Analysis of sterilizer oil losses through variations in pressure and boiling time with dominated fresh fruit bunch overripe fraction

Rengga Arnalis Renjani*, Boy Doli Panjaitan, Nabillah Nissya Fadhillah, Harsunu Purwoto

Department of Agricultural Engineering, Stiper Agricultural University (INSTIPER), Yogyakarta, Indonesia.
Email*): rengga_tepins@instiperjogja.ac.id

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Abstract: The problem is that not all FFBs processed daily are more than 90% ripe fruit, causing the yield not to reach the target. This study aims to analyze condensate oil losses from non-standard FFB quality (FFB overripe as much as 25-26%) against time and pressure variations in the sterilizer. The observed indicators include oil losses, moisture content, and non-oil solids (NOS). The study was conducted in 2 stages; the first stage was to test the length of boiling time for each peak stew. The second stage is divided into two pressure variations treatments at each stew's peak. The quantitative presented data is analyzed using simple statistics. All data analyzed statistically is presented in graphical form to visualize the data distribution. In overripe FFB conditions, as much as 25-26% shows that the three best times for peak 1 are 10 minutes with a pressure of 1.0 kg/cm², peak 2 is 15 minutes with a pressure of 1.5 kg/cm², and peak 3 is 65 minutes with pressure 3.1 kg/cm². he best boiling based on the right boiling time to achieve the lowest oil losses is 90–100 minutes in one boiling cycle. If a boiling cycle of 90-100 minutes is carried out, the oil losses achieved are 0.78-0.98%. The longer the boiling process is under FFB overripe, the more oil comes out of the mesocarp and finally comes out mixed with condensate water.

Keywords: crude palm oil; FFB fraction; oil losses; sterilizer; triple peak

INTRODUCTION
Background

Based on Indonesia's statistical data 2020, palm oil production in 2020 was 45.8 million tons (Statistik, 2020). The number of companies processing palm oil in Indonesia is 2,335 companies. The efficiency value of a Palm Oil Mill (POM) is low if the level of oil loss, quality, oil extraction, and production capacity (throughput) does not meet the standards determined by each company (Pahan, 2006).

POM targets to get a yield of 23-24% with the percentage of Fresh Fruit Bunches (FFB) processed every day based on FFB maturity criteria, including > 90% ripe fruit, < 5% underripe, and overripe < 3%. One of the important processes for achieving successful CPO yield is the boiling or sterilization process of FFB (Mahyunis, 2015). This boiling process optimizes the entire series of FFB processing processes, such as threshing, pressing, and clarification (Mba et al., 2015; Wahyudi et al., 2012).

The problem is that not all percentages of FFB processed every day ≥ 90% of ripe fruit, which causes differences in yield (Oil Extraction Rate/OER) that do not reach the company's target. Palm oil companies that have a limited amount of FFB ultimately can opt for different categories as overripe FFB or underripe FFB, or refuse the load of FFB and then return it to its original location. The former choice is to accept all incoming FFB to process at a later time at the palm oil mill even though the method of processing FFB will be different and more specialized than the usual processing of optimal FFB, especially during the boiling process.

The FFB boiling system consists of various technologies: horizontal, vertical, spherical, tilting, and continuous (Thang et al., 2021). During the boiling process using a horizontal sterilizer, condensation occurs which results in the release of oil along with condensate into the fat pit. Based on the problems that have been raised regarding oil loss in condensate wastewater, it is interesting to research so that oil loss can meet the company's standard, which is ≤ 1% O/WM.

Many previous studies have discussed ways to minimize the use of water for boiling (Hadi et al., 2012) using dry heating, ohmic heating (Pootao & Kanjanapongkul, 2016), ultrasound treatment (Khalis et al., 2015), and according to research by (Omar et al., 2017) using supercritical carbon dioxide. However, the alternative boiling that has been developed, when applied on a large scale, has a high specific energy. Therefore, it has yet to be widely applied to POM in Indonesia. Based on research that has developed, until the present there has been no specific research on how to reduce oil losses in horizontal sterilizers at POM through variations in boiling time and pressure, with fruit types that are not as expected (not standard). The objective of this study was to examine the reduction of condensate oil due to differences in time and pressure in the sterilizer, specifically focusing on non-standard FFB quality.

