



# Effect of Increasing the Number and Changing the Diameter of Nozzle Holes on the Reduction of Moisture Content in CPO Ex Vacuum Dryer at PT Inti Indosawit Subur PMKS Buatan Dua

Mhd Fauzan Affandi\*, Tengku Rachmi Hidayani, Taranipa Marfitania, and Muhammad Afif

Oil Palm Agribusiness Study Program, Politeknik Teknologi Kimia Industri Medan, Medan, 20136, Indonesia

\*Corresponding Author: [fauzanaffandi18@gmail.com](mailto:fauzanaffandi18@gmail.com)

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## ABSTRACT

The moisture content of Crude Palm Oil (CPO) at PT Inti Indosawit Subur, PMKS Buatan Dua, during August and September 2025 averaged 0.29%, exceeding the company's internal standard of below 0.25%. One of the efforts made to reduce the moisture content was modifying the vacuum dryer nozzle, which was found to be suboptimal, by increasing the number of nozzle holes from 9 to 10 and reducing the hole diameter from 7 mm to 6 mm. The data used consisted of 56 secondary data samples before modification (August-October 2025) and 56 samples after modification (October-December 2025), analyzed using descriptive statistics, a normality test, and a paired sample T-test. The results showed that the average moisture content decreased from 0.290% to 0.221% after the modification, a reduction of about 23.6%. The paired sample T-test produced a significance value (2-tailed) of  $< 0.05$ , so  $H_0$  was rejected, indicating that the increase in the number of nozzle holes and the reduction of their diameter had a statistically significant effect in reducing the moisture content of ex-vacuum dryer CPO at PT Inti Indosawit Subur PMKS Buatan Dua.

**Keywords:** Moisture Content of CPO, Vacuum Dryer, Nozzle, Paired Sample T-Test, Modification

## ABSTRACT

The moisture content of Crude Palm Oil (CPO) at PT Inti Indosawit Subur PMKS Buatan Dua during August and September 2025 averaged 0.29%, exceeding the company's internal standard of  $< 0.25\%$ . One effort to reduce moisture content was to modify the suboptimal vacuum dryer nozzle by increasing the number of nozzle holes from 9 to 10 and reducing the hole diameter from 7 mm to 6 mm. The data consisted of 56 secondary-data samples before modification (August–October 2025) and 56 samples after modification (October–December 2025), analyzed using descriptive statistics, a normality test, and a Paired Samples T-Test. The results showed that the average moisture content decreased from 0.290% to 0.221% after modification, corresponding to a reduction of approximately 23.6%. The Paired Samples T-Test produced a significance value (2-tailed) of  $< 0.05$ , so  $H_0$  was rejected, indicating that increasing the number of nozzle holes and changing their diameter had a significant effect on reducing the moisture content of CPO ex vacuum dryer at PT Inti Indosawit Subur PMKS Buatan Dua.

**Kata Kunci:** Kadar Air CPO, Vacuum Dryer, Nozzle, Paired Sample T-Test, Modifikasi

## 1. Introduction

Oil palm is one of the most important plantation commodities in Indonesia because its main products, namely crude palm oil (CPO) and palm kernel oil (PKO), have high economic value and are among the country's major sources of foreign exchange [1]. The processing of fresh fruit bunches (FFB) into CPO involves sterilization to stop lipase enzyme activity, threshing, digesting, and pressing. The crude oil produced from pressing still contains a considerable amount of water and impurities; therefore, it must pass through the clarification station before storage.



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One of the final stages that determines CPO quality is the drying process using a vacuum dryer unit. This unit works by spraying oil through a nozzle into a vacuum chamber so that the water contained in the oil evaporates and is drawn out by the vacuum pump, while the dried oil falls to the bottom of the vessel and is pumped to the storage tank (Figure 1 and Figure 2). The finer the spray droplets produced by the nozzle and the higher the drying temperature, the greater and faster the evaporation of water, resulting in lower CPO moisture content [2]. Conversely, if the spray droplets are still too large, the water in the oil may not evaporate optimally. This condition is generally caused by a nozzle-hole design that is not properly matched to the oil flow rate and pump pressure. High moisture content in CPO is detrimental because it accelerates hydrolysis reactions that increase free fatty acid (FFA) levels during storage [3]; therefore, CPO quality standards generally require a moisture content of  $<0.25\%$ .

