



Evaluating Fiber Losses with NIRS DA1650 and Determination Coefficient

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A B S T R A C T

This study focuses on enhancing the yield of crude palm oil (CPO) during the pressing process by thoroughly examining the oil losses that occur throughout production. The primary aim is to evaluate how different pressures and electric currents impact oil losses from palm fiber at a specific palm oil mill in Pantai Cermin, Kec. Tapung, Kampar, Riau. A systematic methodology was employed to achieve this, which involved detailed measurements conducted using the FOSS NIRS DA1650. This advanced technology allowed for precise assessment and quantification of oil losses during the pressing phase. Following the data collection, a rigorous statistical analysis was performed utilizing determination coefficients to interpret the relationship between the variables. The analysis results revealed a coefficient of determination (R^2) of 49.96% concerning pressure, suggesting that nearly half of the variability in oil losses can be explained by fluctuations in pressing pressure. Additionally, the examination of current showed a higher coefficient of determination of 60.09%, underscoring a substantial influence of electric current on fiber oil losses. These findings highlight the critical importance of optimizing pressure and current in palm oil extraction. By making informed adjustments to these parameters, mill operators can significantly reduce oil losses, thus enhancing the overall extraction efficiency. The study provides practical recommendations for operators aiming to improve their processes, ultimately contributing to better resource utilization and increased profitability in the palm oil industry.

INTRODUCTION

Palm oil produces Fresh Fruit Bunches (FFB), which are the primary raw material in the production of crude palm oil (CPO) and its derivatives [1]. FFB is highly susceptible to post-harvest damage, so it must be processed within 48 hours after harvesting to avoid losing valuable oil content [2]. The high productivity of palm oil has made it a highly competitive raw material for various industries, including food, cosmetics, health products, biofuel, and biodiesel [3]. Crude palm oil (CPO) is a vegetable oil extracted from the flesh and fiber of palm fruit (mesocarp), which contains a substantial amount of oil [4]. Palm oil mills continuously strive to optimize CPO yields [5].

One of the main challenges is reducing oil losses during production [6]. High levels of oil losses affect processing efficiency and can lead to losses, especially when equipment does not have optimal design capabilities and capacities [7]. Oil losses in palm oil production are expected if within standard limits [8]. Residual oil on fiber from production can adversely affect productivity. In press machines processing fiber, attention is typically given to optimal levels that are neither wet nor dry. If the fiber is too moist, there is a high risk of oil losses, while if it is too dry, the likelihood of broken nuts increases. The standard for oil losses in fiber at the screw press unit is approximately < 4% [9]. The screw press machine is designed to optimally extract

crude oil from the mesocarp, minimizing nut breakage. This machine consists of a perforated

cylinder equipped with two counter-rotating screws that push the bunches towards the cone. The pressure is controlled through two cones at the pressing end, which can move forward and backward hydraulically, creating high pressure during extraction. The hydraulic pressure at the screw press unit is adjusted to optimize fiber oil losses and nut breakage. The standard pressure of this machine ranges from 40-50 bar [10].

Previous studies, such as those at PT. Perkebunan Nusantara IV at the Adolina unit showed that oil losses in fiber, considering variations in pressure and the age of the screw press, indicated that the age of the screw press correlated with increased oil losses [11]. Another study at PT. AMP Plantation Unit POM recorded the highest oil loss percentage at 38.01% for fiber from press cake, while the shell of the nut from press cake had 2.84% [9]. Further research on the impact of screw press pressure in pressing fruit into Crude Palm Oil reached 18.32 bar, with hydraulic pressure ranging from 50-60 bar [12]. Additionally, an analysis at the Digesting and Pressing Station found that the optimal pressure to achieve the 17% broken nuts standard was 44.03 bar [13]. Another study indicated a coefficient of determination of 93.39% at 50 bar pressure, showing that higher pressing pressures increase oil losses [14]. At PT. Palma Utama, regression analysis revealed that pressure influenced oil losses by 83%, with