METHODS

Tools and Materials

Equipment used in the study included analytical balances AND GR-200, petri dishes, flasks mats, Memmert UN55 ovens, leads, and desiccators. The materials used in this study were FFB according to grading data, N-Hexan, and sterilizer external condensate water as samples. The object tested was a horizontal *sterilizer* 2.8 m in diameter and 25 m in length.

Research Procedure

The research was conducted at a private POM in Singingi Hilir Regency, Riau Province, and was carried out for 5 (five) months. The first stage of this study is to identify the problems faced by POM and identify the results of FFB grading. FFB that has been graded when entering the lorry with a percentage of unripe, ripe, past ripe, long stalks, and impurities before boiling will be a reference in the boiling process.

The next step is to adjust the pressure and time of decoction in the sterilizer control system. Oil loss sampling occurs at the sample point in Figure 1, where condensate comes out of the sterilizer. *Condensate* is a liquid fluid produced from the steam condensation process when boiling FFB in a sterilizer, which can show oil losses. Samples are taken after 2 hours of POM operating under normal conditions; this is done to ensure that the entire process has run stably and to avoid rested FFB (Palaniandy et al., 2020).

This research was conducted in 2 stages; the first stage was to test the length of boiling time for each peak stew, as presented in Table 1. The second stage is divided into treatments, Treatment A and Treatment B, with pressure variations for each peak stew as presented in Table 2. The boiling system used is a triple peak in the horizontal sterilizer, which is closely related to the temperature of the steam sterilizer in the range of 110-143^{o}C. Samples were taken at condensate discharge water at peaks 1, 2, and 3 (Babatunde et al., 1988; Tang et al., 2017).

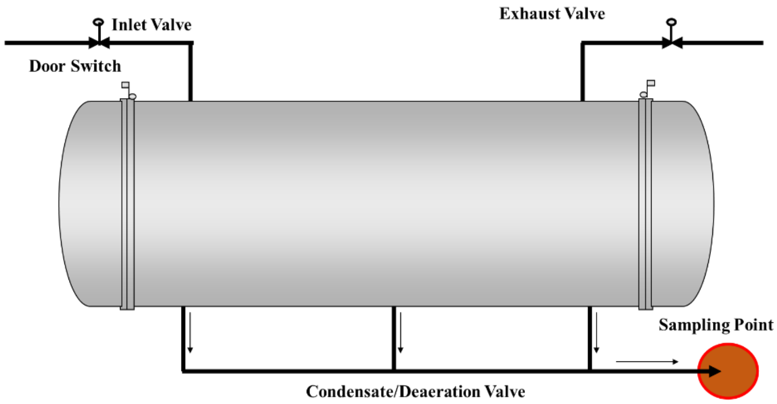

Figure 1. Research sampling point on sterilizer

The time required for P1 and P2 treatment is 90-110 minutes. In treatments A and B, the number of samples observed was 15 per *peak* in one cycle of FFB foaming. The parameters observed in the sterilizer external condensate include oil losses, moisture content, and Non-Oil Solid (NOS) levels. The extraction method is utilized to determine oil losses, the oven method is employed to determine moisture content, and the extraction thimble cellulose method is utilized to determine NOS (Maulidna & Mawarni, 2019; Pootao & Kanjanapongkul, 2016; Renjani et al., 2020; Wulandari et al., 2011).

Table 1. Treatment of boiling time for each *peak*

Length of boiling time (minutes)		
Peak 1	**Peak 2**	**Peak 3**
10 (X1)	15 (Y1)	65 (Z1)
15 (X2)	20 (Y2)	70 (Z2)
-	-	75 (Z3)
-	-	80 (Z4)

Table 2. Pressure treatment applied to for each *peak*

Parameter	Pressure (kg/cm^2)		
	Peak 1	**Peak 2**	**Peak 3**
Treatment A (P1)	1.0	1.5	3.1
Treatment B (P2)	1.5	2.5	3.5

Data Analysis

The data in this study were analyzed quantitatively using basic statistical measures such as the mean and standard deviation. Data that has been examined statistically is displayed in graphical form to represent the data distribution for certain descriptions visually (Renjani et al., 2020).

