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The effect of sterilization time on oil loss into the condensate water of sterilizer in the crude palm oil industry

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Abstract

Sterilization in the sterilizer unit is one of the important processes in the Crude Palm Oil (CPO) industry but it can cause oil loss in the palm fruit which reduces the oil yield if the sterilization process is carried out over time. Therefore, the sterilization time needs to be considered so that this study aims to analyze the effect of the length of Fresh Fruit Bunches (FFB) sterilization time on oil loss in condensate water sterilizer on the industry of CPO and determine the maximum time in the Sterilizer. This study was conducted at a CPO plant in West Sumatra with a maximum standard of 1.2 % oil loss, the optimum sterilization time can be determined. This study uses a horizontal-type sterilizer through a triple-peak sterilization system. Peak pressure 1 is 1.2 bar; peak pressure 2 is 2.0 bar; and the triple peak pressure is 3.0 bar with a temperature of 130-140 °C. The time varies from 83 – 90 minutes. The results showed that the longer the sterilization time, the greater the percentage of oil loss. In conclusion, the maximum time in sterilizer is achieved under 87.4 minutes with an maximum oil loss standard of 1.2 %.

Keywords: oil loss, oil processing, maximum condition, sterilization time

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1. INTRODUCTION

The palm oil industry is a promising industry today. Palm oil is an important commodity because of the increasing demand for vegetable oil around the world. The palm oil processing industry began by processing fresh fruit bunches (FFB) into Crude Palm Oil (CPO) and palm kernel (Mba et al., 2015). There are various stages of the process to go through to get palm oil that has quality according to standards, one of which is the sterilization process at the sterilizer station (Wae-hayee et al., 2022)

Processing of palm fruit aims to obtain good quality palm oil. The process lasts quite a long time and requires careful handling. The stages of palm oil fruit processing affect the process at the next stage. One of the early processing stages is the sterilization. It is important for (i) microorganism sterilization, (ii) fat melting, (iii)

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increasing oil yield, (iv) quality control. Freshly harvested FFB contains many microorganisms, including bacteria, fungi and enzymes that can cause damage and putrefaction. The process of sterilization FFB in the sterilizer aims to eliminate or reduce the number of these microorganisms, resulting in palm oil that is sterile and lasts longer. Effective sterilization also helps prevent cross-contamination between one fruit bunch and another (Mohd Yusof et al., 2023; Primandari et al., 2021).

In the sterilization process, fresh fruit bunches are boiled with steam at a temperature ranging from 130-140 $^{\circ}$C and a pressure of 1.5 – 2.8 bar for 90 minutes. The sterilization process is carried out in a system of three pressure peaks in order to obtain optimal results (Gold et al., 2012). Steam is flowing at different pressures according to the peak system used, where the higher the pressure, the more steam will be used. Sterilization for too long will also cause high oil loss, while if the process is too short, the fruit will become less soft, thus hindering further processes such as chopping and pressing (Harun et al., 2015; Muhammad et al., 2021).

FFB contains fat trapped in the fruit cells. Through sterilization, the high temperature causes the fat to become liquid, facilitating the separation of the fruit fibres and cells. It also changes the structure of the proteins in the fruit cells, thus facilitating a better separation between the oil and the fruit solids (Zamanhuri et al., 2022). Further, the FFB sterilization process increases the yield of palm oil. The heat applied during sterilization helps free the oil trapped in the fruit cells. In addition, it also changes the physical and chemical properties of fruit bunches, such as softening the fibre and dissolving pectin which allows for a more efficient and optimal separation between oil and fruit solids (Hock et al., 2020).

Thus, the sterilization process of FFB is a critical stage in palm oil production. It plays an important role in controlling the quality of palm oil (Foong et al., 2018). One of the controllers in determining the quality of palm oil is the sterilization time as well as temperature and pressure. The time must be carefully controlled so that the palm oil produced meets the quality standards set (Nik Norulaini et al., 2008). The duration of sterilization in the CPO oil sterilizer unit can affect oil loss. The longer the FFB is heated in the sterilizer unit, the longer the oil is exposed to high temperatures and condensation water. This can cause the oil released from the fruit cells to oxidize or be washed away by water, causing greater oil loss (Foon et al., 2004; Mohd Yusof et al., 2023; Yosenov et al., 2023).