the highest losses of 4.48% occurring in February [15]. At PT. XYZ, the optimal screw press pressure was found to be 70 bar with a current of 43-46 amperes, resulting in fiber oil losses of 9.34% and broken nuts of 10.86% [16]. The use of the Foss NIRS DA 1650 in previous research for measuring oil losses in press cake showed results very similar to the Soxhlet method, with measurements of 0.50% and 0.49%, respectively, both below the company's standard oil loss (0.62%). This demonstrates that NIRS is more efficient, safe, and non-destructive than Soxhlet [17]. Another study on variations in agitator blades in continuous sedimentation tanks to reduce oil losses showed that using six blades resulted in the lowest oil content percentage of 7.652%, meeting the desired standard [18]. Research at PTPN IV Kebun Adolina found that oil losses in wastewater often exceeded the factory standard of 0.60%, primarily due to the high operational hours of the sludge separator [19]. These results emphasize the benefits and accuracy of the FOSS NIRS DA 1650 in measuring oil losses under various operational conditions [20].

This research investigates the combined influence of pressure and current strength in the screw press machine on oil losses in palm oil fiber as a key area in optimizing oil extraction efficiency. While previous studies have largely focused on pressure, this study includes current strength as an additional operational factor. Leveraging the precision and efficiency of the FOSS NIRS DA 1650, which is well regarded for accurate oil loss measurements, this study is conducted in a palm oil plantation in Pantai Cermin, Kampar Regency, Riau Province. By calculating the coefficient of determination for pressure and current strength, the research aims to quantify each factor's contribution to oil loss reduction, offering valuable insights for operational improvements in palm oil processing.

METHODS

Research Stages

In this stage, a flowchart methodology is conducted to understand methodology related to research on oil losses, screw press pressure, and current strength. Relevant literature will be gathered from journals, books, and publications to underpin the theory and analysis of this research [1]-[20]. Figure 1 shows, study will be conducted at one of the palm oil plantations in Riau Province, located in Pantai Cermin, Kec. Tapung, Kampar Regency, Riau.



Figure 1. Palm Oil Plantations Case Study

The methodology begins with a literature review to establish a foundation for the study. Data collection follows, where fiber samples are taken from the presscone outlet of a screw press

machine, and hydraulic pressure and current strength are recorded simultaneously. The data processing involves analyzing the fiber samples using the Foss NIRS DA1650 to measure oil loss. In the data analysis phase, the oil loss data is integrated with pressure and current strength measurements, applying Pearson's correlation to determine relationships and evaluating their impact through the coefficient of determination. The study concludes with results and discussion, interpreting the findings and their implications. Figure 1 shows, overview of flowchart methodology.

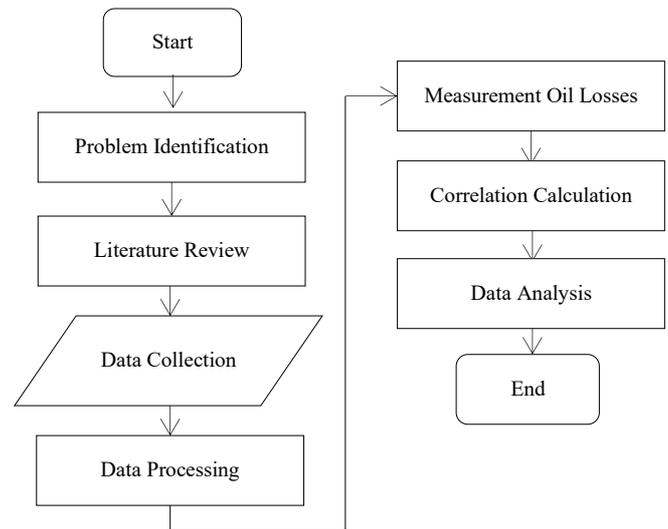


Figure 2. Overview of Flowchart Methodology

Data Collection

The data collection process involves gathering three key types of data. First, fiber samples from the screw press unit will be collected at the presscone outlet. Concurrently, hydraulic pressure will be measured following established procedures. Additionally, current strength will be recorded simultaneously with fiber sampling to explore the relationship between current and oil losses. Figure 3, Figure 4 and Figure 5 shows three locations for varying the variables.