RESULTS AND DISCUSSION

Results of FFB Grading

Table 3 presents the maturity level of grading FFB on the parameters of unripe fruit, ripe, overripe fruit, and dirt. The FFB grading results show that they need to meet the established standards. Conditions like this are a difficult choice for companies in processing FFB; there is no choice but to continue to be processed but with the consequence of low-quality CPO results. For entrepreneurs in the palm oil industry, low quality cannot be tolerated and must be of the highest quality. Special strategies are needed to process FFB with non-standard quality, especially in boiling (Fadhilah et al., 2024).

Table 3. Results of FFB Grading

Sample	FFB Grading	Standard
Under ripe (%)	1.4 - 3	< 5
Ripe (%)	61- 63	> 90
Overripe (%)	25 - 26	< 3
Dirt Content (%)	1.2 - 3	0

Oil Losses on the Length of Boiling Time at Each Peak

The boiling process at peak 1 is a deaeration process that efficiently eliminates air from the sterilizer. This air removal must happen because air is the most insulator or inhibitor during boiling. The amount of oil loss mixed with condensate will differ for each boiling time length. Figure 2 presents the results of oil losses at 10 minutes (X1) and 15 minutes (X2). Oil losses X1 at peak 1 are smaller than X2. The oil loss produced by X1 and X2 is still above the standard (1%). The high oil losses above the standard are caused by the condition of overripe FFB, which is processed and reaches 26%. Overripe FFB processed at POM is very high compared to the standard of <3%. When 26% of the FFB is overripe, excessive oil from the mesocarp is released into the condensate during boiling (Thang et al., (2021).

The boiling process at peak 2 was dehydration, which removes water from the condensation process in the sterilizer. Condensate water removal is carried out to maximize the boiling process. Oil losses at peak two result in Y1 being smaller than Y2. Factors that cause oil to be included in condensate are the quality of the processed fruit dominated by mature fruit (Table 1) and condensate that has not fully come out at peak one mix with peak 2, causing oil loss to increase. Based on our analysis, it is evident that selecting boiling time Y1 is the most optimal decision to reduce oil loss at peak 2. A high percentage of oil loss in the condensate is attributed to an extended boiling time, as stated by Tang et al., (2017).

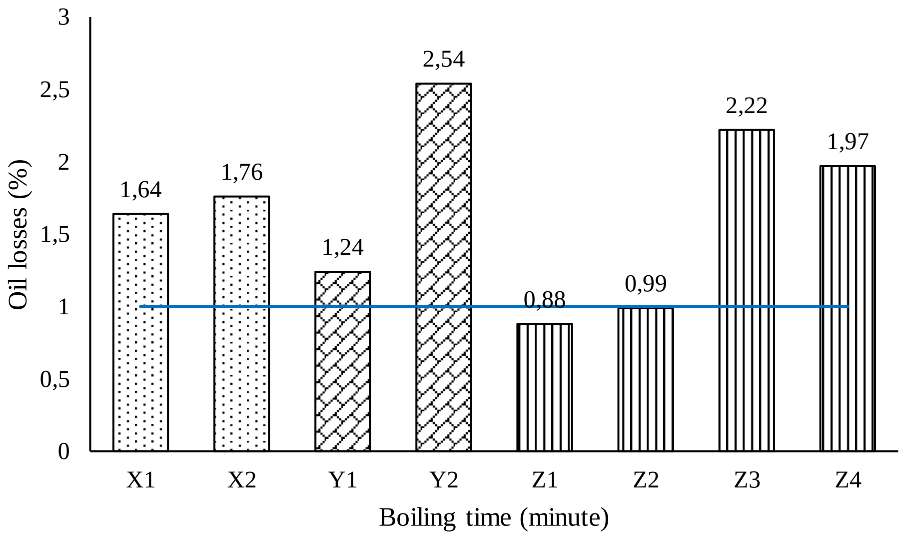

Figure 2. Oil losses on the length of boiling time at each peak

Figure 2 shows that the longer the boiling time at peak 3, the higher the potential oil losses associated with condensate. Boiling time Z1 and Z2 are maximal enough to minimize oil losses in the sterilizer. It should be noted that the condition of this study is overripe FFB, which is as much as 25-26%. Boiling with a triple peak system aims to inactivate the lipase enzyme and also to soften FFB to the inside of the fruit so that there is no loose fruit attached to the spikelet or unstripped bunches (USB) (Anyaoha et al., 2018). The boiling process at peak 3 is the core process of the boiling stage, namely the penetrating ripening to the inside of the fruit. The proper boiling process also impacts the softening of the endocarp, making it easier for the nut to crack (Koya & Faborode, 2005). Figure 3 depicts the FFB structure that necessitates the softening process.