To reduce oil loss in the sterilization process, it is necessary to carefully adjust the time parameters. Optimizing the sterilization process can help minimize oil loss and increase the yield of CPO oil (Foong et al., 2018). The loss of palm oil that is too high in the sterilization unit contained in condensate water can affect the final yield of palm oil, so it is necessary to analyze the loss of oil in the condensate water. Loss of oil in the condensate water sterilizer is the oil lost in the oil palm fruit bunches carried by the condensate water. Prolonged exposure to high temperatures and pressures can lead to oil degradation, resulting in higher viscosity and increased emulsification of condensate water. This has an impact on the separation of oil from condensate is inefficient (Parvand & Rasiah, 2022; Romero-Guzmán et al., 2020).

In the process, the standard of oil loss in an industry differs from one another specifically, but in general, it is 1.2 % (Wae-hayee et al., 2022; Zamanhuri et al., 2022). If the oil loss exceeds the requirements then the industry suffers a loss due to reduced oil yields (Jusoh et al., 2020). Although oil loss cannot be avoided, it can be optimized by identifying the optimum sterilization time based on the operating conditions prevailing in the plant. Therefore, this study aims to determine the effect of sterilization time on oil loss in the sterilizer in the CPO industry and to determine the optimum sterilization time for a maximum oil loss of 1.2 %w.

2. MATERIALS AND METHODS

This research was conducted at a palm oil factory in Agam Regency, West Sumatra. Data such as steam pressure, back vessel pressure taken are data from the logbook from 01 August to 7 August 2023.

2.1 Sterilizer Specifications

The sterilizer used in this study is a horizontal type. The steam used is at a pressure of 28 bar and a back vessel pressure of 2.8 bar. Parts of the horizontal sterilizer as described in Figure 1.

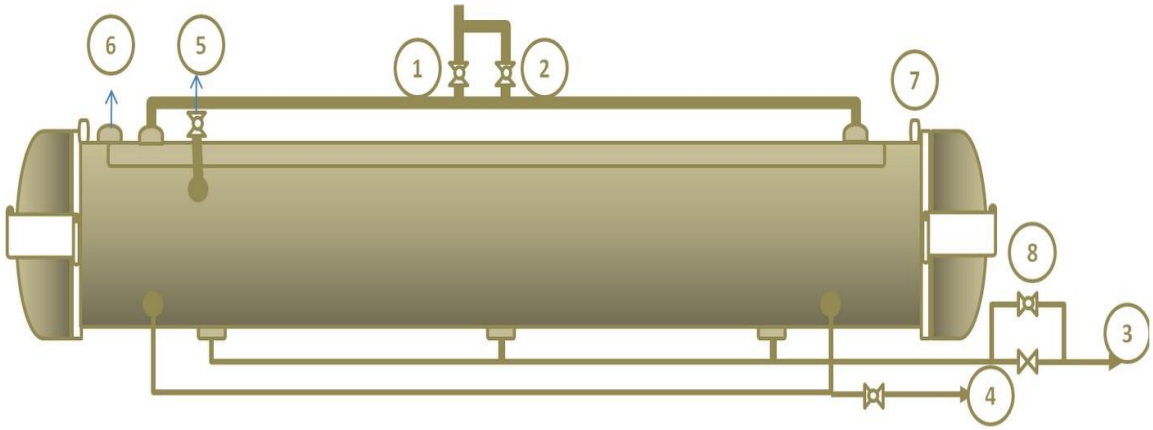

Figure 1. Sterilizer horizontal (Latif Mubarok et al., 2022)

Horizontal sterilizer has eight parts as follows:

1. Main steam inlet as inlet of steam supply from the back pressure vessel
2. Auxiliary steam inlet as inlet of secondary steam supply
3. Condensate c/w strain to drain condensate
4. Deaeration to air release to maintain optimum sterilization process
5. Exhaust to drain steam that passes by blow down silencer
6. Safety valve to maintain pressure in the vessel
7. Pressure gauge to measure the pressure inside the vessel
8. By-pass condensate to drain condensate along sterilization in by-pass to keep draining condensate continuously.