Figure 3. Fiber Sampling from the Screw Press Machine



Figure 4. Hydraulic Pressure Location



Figure 5. Current Strength at Press Panel

Data Processing

The data collection process involves gathering three critical types of data. First, fiber samples from the screw press unit will be collected at the press cone outlet. Concurrently, hydraulic pressure will be measured following established procedures. Additionally, current strength will be recorded simultaneously with fiber sampling to explore the relationship between current and oil losses. The collected data will undergo two main stages of processing. Then, fiber samples will be analyzed using the Foss NIRS DA1650. Foss NIRS DA1650 is a laboratory instrument designed for quick and accurate analysis in industrial settings, particularly for measuring oil losses in production by-products. Using Near-Infrared Reflectance Spectroscopy (NIRS), it provides chemical composition data without complex sample preparation.

The process begins by preparing a 30-gram sample, carefully ensuring that it is homogeneous to maintain consistency in the analysis. This sample is then placed into a large cup, spread evenly, and compacted to the point where no light can penetrate the bottom. Next, the instrument is opened, and the large cup is properly inserted before the instrument is closed securely. The appropriate product type, specifically press cake fiber, is selected on the instrument to tailor the analysis to the sample. Once the process is initiated, the oil loss in the fiber is measured, which typically takes about 2 minutes to complete. Then, after obtaining the oil loss measurements, the next step is to analyze the impact of oil losses on pressure and current strength data. This involves understanding the relationships between these variables and their influence on oil losses.

Data Analysis

The data analysis phase combines the results of fiber oil loss measurements with the analysis of pressure and current strength impacts. First, the oil loss data should be integrated with pressure

and current strength measurements, and second, Pearson's product-moment correlation should be applied to determine the relationship between these variables and oil losses. The Pearson product-moment correlation analysis falls into the category of parametric statistical techniques, which use data with interval and ratio scales. For example, the data must be randomly selected, the distribution should be normal, the relationship between the data must be linear, and the paired data should correspond to the same subjects. If all these conditions are satisfied, Pearson product-moment correlation can be applied. However, the analysis cannot be conducted if any of these conditions are not met. The formula for Pearson product-moment correlation is described as equation (1) [21].

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}} \quad (1)$$

The interpretation of the correlation coefficient r is consulted if $0.90 < r < 1.00$ or $-1.00 < r < -0.90$ it indicates a very strong relationship. Then, if $0.70 < r < 0.90$ or $-0.90 < r < -0.70$ it indicates a strong relationship. Next, if $0.50 < r < 0.70$ or $-0.70 < r < -0.50$ it indicates a moderate relationship. If $0.30 < r < 0.50$ or $-0.50 < r < -0.30$ it indicates a weak relationship. Last, if $0.00 < r < 0.30$ or $-0.30 < r < 0.00$ it indicates a very weak relationship. Third, to determine the extent of the impact of variable X on variable Y, the coefficient of determination is used with the following equation (2) [21].

$$\text{coefficient of determination} = r^2 \times 100\% \quad (2)$$

The coefficient of determination (R), tested using Pearson's product-moment correlation, means how variable X contributes to the variation in variable Y. In other words, this coefficient provides information on the extent to which variable Y is influenced by the tested variable X. In simpler terms, the coefficient of determination can be interpreted as the extent to which all independent variables (X) explain the variation in the dependent variable (Y) [22].

RESULTS AND DISCUSSION

Measurement of Oil Losses in Fiber with Foss NIRS DA1650

The measurement involved collecting fiber from the presscone outlet of the screw press unit just before the cake breaker conveyor (CBC). Sampling was carefully conducted at various positions, which are left, right, top, and bottom, following the standard sampling procedure for the screw press unit, and measurements were taken using the Foss NIRS DA1650. Sampling was conducted at 10:00 AM and 12:00 PM on January 20, 22, 24, 26, and 29, 2024.

The fiber sample measurement conducted on January 20 at 10:00 AM began with the collection of fiber samples from the screw press unit under established standards. Sampling positions were systematically selected from the left, right, top, and bottom of the screw press. This method was employed to account for potential variations in oil content across different unit sections, thereby providing a thorough and accurate evaluation of the overall

losses. Figure 6 shows the fiber samples collected by the variations section.



Figure 6. Collecting Fiber Samples from Left, Right, Top, and Bottom Press

Then, a fiber sample weighing 30 grams was prepared to ensure homogeneity, essential for achieving consistent and reliable results. The sample's homogeneity minimizes variability and accurately represents fiber losses. Figure 7 illustrates the process of weighing the fiber sample to the required 30 grams for analysis.