Boiling times Z1 and Z2 causes the oil contained in the mesocarp not to come out completely, causing a low percentage of oil loss in the condensate. Conversely, Z3 and Z4 cause the oil in the mesocarp to come out in greater quantities and result in a high percentage of oil loss in condensate water discharge. The research results show that the three best times for peak 1 are 10 minutes, peak 2 is 15 minutes, and peak 3 is 65 minutes.

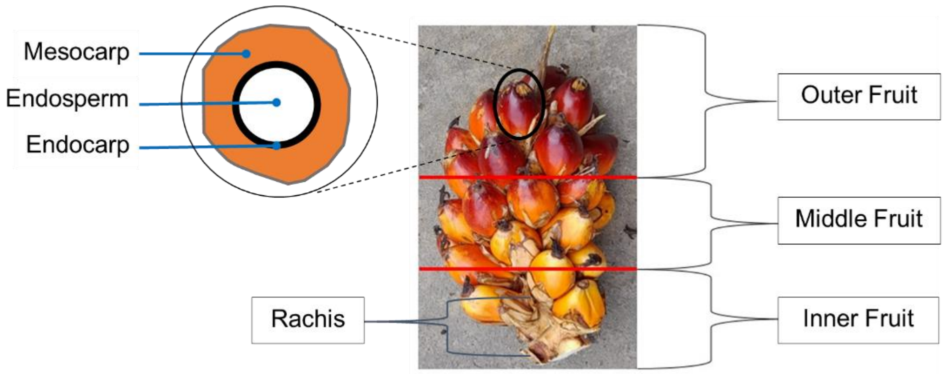

Figure 3. The FFB structure must be boiled or softened

Oil Losses Against the Length of Boiling Time in One Cycle of Boiling

Figure 4 presents data on the optimal total time to reduce oil losses in 1 boiling cycle is 95 minutes. This study's results align with the opinion Thang et al., (2021) that the boiling process causes negative impacts for too long, including increased oil losses on condensate, oil becoming burnt, reduced oil quality, and the potential for emulsion formation.