Sterilizer specification data can be seen in Table 1.

Table 1. Sterilizer specification data

No	Parameters	Value
1	Length (m)	30
2	Inner diameter (m)	2.7
3	Outer diameter (m)	2.8
4	Peak Pressure 1 (bar)	1.2
5	Peak Pressure 2 (bar)	2.0
6	Peak Pressure 3 (bar)	3.0
7	Sterilization system	3 peaks
8	Number of Sterilizers (units)	4
9	Lorry Length (m)	2.4
10	Lorry Width (m)	2.3
11	Lorry Height (m)	2.4

2.2 Sterilizer Operation

Sterilizer operation is determined to follow the type of peak that is set. The horizontal type uses a truck will apply pressure until the tripple peak. The fruit will properly ripen to the bottom layer if the pressure reaches 3 bars. Where at the beginning of the steam pressure of Peak I entered was 2 kg/cm^2 for ± 8 minutes, then steam discharge from 2 - 0 kg/ cm^2, then remove the condensate for ± 4 minutes, after which the steam is raised on the Peak II from 0 - 2.6 kg/cm^2 for ± 12 minutes, then steam removal from 2.6 - 0 kg/ cm^2 condensate water discharge for ± 7 minutes, after which at Peak III the pressure is increased from 0 - 3 kg/cm^2 for ± 14 minutes, After the peak III is completed, the boiling time is ± 45 minutes, then steam is removed from 3 - 0 kg/cm^2, condensate water is removed for ± 45 minutes and steam removal from 3 - 0 kg/cm^2, discard the condensate water for ± 5 minutes and the sterilizer door can open to proceed to the next process.

2.2 Experimental Procedures

The condensate water used in this study is condensed water coming out of the sterilizer towards the fat pit (oil reservoir). Condensate water consists of three layers: oil layer, water layer and mud layer. The layers taken are oil and water layers.
The procedure for calculating the percentage of oil loss is as follows:

a. There is a pre-treatment that is carried out. It is the removal of moisture content. This step is to remove the water content contained in the sample so that a dry sample is obtained. Samples were heated at 110 ^{o}C for 3 hours.
b. The dry samples were extracted using n-Hexane solvent. The sample was extracted so that the hexane solution was clear in colour as an indicator that the oil content had been extracted completely.

The lost oil content is determined by Equation [1] below.

$$\% \text{ Oil loss} = \frac{\text{Oil mass (g)}}{\text{Sample mass (g)}} \text{ X } 100\% \qquad (1)$$

This experimental procedures are adapted from (Hikmawan & Angelina, 2019; Nugraha et al., 2023).

3. RESULTS AND DISCUSSION

Based on the research results, the effect of sterilization time on the percentage of oil loss in condensate water is shown in Figure 2.

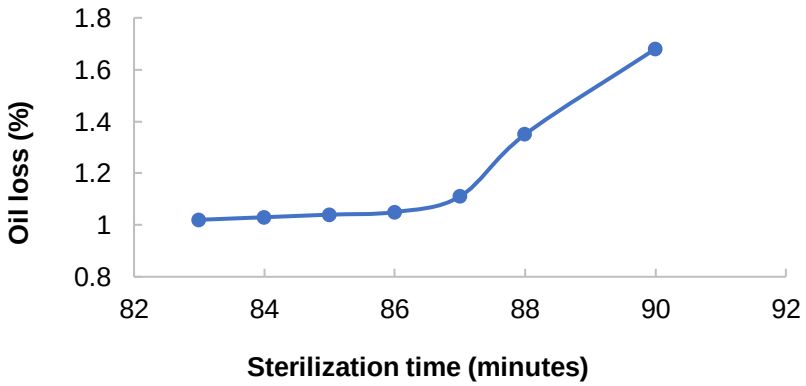

Figure 2. The effect of sterilization time on the sterilizer on the percentage of oil loss

From Figure 2, it can be seen that the longer the sterilization period, the higher the percentage of oil loss. With sterilization time varying from 83 bars – 90 bars, the percentage of oil loss increased polynomial order 4 from 1.02 % (w) to 1.68 % (w). This finding is aligned with (Hock et al., 2020; Nik Norulaini et al., 2008). They revealed that the percentage of oil loss is also affected by the maturity level of the fruit. The high degree of maturity will result in increased oil loss in condensate water.

