660% after 5 days, and reached 6.970% after 7 days. A similar trend was observed at 28 °C, where the FFA content increased from 3.930% on day 1 to 5.115% on day 3, 6.180% on day 5, and 6.520% on day 7. At 30 °C, the FFA content also increased from 3.645% on day 1 to 5.100% on day 3, 6.150% on day 5, and 6.505% on day 7. This consistent increase demonstrates that storage duration plays an important role in the formation and accumulation of free fatty acids in the stored material.

The increase in FFA during storage can generally be associated with the hydrolysis of triglycerides. Triglycerides can react with water in the presence of lipolytic enzymes or other catalytic factors, resulting in the formation of free fatty acids and glycerol. As storage time becomes longer, the opportunity for hydrolytic reactions to occur also increases. Consequently, more triglycerides may be converted into free fatty acids, causing the FFA value to increase. The continuous increase from day 1 to day 7 observed in all temperature treatments suggests that the hydrolytic process continued throughout the storage period. In addition, prolonged storage may also facilitate oxidative and enzymatic deterioration, particularly when the sample contains sufficient moisture and endogenous lipase activity.

Among the storage treatments, the highest FFA content was obtained at 25 °C after 7 days, with a value of 6.970%. In contrast, the lowest FFA content was observed at 30 °C after 1 day, at 3.645%. Although the general expectation is that higher temperatures may accelerate chemical and enzymatic reactions, the present results do not show a simple linear relationship between storage temperature and FFA content. For example, at day 1, the FFA content at 25 °C (3.935%) and 28 °C (3.930%) was higher than that at 30 °C (3.645%). The same pattern was generally maintained at the later storage periods, with the 25 °C treatment producing slightly higher FFA values than the 28 and 30 °C treatments. This indicates that temperature alone may not explain the variation in FFA formation. Other factors, such as initial sample composition, moisture availability, enzyme activity, oxygen exposure, and storage conditions, may have contributed to the observed differences.

The increase in FFA was particularly pronounced between the first and third days and between the third and fifth days of storage. At 25 °C, for example, FFA increased by 1.375 percentage points from day 1 to day 3 and by another 1.350 percentage points from day 3 to day 5. However, the increase between day 5 and day 7 was smaller, at 0.310 percentage points. A similar pattern was observed at 28 °C and 30 °C, where the increase in FFA became relatively smaller during the final storage period. This pattern may indicate that the rate of triglyceride hydrolysis was relatively high during the initial stages of storage and subsequently began to slow down. The reduction in the rate of FFA formation may occur because the concentration of readily hydrolyzable substrates decreases or because enzymatic activity becomes limited during prolonged storage.

The statistical analysis presented in Table 2 further confirms that storage conditions significantly affected FFA content. The two-way factorial ANOVA showed that storage temperature had a statistically significant effect on FFA, with an F-value of 2,976.292 and a p-value of <0.001. This result indicates that the differences in FFA content among the temperature treatments were statistically significant. Therefore, although the numerical differences between temperatures appear relatively small in some storage periods, these differences were sufficient to produce a significant statistical effect.

Storage time showed an even stronger influence on FFA content. The ANOVA results produced an F-value of 98,368.333 with a p-value of <0.001. The substantially larger F-value compared with that of temperature indicates that storage time was the dominant factor affecting FFA variation in this study. This finding is consistent with the results in **Table 1**, where FFA increased systematically from day 1 to day 7

regardless of the storage temperature. Therefore, extending the storage period appears to provide a greater contribution to FFA accumulation than the differences among the tested temperatures.

Furthermore, the interaction between storage temperature and storage time was also statistically significant, with an F-value of 294.625 and a p-value of <0.001. The significant interaction indicates that the influence of storage time on FFA content was not completely independent of temperature. In other words, changes in FFA over the storage period differed depending on the temperature treatment. This result is important because it demonstrates that the effects of temperature and storage duration should not be interpreted separately. The significant interaction suggests that changes in storage temperature can modify the rate or extent of FFA development during storage.

Overall, the results demonstrate that FFA content is strongly influenced by storage conditions, particularly storage duration. The progressive increase in FFA from day 1 to day 7 indicates that prolonged storage promotes lipid deterioration and the accumulation of free fatty acids. Although temperature also had a significant effect, the much higher F-value for storage time indicates that storage duration was the most influential factor in determining FFA content. Therefore, controlling storage duration is important for maintaining product quality and minimizing lipid hydrolysis. The significant temperature × storage time interaction further emphasizes the importance of considering both factors simultaneously when determining appropriate storage conditions.

3.4 Comparison with previous studies

The increase in FFA with longer storage is consistent with the study of Emebu et al. (2022), which reported that moisture content, temperature, and storage time influence FFA changes in stored CPO. The present study similarly demonstrates that storage duration is an important factor in FFA formation. The temperature trend should not be generalized beyond the tested range because the temperature × time interaction was significant.