Figure 7. Weighing the Fiber Sample to 30 grams

Next, the fiber sample was placed into a large cup and leveled to ensure no light gaps were visible through the bottom. This step was essential to prevent interference during measurement and ensure the analysis's accuracy. Figure 8 shows the fiber sample placed into the large cup, with proper leveling, to achieve uniformity for precise analysis.



Figure 8. Placing the fiber Sample into the Large Cup

After that, the instrument cover of the Foss NIRS DA1650 was opened, and the large cup containing the fiber sample was carefully inserted into the instrument. The cover was then closed to maintain optimal conditions for the analysis. Figure 9 depicts the insertion of the large cup containing the fiber sample into the Foss NIRS DA1650 instrument, showing that the sample was securely positioned for analysis.



Figure 9. Inserting the Large Cup with the Fiber Sample into the Foss NIRS DA1650 Instrument

Last, the analysis was initiated by selecting the “Press Cake” option menu number 5 on the instrument. The process button was pressed, and the analysis was completed in approximately two minutes. This step provided rapid and accurate results of the fiber sample’s oil losses. Figure 10 displays the output of the Foss NIRS DA1650 instrument.



Figure 10. The result of Foss NIRS DA1650 Instrument

Following the measurement of oil losses, the accumulated oil losses for the dates January 20, January 22, January 24, January 26, and January 29, 2024 shown in Table 1.

Table 1. Oil Losses (%) Measured at Different Times

Date	Time	Oil Losses (%)
January 20, 2024	10:00	5.83
	12:00	4.28
January 22, 2024	10:00	3.91
	12:00	4.27
January 24, 2024	10:00	4.13
	12:00	3.91
January 26, 2024	10:00	4.07
	12:00	3.80
January 29, 2024	10:00	4.13
	12:00	3.88

Data Collection of Pressure and Current

After obtaining fiber oil losses from measurements using the Foss NIRS DA1650, the next step is to collect pressure and current strength data from the hydraulic press and power box of press number 5. Figure 11 and Figure 12 show the pressure and current strength data on January 20, 2024, at 10:00 AM.



Figure 11. Pressure data from hydraulic press number 5



Figure 12. Current strength data from Panel

The accumulated data for pressure and current strength on January 20, 22, 24, 26, and 29, 2024, shows in Table 2.

Table 2. Accumulated Data of Pressure and Current

Date	Time	Pressure (Bar)	Current (A)
January 20, 2024	10:00	45	25
	12:00	46	34
January 22, 2024	10:00	55	30
	12:00	54	35
January 24, 2024	10:00	53	35
	12:00	49	32
January 26, 2024	10:00	54	35
	12:00	53	36
January 29, 2024	10:00	53	34
	12:00	55	39

Correlation of Pressure and Fiber Oil Losses

The Pearson Product Moment Correlation Coefficient is utilized to quantify this relationship, shown in Table 3.

Table 3. Pearson Correlation for Pressure and Oil Losses

Pressure (X)	Losses (Y)	Coefficient t (X ²)	Coefficient t (Y ²)	Coefficient t (XY)
45	5.83	2025	33.9889	262.35
46	4.28	2116	18.3184	196.88
54	3.91	2916	15.2881	211.14
55	4.27	3025	18.2329	234.85
54	4.13	2916	17.0569	223.02
53	3.91	2809	15.2881	207.23
49	4.07	2401	16.5649	199.43
53	3.80	2809	14.44	201.40
53	4.13	2809	17.0569	218.89
55	3.80	3025	14.44	209.00
517	42.13	26851	180.6751	2164.19

Based on equations (1) and (2), the values of r and the coefficient of determination are obtained as shown in Table 4.

Table 4. The value of r and Coefficient of Determination

Parameters	The Value
r	-0.70683
Coefficient of Determination	49.96%

The Influence of Correlation Between Pressure and Fiber Oil Losses

Based on Table 4, the effect of pressure on oil losses in fiber is observed through the Pearson product-moment correlation coefficient (r), which is calculated at -0.70683. This coefficient, falling within the range of -0.90 to -0.70, indicates a strong negative relationship between pressure and oil losses, meaning that as pressure increases, oil losses decrease. The coefficient of determination, 49.96%, shows that nearly half of the variation in oil losses can be explained by pressure changes, while other external factors likely influence the remaining 50.04%.