The appropriate level of maturity and sterilization time is proper so that the next process makes it easier for loose lollipops to separate from the bunches. The fruit will easily be crushed and the compression on the screw press will be perfect so that the oil loss in sterilization will be decreased (Tan et al., 2021). The over-time sterilization will cause the following things, the fruit will become bruised, experience a loss of oil in the condensate water and the quality of the oil and core will decrease, and some of the fruit will become burnt, caused by the over-time which is in line with the increasing temperature, the oil content in the condensate water will increase (Vincent et al., 2014).

If the pressure is low, the temperature is low and the sterilization time will cause fruit ripe partially. It impacts the inefficient bunch threshing process. Further, the water content in the seeds will increase so that it will be more difficult to separate the core from the shell. It influences the pressing process which impact imperfect pressing process (Thang et al., 2021). Omar et al. (2018) describe the mechanism of oil loss in the sterilizer unit during the processing of fresh fruit bunches can be related to several factors. Following are some of the common mechanisms that can cause oil loss namely evaporation, process extraction, over-sterilization, inadequate moisture control, fruit damage, and inefficient heat transfer. The high temperature used in the sterilizer can cause evaporation of the volatile components in the palm fruit, including some of the oil. When fruit is exposed to heat, its volatile components are released into the surrounding atmosphere, resulting in loss of oil.

Extraction during condensation, the evaporated water and volatile components are condensed and collected. However, during the condensation process, some of the oil can also be carried away and collected with the condensate. This may result in loss of oil from the sterilizing unit. In the sterilizer, over-sterilization can also occur where the sterilization time that is extended beyond the required duration can cause the palm fruit to overripe, causing an increase in oil loss. Excessive sterilization can cause damage to the oil-carrying cells, making it more difficult to extract the oil during further processing.

Inadequate humidity control also affects the degree of oil loss in the condensate. The water content of the palm fruit is an important parameter in the sterilization process. If the fruit is too dry or too moist, it can affect the oil extraction efficiency. Inadequate humidity control can cause loss of oil during sterilization (Antwi et al., 2023). Damaged or overripe fruit can release more oil during the sterilization process. This can occur due to the rupture of the oil-carrying cells, thus allowing the oil to be released and lost in the sterilizer unit.

Inefficient heat transfer due to inadequate steam distribution and circulation inside the sterilizer can result in uneven heating or insufficient heat transfer throughout the fruit. This can lead to incomplete sterilization and increased oil loss. Irregularities in the sterilization process will cause high oil loss in the steam. This deviation can be caused by the inclusion of raw fruit in the stew. When injecting steam into the boiler, the operator is late, resulting in reduced processing capacity (Pakdeechot et al., 2020)

In Figure 2 it can be seen that the oil loss in the sterilization system still does not meet the oil loss standard of 1.2 %w. To minimize oil loss in the sterilization unit, and determine the maximum length of sterilization time so that the percentage of oil loss that meets the maximum standard of 1.2 %w is shown in Figure 3. Figure 3 presents the maximum sterilization time based on data in Figure 2.