4. Conclusion

Storage temperature, storage time, and their interaction significantly affected the free fatty acid (FFA) content in crude palm oil (CPO) during the study. Among these variables, storage time demonstrated the clearest effect, with the overall mean FFA value steadily increasing from 3.837% on day 1 to 6.665% on day 7. Specifically, the highest FFA concentration reached 6.970% when stored at 25 °C for 7 days, whereas the lowest value was recorded at 3.645% at 30 °C for 1 day. Overall, these results strongly indicate that properly controlling storage duration is essential for maintaining optimal CPO quality based on FFA parameters.

5. Recommendations

CPO storage duration should be minimized and FFA should be monitored periodically during storage. Future studies should use a larger number of replications and evaluate statistical assumptions more thoroughly to strengthen the inference regarding temperature and storage time effects.

6. References

[1] Aldi, A., Giyanto, & Purwanto, H. (2024). Pengaruh kadar air, suhu dan lama penyimpanan terhadap kenaikan asam lemak bebas pada crude palm oil (CPO). Agro Fabrica, 6(2), 96–106.

[2] Emebu, S., Osaikhuiwuomwan, O., Mankonen, A., Udoye, C., Okieimen, C., & Janáčová, D. (2022). Influence of moisture content, temperature, and time on free fatty acid in stored crude palm oil. Scientific Reports, 12, 9846. https://doi.org/10.1038/s41598-022-13998-1

[3] Nurfiqih, D., Hakim, L., & Muhammad. (2021). Pengaruh suhu, persentase air, dan lama penyimpanan terhadap persentase kenaikan asam lemak bebas (ALB) pada crude palm oil (CPO). Jurnal Teknologi Kimia Unimal, 10(2), 1–14.

[4] Pranata, D. I., & Husin, H. (2023). Analisis mutu crude palm oil (CPO) dengan parameter kadar asam lemak bebas (ALB) dan kadar air yang terdapat pada daily tank di PT. Socfin Indonesia Kebun Seunagan. Jurnal Pertanian Agros, 25(3), 1219–1225.

[5] Tan, B. A., Nair, A., Zakaria, M. I. S., Low, J. Y. S., Kua, S. F., Koo, K. L., et al. (2023). Free fatty acid formation points in palm oil processing and the impact on oil quality. Agriculture, 13(5), 957.

[6] Ayu, D. F., Sormin, D. S., & Rahmayuni. (2020). Pengaruh waktu tunda pengolahan terhadap mutu minyak sawit mentah (crude palm oil) yang dihasilkan. Jurnal Teknologi dan Industri Pertanian Indonesia, 12(2), 10–16.

[7] Bahri, S., Lubis, R. R. H., & Siregar, L. A. M. (2019). Pengaruh suhu dan lama penyimpanan terhadap mutu minyak sawit mentah. Jurnal Keteknikan Pertanian, 7(1), 41–48.

[8] Anggraini, D. A., & Suyitno, P. T. (2021). Analisis pengendalian kualitas crude palm oil (CPO) PT. Kampar Tunggal Agrindo dengan menggunakan Statistical Process Control. Surya Teknika, 8(1), 327–332.

[9] Arrahman, M., et al. (2022). Analisis mutu CPO menggunakan metode titrasi (Studi kasus: PT Hari Sawit Jaya). Jurnal Pertanian Agroteknologi, 10(2), 82–87.

[10] Chandrahadinata, D., & Nurdiana, W. (2021). Analisis pengendalian kualitas pada crude palm oil untuk meningkatkan kualitas di PT. Condong Garut. Jurnal Kalibrasi, 19(1), 43–52.

[11] Dewi, H., & Yannimar, A. S. (2023). Analisa pengendalian mutu produksi crude palm oil (CPO) menggunakan metode Statistical Quality Control (SQC). Jurnal Teknologi Pertanian, 12(1), 20–32.

[12] Levia, D., & Muhbaliq. (2023). Analisis proses produksi CPO untuk mengidentifikasi faktor-faktor yang mempengaruhi kualitas mutu CPO. Jurnal Teknologi dan Manajemen Industri Terapan (JTMIT), 2(1), 82–89.

[13] Murjana, L., & Handayani, W. (2022). Analisis pengendalian kualitas crude palm oil (CPO) dengan menggunakan metode Statistical Quality Control (SQC) pada PT. Sapta Karya Damai Kalimantan Tengah. Widya Karya Journal, 9(1), 47–61.

[14] Shidiq, M., Lestari, W., & Saragih, S. H. Y. (2022). Analisis kualitas mutu minyak mentah kelapa sawit di pabrik kelapa sawit PT. Sinar Pandawa, Kabupaten Labuhanbatu (Berdasarkan kadar asam lemak bebas, kadar air, dan kadar kotoran). Jurnal Pembelajaran dan Biologi Nukleus, 8(2), 386–398.

[15] Syafrianti, A., Lubis, Z., & Elisabeth, J. (2021). Study of crude palm oil (CPO) handling and storage process in palm oil mills in an effort to improve CPO quality and reduce the risk of contaminants formation. Journal of Food and Pharmaceutical Sciences, 9(2), 461–470.