In Figure 13 below, this trend is illustrated by the decrease in oil losses as pressure rises. For instance, at a minimum pressure of 45 bar, oil losses in fiber reach 5.83%, whereas at a maximum pressure of 55 bar, oil losses reduce significantly to 3.8%. Interviews with operators further reveal that external factors influence oil loss outcomes, including processes at the sterilizer and boiling stations, as well as variability from human factors. These elements contribute to fluctuations in oil loss data, underscoring that while pressure is a significant factor, other operational and environmental aspects also play important roles.

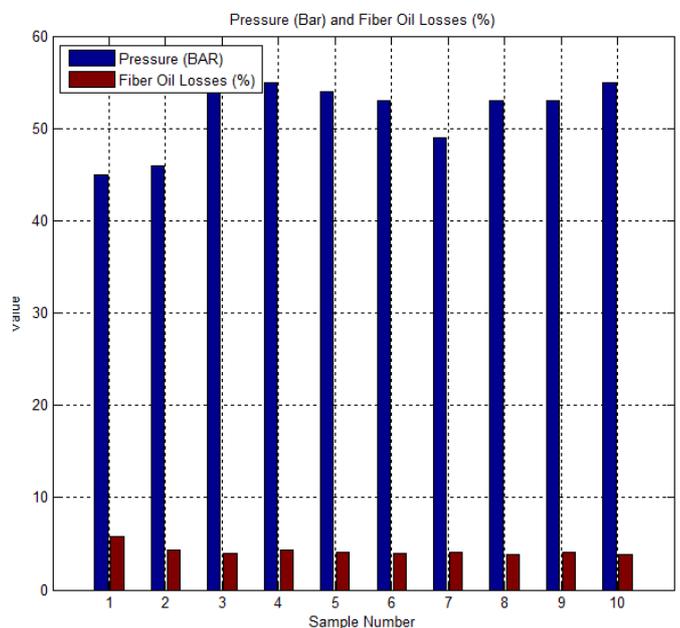


Figure 13. The Effect of Pressure on Fiber Oil Losses

Correlation of Current and Fiber Oil Losses

Table 5, presents the data collected for current strength and the corresponding fiber oil losses.

Table 5. Pearson Correlation Coefficient for Pressure and Losses

Current (X)	Losses (Y)	Coeffice nt (X ²)	Coeffice nt (Y ²)	Coefficient (XY)
25	5.83	625	33.9889	145.75
34	4.28	1156	18.3184	145.52
30	3.91	900	15.2881	117.30
35	4.27	1225	18.2329	149.45
35	4.13	1225	17.0569	144.55
32	3.91	1024	15.2881	125.12
35	4.07	1225	16.5649	142.45
36	3.80	1296	14.44	136.80
34	4.13	1156	17.0569	140.42
39	3.80	1521	14.44	148.20
335	42.13	11353	180.6751	1395.56

Based on equations (1) and (2), the values of *r* and the coefficient of determination are obtained as shown in Table 6.

Table 6. The value of *r* and Coefficient of Determination

Parameters	The Value
<i>r</i>	-0.77518
Coefficient of Determination	60.090%

The Influence of Correlation Between Current and Fiber Oil Losses

Based on Table 6, the Pearson product-moment correlation coefficient (*r*) is -0.77518. An *r*-value within the range of -0.90 to -0.70 indicates a strong negative correlation, meaning that as the current strength increases, the oil losses within the fiber decrease. This finding shows that current strength is a key factor influencing oil extraction efficiency, specifically in minimizing oil losses in the press cake fiber. Furthermore, the coefficient of determination was found to be 60.09%. This value indicates that approximately 60.09% of the variance in oil losses can be directly attributed to changes in current strength. In other words, more than half of the reduction in oil losses can be explained by variations in the current strength applied during the operation of the screw press machine. However, it also implies that the remaining 39.91% of the oil losses are influenced by other factors not covered in this study.