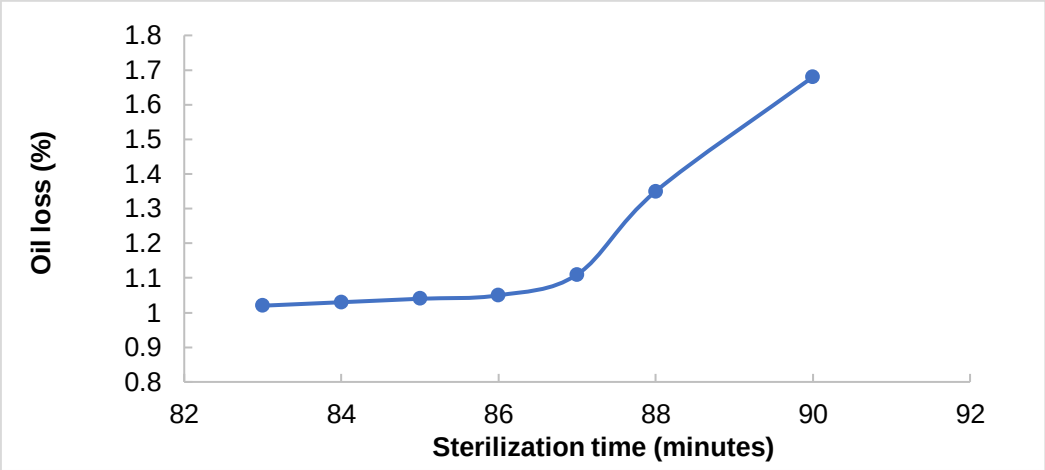

Figure 3. Determination of the maximum sterilization time

The maximum sterilization time is determined by mathematical analysis from the equation generated by the graph in Figure 2. The analysis shows that the maximum sterilization time is 87.4 minutes. If the sterilization time exceeds 87.4 minutes, then the percentage of oil loss in the condensate water of the type 3 peak sterilizer unit will exceed 1.2 %w. It is important to maximize process parameters such as temperature, moisture content, and sterilization time, and ensure proper sealing and maintenance of equipment. By maintaining optimal conditions and implementing efficient operational practices, the rate of oil loss in the sterilization unit can be reduced, thereby increasing the overall efficiency of oil extraction. Simarani et al. (2009) reported that optimization of the sterilizer time will affect the yield of palm oil. The higher the sterilizer temperature, the faster the sterilization will be and the more oil produced. This is because the viscosity of oil in the palm fruit is down when pressed and easily separated from the fruit. The water contained in the oil will convert the oil into Free Fatty Acids. It will cause rancidity if too long in the store. This will degrade the quality of the oil itself which could not be stored for too long (bin Ab Hadi et al., 2016).

Further, to maintan sterilization runs smoothly and to anticipate corrosion, it is necessary to carry out preventive maintenance. Apart from that, the equipment in the plants must be cleaned frequently at least once a week, the inside of the cooker should be cleaned of oil to prevent corrosion, the cooker door must be in good condition and not leaking, the condensate water tap must be good so that the condensate water drainage process takes place perfectly and gaps between the rail system in the boil must be checked frequently so that the FFB can easily enter the boil.

4. CONCLUSION

The sterilization time has a significant effect on oil loss in the sterilizer. Longer sterilizer time, more percentage of oil loss in the condensate water. The maximum

sterilizer time is 87.4 minutes. The sterilization time is a crucial parameter to control during the sterilization process of oil palm fresh fruit bunches. Sterilization time has a polynomial proportional effect on the increase in the percentage of oil loss in condensate water. As limitation, this study focuses on sterilizer time and is limited to certain sites that use same sterilizer specification and operation conditions. However, the effect of time on oil loss can vary depending on various factors, including the type of sterilizer, operating conditions, and the characteristics of the fruit bunches used. Therefore, it is important to carry out tests on other parameters such as temperature, and moisture content, and ensure proper sealing and maintenance of equipment for further studies. Further studies also can consider the Response Surface Method to optimize the operating condition in the sterilization process.

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REFERENCES

Antwi, L. A. A., Nimoh, F., Agyemang, P., & Apike, I. A. (2023). Perception and adoption of free fatty acid reduction techniques by small scale palm oil processors: Evidence from Ghana. *Journal of Agriculture and Food Research*, *11*, 100462. https://doi.org/10.1016/j.jafr.2022.100462

bin Ab Hadi, A., Abd Wahab Mohammad, I., & Mohd Sobri Takriff, I. (2016). *Determination of optimum sterilization condition based on calculated heat transfer rate for palm oil mill process*. *11*(13). www.arpnjournals.com

Foon, C. S., May, C. Y., Ngan, M. A., & Hock, C. C. (2004). Kinetics study on transesterification of palm oil. *Journal of Oil Palm Research*, *16*(4), 19–29.