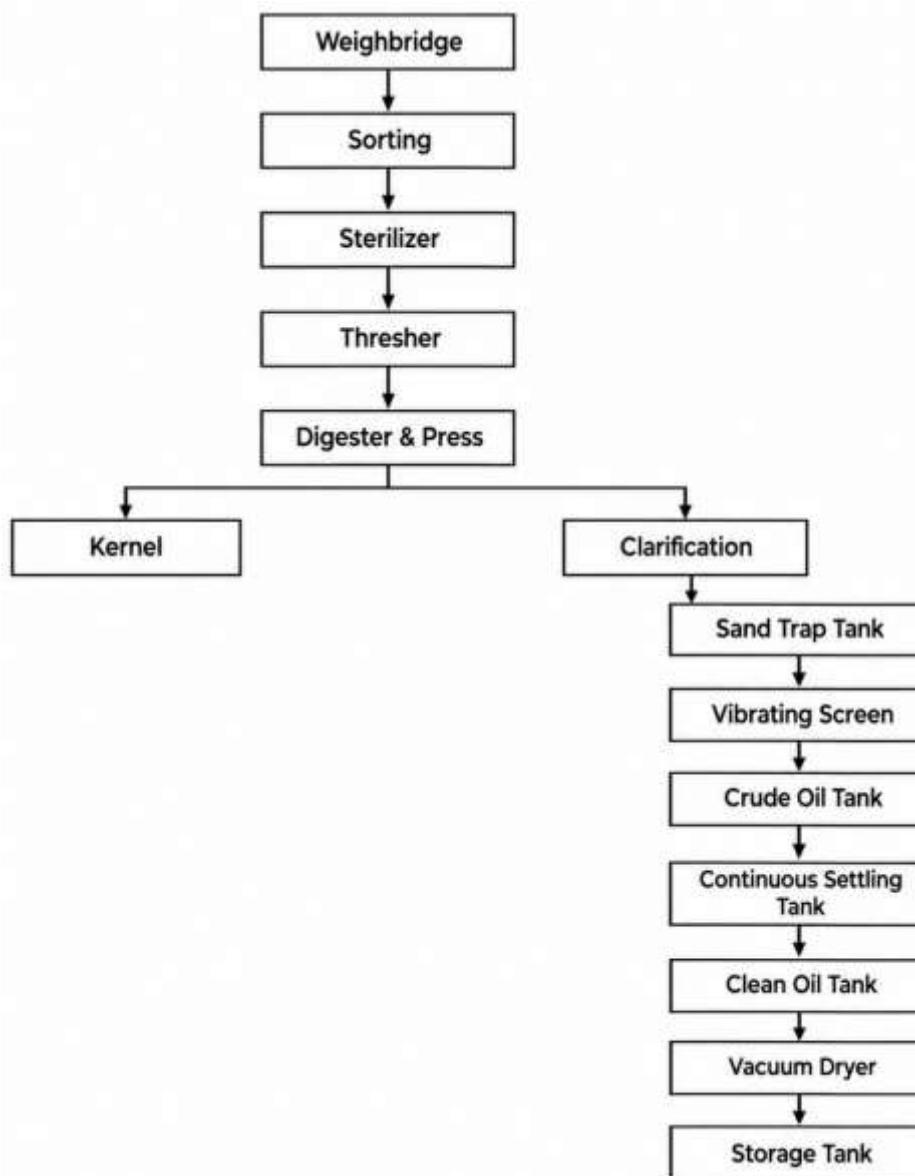


Figure 1. Flow diagram of the CPO processing process

PT Inti Indosawit Subur PMKS Buatan Dua, an oil palm mill with a processing capacity of 60 tons FFB/hour, sets a CPO moisture-content standard of  $<0.25\%$ . However, production data showed that the average CPO moisture content reached  $0.29\%$  in August 2025 and also  $0.29\%$  in September 2025, both exceeding the specified standard. If the oil droplets are still too large, the water contained in the oil may not evaporate optimally; one common cause is a nozzle-hole design that is not balanced with the oil flow rate and pump pressure. As an improvement measure, the company modified the nozzle by increasing the number of holes from 9 to 10 and reducing the hole diameter from 7 mm to 6 mm.

Previous research by Yuselin [4] showed that changing the nozzle diameter in a vacuum dryer was able to reduce the average CPO moisture content to 0.21%, with a reduction of 23%. Rokhim [5] found that temperature and vacuum pressure also had a significant effect on the moisture content achieved by a vacuum dryer, while Lubis et al. [6] reported that suboptimal use of a vacuum dryer could still result in CPO moisture contents above the mill quality standard. These findings confirm that equipment factors, particularly nozzle design, have an important influence on final CPO quality. Increasing the spray pressure by reducing the hole diameter and distributing the oil flow through a larger number of holes is expected to produce a finer oil mist, thereby increasing the contact area available for water evaporation.