The relationship between current and oil losses is visually represented in Figure 14. The figure illustrates a clear inverse trend, where oil losses decrease progressively as the current strength increases. At the lower end of the current spectrum, with a minimum of 25 amperes, oil losses are observed to reach a peak of 5.83%, indicating a relatively inefficient extraction process at lower mechanical power. In contrast, at the upper limit of the current range, where the maximum current is recorded at 39 amperes, oil losses drop significantly to 3.8%. This marked reduction demonstrates the enhanced efficiency of the oil extraction process achieved with higher current, which corresponds to increased mechanical power applied by the screw press. The findings align with theoretical principles and show that higher mechanical power improves the press's ability to separate oil from the fiber, reducing the oil retained within the press cake. This trend underscores the important role of optimizing current strength in minimizing oil losses, thereby enhancing the overall efficiency of the oil extraction process in palm oil milling operations

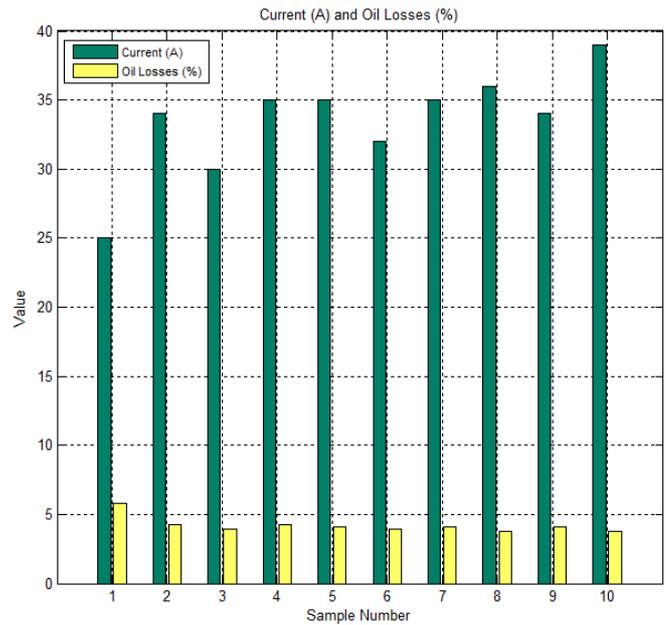


Figure 14. The Effect of Current on Fiber Oil Losses

Comparative Analysis of the Relationship Between Pressure and Current on Oil Losses

The study by [13] highlighted that the required electrical current increases as the pressure increases, showing that a higher current is associated with reduced oil losses. Higher pressure improves oil extraction efficiency by minimizing oil retention in the press cake. Research by [14] suggests that each incremental increase in press machine pressure reduces oil losses by approximately 0.0757%, with a determination coefficient (*R*²) of 46.81%. Similarly, the study by [15] observed that both press and pressure significantly influence oil losses, with a coefficient of determination of 70.4% for the effect of pressure on oil loss percentage. This finding underscores the strong correlation between pressure and oil recovery efficiency, showing that higher pressure reduces oil retention in the fiber. In addition, the study by [23] mentions that a hydraulic pressure of 18.2 bar, which represents a low pressure, causes wear on the screw press, leading to inefficient pressing where some fiber does not undergo proper compression. As a result, this condition leaves a higher amount of palm oil in the press cake. Furthermore, research by [24] reports a correlation coefficient of 0.923, which is very close to 1, indicating a very strong relationship between the pressure applied by the screw press and the reduction in oil losses in the press cake.

Then, the relationship between electric current and oil losses has not been explicitly detailed in previous studies. However, some research has linked electric current to oil losses. For instance, [9] indicates that at 25 amperes, the screw press is unable to properly process fiber due to high losses, meaning that low current results in high losses due to slower rotation. Research by [12] shows that pressure is proportional to electric current, where higher pressure results in lower losses, and similarly, higher current strength leads to reduced losses. Furthermore, [25] recommends a current strength range of 35-40 amperes, which is considered optimal, as too low current results in higher losses. Although higher electric

current shows lower losses, it is advised not to exceed optimal levels, as excessively high current can shorten the lifespan of the equipment and lead to other damages, such as increased wear on the nut, further contributing to operational inefficiencies.

CONCLUSIONS

The experimental results show that increasing both pressure and current strength in the screw press operation significantly reduces oil losses in the fiber. Pressure affects approximately 49.96% of the oil loss variation, while current strength accounts for around 60.09%. These findings confirm that optimizing these parameters can effectively minimize oil losses, providing a practical recommendation for operators to enhance extraction efficiency in the pressing process.

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