Foong, S. Z. Y., Lam, Y. L., Andiappan, V., Foo, D. C. Y., & Ng, D. K. S. (2018). A Systematic Approach for the Synthesis and Optimization of Palm Oil Milling Processes. *Industrial and Engineering Chemistry Research*, *57*(8), 2945–2955. https://doi.org/10.1021/ACS.IECR.7B04788

Gold, I. L., Ikuenobe, C. E., Asemota, O., & Okiy, D. A. (2012). Palm and Palm Kernel Oil Production and Processing in Nigeria. *Palm Oil: Production, Processing, Characterization, and Uses*, 275–298. https://doi.org/10.1016/B978-0-9818936-9-3.50013-7

Harun, M. Y., Che Yunus, M. A., Morad, N. A., & Ismail, M. H. S. (2015). An industry survey of the screw press system in palm oil mills: Operational data and malfunction issues. *Engineering Failure Analysis*, *54*, 146–149. https://doi.org/10.1016/J.ENGFAILANAL.2015.04.003

Hikmawan, O., & Angelina, R. (2019). Pengaruh Variasi Waktu dan Tekanan terhadap Kehilangan Minyak pada Air Kondensat di Unit Sterilizer Pabrik Kelapa Sawit. *Jurnal Teknik Dan Teknologi*, *14*(28), 33–39.

Hock, T. K., Chala, G. T., & Cheng, H. H. (2020). An innovative hybrid steam-microwave sterilization of palm oil fruits at atmospheric pressure. *Innovative Food Science & Emerging Technologies*, *60*, 102289. https://doi.org/10.1016/J.IFSET.2020.102289

Jusoh, N., Rosly, M. B., Othman, N., Raja Sulaiman, R. N., Mohamed Noah, N. F., & Kamarudin, K. S. N. (2020). Valorization of palm oil mill sterilization condensate via synergistic green reactive extraction of bioactive compounds. *Food and Bioproducts Processing*, *122*, 205–213. https://doi.org/10.1016/J.FBP.2020.05.006

Latif Mubarok, A., Sofwan, A., & Bismantolo, P. (2022). *Analisa performa kerja sterilizer of crude palm oil analysis of the work performance of the sterilizer of crude palm oil* (Vol. 6, Issue 1).

Mba, O. I., Dumont, M. J., & Ngadi, M. (2015). Palm oil: Processing, characterization and utilization in the food industry – A review. *Food Bioscience*, *10*, 26–41. https://doi.org/10.1016/J.FBIO.2015.01.003

Mohd Yusof, M. A. Bin, Chan, Y. J., Chong, C. H., & Chew, C. L. (2023). Effects of operational processes and equipment in palm oil mills on characteristics of raw Palm Oil Mill Effluent (POME): A comparative study of four mills. *Cleaner Waste Systems*, *5*, 100101. https://doi.org/10.1016/J.CLWAS.2023.100101

Muhammad, I. B., Husaini, Nurdin, A., Rauzatul, A., & Teuku, E. P. (2021). Failure analysis of the short drive shaft in a screw press machine. *Key Engineering Materials*, *892 KEM*, 74–80. https://doi.org/10.4028/WWW.SCIENTIFIC.NET/KEM.892.74

Nik Norulaini, N. A., Ahmad, A., Omar, F. M., Banana, A. A. S., Md. Zaidul, I. S., & Ab. Kadir, M. O. (2008). Sterilization and extraction of palm oil from screw pressed palm fruit fiber using supercritical carbon dioxide. *Separation and Purification Technology*, *60*(3), 272–277. https://doi.org/10.1016/J.SEPPUR.2007.08.024

Nugraha, I., Supriyanto, G., & Priyambada. (2023). Pengaruh Lama Waktu Penaikan Setiap Puncak Kehilangan Minyak (Oil Losses) pada Air Rebusan di PKS Adolina Sumatera Utara. *Agroforetech*, *1*(3), 2040–2050.