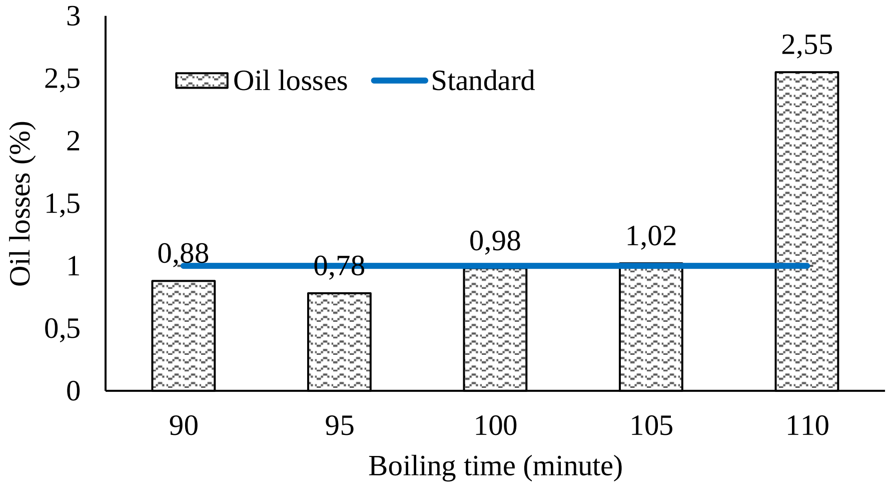

Figure 4. Oil losses against boiling time in one boiling cycle

The amount of oil lost mixed with condensate will be different at each boiling time. The oil loss at the boiling time of 110 minutes is huge compared to other boiling times. This is due to the boiling process that is too long. The longer the boiling process, the more oil comes out of the loose fruit skin (mesocarp) and mixes with the cooking water, which eventually comes out together with condensate water; this is in line according to Tang et al., (2017) if the boiling time is too long it will make the fruit soft and will become overripe so that a lot of oil will come out of the fruit and be followed by condensate which causes a large oil loss. Based on the utilized boiling time, the optimal boiling time is between 90 and 100 minutes, with a third peak pressure of 3.1 kg/cm². This boiling time has enabled optimal oil losses corporate requirements and CPO production fulfillment (Hafiz et al., 2016).

The Relationship Between Oil Loss and Changes in Pressure

The result of Figure 5 is that P1 is better than P2 because the pressure change at P2 is higher than P1, which results in large oil losses. However, too low pressure causes a decrease in the quality of the oil produced. Too low pressure is caused by steam not penetrating the fruit and kernel, so the fruit is difficult to escape from the rachis, while high pressure will cause high oil loss in the condensate.

According to Hikmawan, O., (2019) the effect of pressure on oil loss is that the higher the boiling pressure, the higher the oil discharged. This phenomenon occurs because the pressure of steam in the sterilization container presses FFB and breaks down palm fruit particles so that oil is easier to escape from the mesocarp (Anyaoha et al., 2018). However, for overripe FFB, when given high steam pressure, it causes the mesocarp to release oil and be carried away by water which is the result of the condensation process.

The boiling temperature process of the sterilization station affects the final output of CPO production. If the temperature is higher, the cooking process will be faster, producing more oil, which also has a high moisture content. The optimal pressure at P1 each peak is peak 1 with a pressure of 1.0 kg/cm², peak 2 with a pressure of 1.5 kg/cm² and peak 3 with a pressure of 3.1 kg/cm².

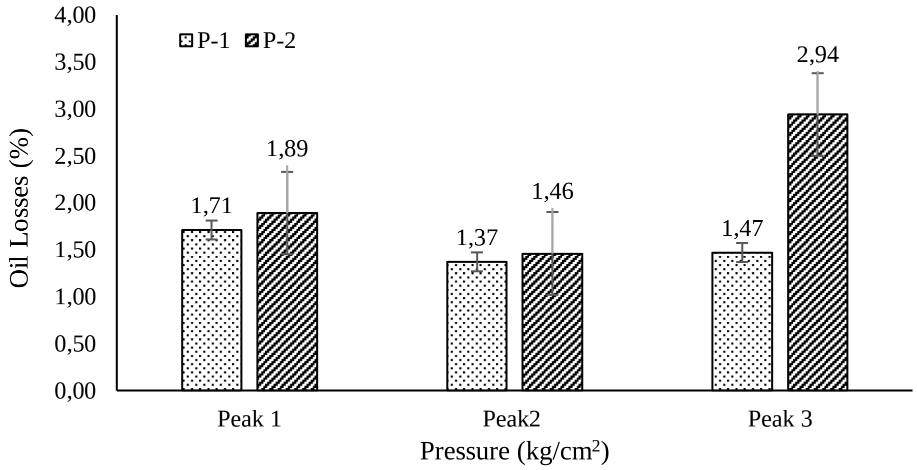

Figure 5. Oil losses at every pressure change

Moisture Content in Relation to Pressure Changes

Figure 6 presents the results of observations of moisture content of condensate that has met company standards. The highest moisture content is found at the second peak (dehydration) with an average of 94.52%, this is because the steam at peak pressure 1 is not all wasted, most of it is still left in the *sterilizer* and the whole is wasted at the second peak (Anyaoha et al., 2018). The results showed that the moisture content produced was still below the established standard of < 95%. Based on research that has been done shows that the amount of pressure on the sterilizer, resulting in small moisture content and inversely proportional to oil losses.