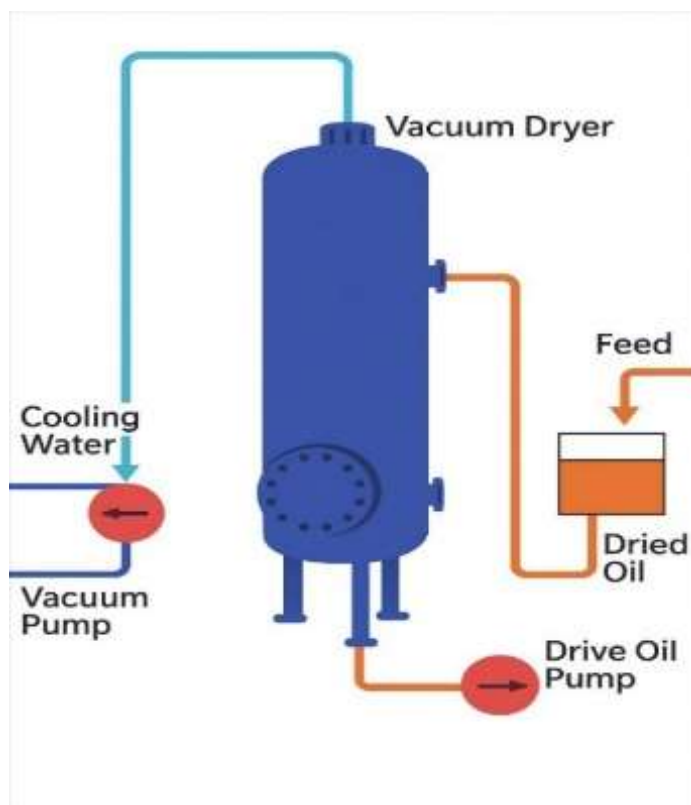


Figure 2. Schematic diagram of the vacuum dryer unit

Based on the above description, this study aimed to: (1) determine the CPO moisture content before and after increasing the number of nozzle holes and changing the nozzle-hole diameter; and (2) statistically analyze the effect of increasing the number and changing the diameter of nozzle holes on the reduction of moisture content in CPO ex vacuum dryer at PT Inti Indosawit Subur PMKS Buatan Dua.

## 2. Research Methods

The study was conducted at PT Inti Indosawit Subur PMKS Buatan Dua, located on Jl. Lintas Timur, Simpang Perak, Lalang Kabung Village, Pelalawan Regency, Riau Province. The industrial internship was carried out from 5 May to 20 December 2025, while research data were collected from August to December 2025.

This study used secondary data in the form of daily moisture-content data for CPO ex vacuum dryer obtained from the mill laboratory during the field internship at the clarification station. The data were grouped into two conditions: before nozzle modification (August–early October 2025; nozzle with 9 holes, 7 mm in diameter) and after nozzle modification (October–December 2025; nozzle with 10 holes, 6 mm in diameter), as shown in Figure 3. A total of 56 data points were used for each condition so that the number of paired observations was balanced. A computer/laptop equipped with SPSS software was used for data processing.

The CPO moisture content was determined in the laboratory using the oven (gravimetric) method according to the following procedure: (1) an empty Erlenmeyer flask was heated in an oven at approximately 103°C for 30 minutes, cooled in a desiccator, and then weighed to the nearest 0.1 mg; (2) approximately 10 g of liquid oil sample was placed in the Erlenmeyer flask; (3) the sample was heated in the oven at approximately 103°C for 4 hours without opening the oven door; (4) the sample was cooled in a desiccator for 30–40 minutes and

then reweighed, and the analysis was performed at least in duplicate. Moisture content was calculated using the following Equation 1.

$$MC (\%) = [(W2 - W3) / (W2 - W1)] \times 100\% \quad (1)$$

where W1 = weight of the empty Erlenmeyer flask, W2 = weight of the Erlenmeyer flask + oil before heating, and W3 = weight of the Erlenmeyer flask + oil after heating.