Omar, A. K. M., Tengku Norsalwani, T. L., Asmah, M. S., Badrulhisham, Z. Y., Easa, A. M., Omar, F. M., Hossain, Md. S., Zuknik, M. H., & Nik Norulaini, N. A. (2018). Implementation of the supercritical carbon dioxide technology in oil palm fresh fruits bunch sterilization: A review. *Journal of CO2 Utilization*, *25*, 205–215. https://doi.org/10.1016/j.jcou.2018.03.021

Pakdeechot, S., Hanifarianty, S., & Wae-hayee, M. (2020). The Effects of Sterilization Time of FFB on Fruit-Bunch Separation and Crude Palm Oil Quality Using Direct Steaming. *Journal of Advanced Research in Applied Mechanics*, *72*(1), 1–9. https://doi.org/10.37934/aram.72.1.19

Parvand, S., & Rasiah, R. (2022). Adoption of advanced technologies in palm oil milling firms in malaysia: The role of technology attributes and environmental and organizational factors. *Sustainability (Switzerland)*, *14*(1). https://doi.org/10.3390/SU14010260

Primandari, S. R. P., Arafat, A., & Veny, H. (2021). Optimization of reducing waste cooking oil's FFA content as biodiesel feedstock. *Teknomekanik*, *4*(1), 14–21. https://doi.org/10.1088/1742-6596/1940/1/012081

Romero-Guzmán, M. J., Jung, L., Kyriakopoulou, K., Boom, R. M., & Nikiforidis, C. V. (2020). Efficient single-step rapeseed oleosome extraction using twin-screw press. *Journal of Food Engineering*, *276*, 109890. https://doi.org/10.1016/J.JFOODENG.2019.109890

Simarani, K., Hassan, M. A., Abd-Aziz, S., Wakisaka, M., & Shirai, Y. (2009). Effect of Palm Oil Mill Sterilization Process on the Physicochemical Characteristics and Enzymatic Hydrolysis of Empty Fruit Bunch. *Asian Journal of Biotechnology*, *1*(2), 57–66. https://doi.org/10.3923/ajbkr.2009.57.66

Tan, C. H., Lee, C. J., Tan, S. N., Poon, D. T. S., Chong, C. Y. E., & Pui, L. P. (2021). Red Palm Oil: A Review on Processing, Health Benefits and Its Application in Food. *Journal of Oleo Science*, *70*(9), ess21108. https://doi.org/10.5650/jos.ess21108

Thang, Y. M., Yunus, R., Mokhtar, M. N., Appleton, D. R., Asis, A. J., Kong, P. S., Teh, H. F., & Ariffin, A. A. (2021). Roles and Principles of Sterilisation Process in Palm Oil Mills. *Pertanika Journal of Science and Technology*, *29*(4). https://doi.org/10.47836/pjst.29.4.26

Vincent, C. J., Shamsudin, R., & Baharuddin, A. S. (2014). Pre-treatment of oil palm fruits: A review. *Journal of Food Engineering*, *143*, 123–131. https://doi.org/10.1016/j.jfoodeng.2014.06.022

Wae-hayee, M., Pakdeechot, S., Hanifarianty, S., & Suksuwan, W. (2022). Minimizing water consumption in oil palm sterilization using direct steaming: Effects of sterilization pressure and time. *Journal of Food Engineering*, *315*, 110804. https://doi.org/10.1016/J.JFOODENG.2021.110804

Yosenov, H., Bachtiar, V. S., & Zulkarnaini, Z. (2023). Analysis of air pollution distribution in West Pasaman Regency effects of palm oil mills. *Jurnal Pendidikan Teknologi Kejuruan*, *6*(2), 120–128. https://doi.org/10.24036/jptk.v6i2.33323

Zamanhuri, N. A., Rahman, N. A., & Bakar, N. F. A. (2022). Extraction of palm fatty acids from sterilized oil palm mesocarp by microwave technique: Optimization and kinetics. *Materials Today: Proceedings*, *63*, S166–S173. https://doi.org/10.1016/J.MATPR.2022.02.127