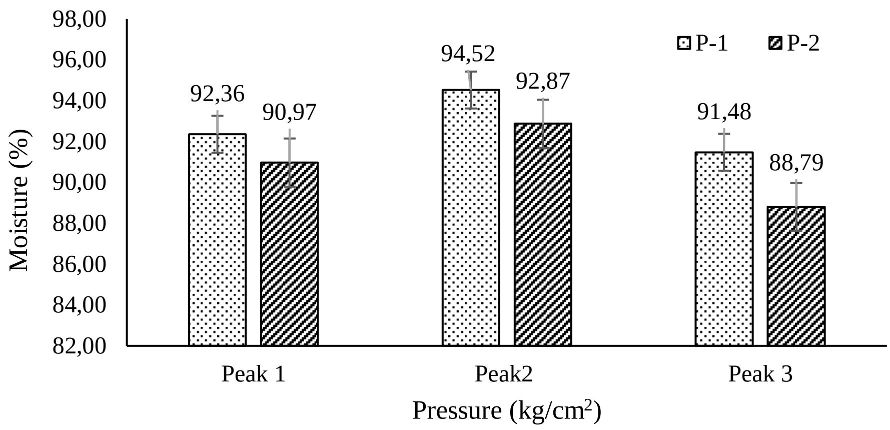

Figure 6. The moisture content at each change in pressure

NOS Content Against Pressure Changes

Figure 7 presents the results of observations of NOS content from condensate that has met company standards. The highest level is found at the third peak with an average of 7.05%; this is because most of the dirt has been wasted at the disposal at the first peak. At the second peak, ripening with higher pressure, the remnants of disposal on the first and second peaks and dirt still left on the fruit will be removed at the third peak.

The dirt can rise as the shelf life lengthens (Basyuni et al., 2017). Increasing the amount of dirt on FFB will result in a greater NOS content. The standard parameter of NOS content is <8%. The duration of boiling time does not impact the levels of NOS. Instead, the quantity of contaminants from FFB that enter POM influences the levels of NOS (Juliano et al., 2012).

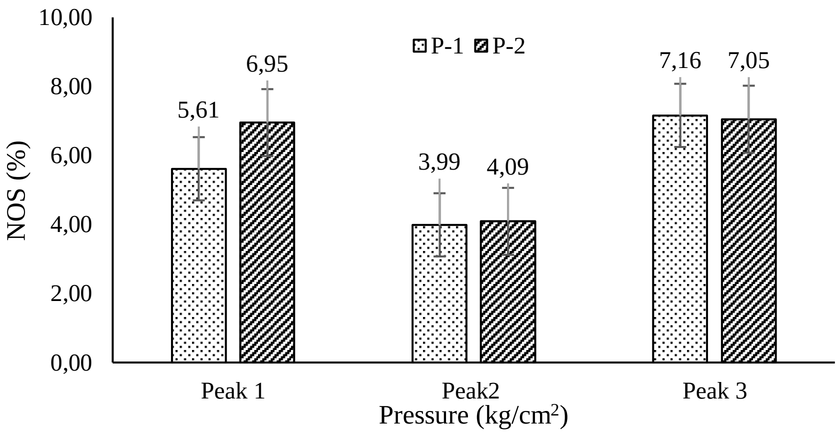

Figure 7. NOS content at each pressure variation

CONCLUSION

Based on the results of research that has been conducted on overripe FFB conditions, as much as 25-26% shows that the three best times for peak 1 are 10 minutes at pressure 1.0 kg/cm^2, peak 2 is 15 minutes with pressure 1.5 kg/cm^2, and peak 3 is 65 minutes with pressure 3.1 kg/cm^2. The optimal boiling duration for minimizing oil losses is between 90 and 100 minutes during a single boiling cycle. A boiling cycle lasting between 90-100 minutes results in oil losses ranging from 0.88 to 0.98 %. A boiling procedure lasting over 100 minutes has a significant effect on the extraction of oil from the overripe FFB. The longer the boiling process, the greater the amount of oil released from the mesocarp, and finally comes out mixed with condensate water.

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CONFLICT OF INTEREST

At this moment, declare that I have no conflicts of interest related to the manuscript titled "The Analysis of Sterilizer Oil Losses Through Variations in Pressure and Boiling Time is Dominated by Fresh Fruit Bunch Overripe Fraction" submitted for publication in Jurnal Ilmiah Rekayasa Pertanian dan Biosistem. The study is unaffected by any financial, personal, or professional affiliations. The research is conducted objectively to develop process technology at POM and any potential conflicts of interest.

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