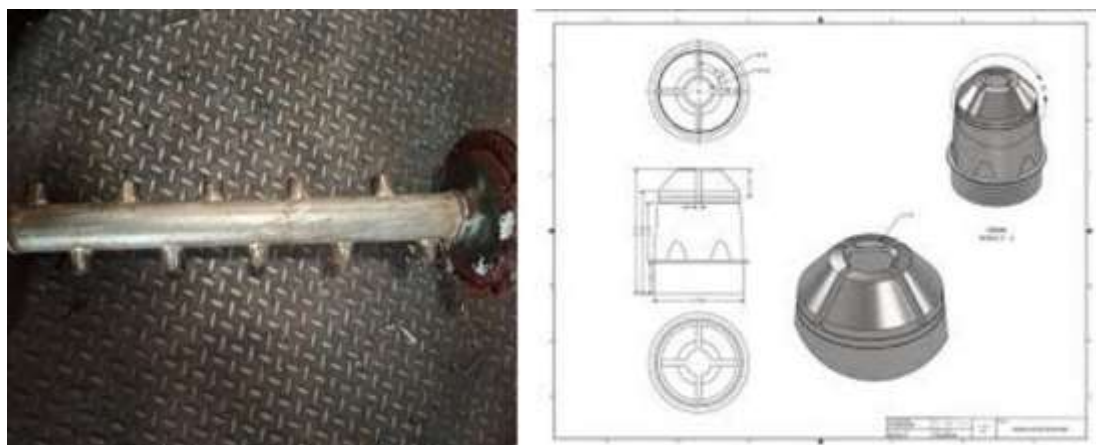


Figure 3. (a) Modified vacuum dryer nozzle; (b) technical drawing of the nozzle

The measurement data were analyzed using SPSS software in three stages. First, descriptive analysis was performed to obtain the mean, minimum, maximum, and standard deviation of CPO moisture content before and after modification. Second, a Shapiro–Wilk normality test was conducted, with the criterion that the data were normally distributed when the significance value (Sig.) was  $>0.05$  [7]. The Shapiro–Wilk method was selected because it has higher sensitivity and statistical power than other methods, making it more accurate for detecting data distributions, particularly for small to medium sample sizes [8]. Third, a Paired Samples T-Test was used to test the significance of the difference in mean moisture content before and after modification, with the hypotheses  $H_0$ : there is no significant difference, and  $H_1$ : there is a significant difference.  $H_0$  was rejected when the Sig. (2-tailed) value was  $<0.05$ .

### 3. Results and Discussion

The monthly average moisture content of CPO ex vacuum dryer during the observation period is presented in Table 1. Moisture contents in August, September, and early October 2025 (before nozzle modification) were above the company standard of 0.25%, whereas after the modification was implemented in the second week of October 2025, the monthly average moisture content gradually decreased to below the standard.

Table 1. Average moisture content of CPO ex vacuum dryer before modification with 9 nozzle holes and a diameter of 7 mm and after modification with 10 nozzle holes and a diameter of 6 mm

| Month                                           | Nozzle Condition                    | n (number of data points) | Average Moisture Content (%) |
|-------------------------------------------------|-------------------------------------|---------------------------|------------------------------|
| August 2025–early October 2025                  | Before modification (9 holes, 7 mm) | 56                        | 0.290                        |
| October 2025 (after modification)–December 2025 | After modification (10 holes, 6 mm) | 56                        | 0.221                        |

The collected data were secondary data from laboratory testing of the moisture content of CPO leaving the vacuum dryer during four months of mill operation, consisting of 56 samples before modification (9-hole nozzle, 7 mm diameter) and 56 samples after modification (10-hole nozzle, 6 mm diameter), which were treated as paired observations. Moisture content was calculated using Equation (1) based on the difference in sample weight before and after heating at approximately  $103^{\circ}\text{C}$  for 4 hours.

Table 2. Descriptive statistics of CPO moisture content before modification with 9 nozzle holes and a diameter of 7 mm and after modification with 10 nozzle holes and a diameter of 6 mm

| Statistic                 | Condition with 9 nozzle holes & 7 mm diameter | Condition with 10 nozzle holes & 6 mm diameter |
|---------------------------|-----------------------------------------------|------------------------------------------------|
| n (number of data points) | 56                                            | 56                                             |
| Mean                      | 0.28984                                       | 0.22134                                        |
| Standard Deviation        | 0.032583                                      | 0.041167                                       |
| Minimum – Maximum         | 0.215 – 0.354                                 | 0.152 – 0.367                                  |

The descriptive analysis of 56 moisture-content data points for each condition is presented in Table 2. The average moisture content decreased from 0.290% before modification to 0.221% after modification, corresponding to a reduction of approximately 23.6%. The minimum value also decreased from 0.215% to 0.152%, indicating that the new number and diameter of nozzle holes were able to reduce the moisture content to a lower level than the previous nozzle configuration. Although the maximum value slightly increased to 0.367%, causing the standard deviation to widen from 0.032583 to 0.041167, the overall central tendency of the data showed a consistent downward trend.

Table 3. Results of the Shapiro–Wilk normality test

| Condition                       | Statistic | df | Sig.  |
|---------------------------------|-----------|----|-------|
| 9 nozzle holes & 7 mm diameter  | 0.988     | 56 | 0.830 |
| 10 nozzle holes & 6 mm diameter | 0.959     | 56 | 0.053 |

Before the difference test was conducted, the data were tested for normality using the Shapiro–Wilk test (Table 3). The significance values for both groups were greater than 0.05, namely 0.830 for the pre-modification data and 0.053 for the post-modification data. Therefore, both groups were considered normally distributed and met the requirement for analysis using the parametric Paired Samples T-Test.

Table 4. Results of the Paired Samples T-Test for CPO moisture content before modification with 9 nozzle holes and a diameter of 7 mm and after modification with 10 nozzle holes and a diameter of 6 mm

| Mean Difference | Std. Deviation | Std. Error Mean | 95% CI Lower | 95% CI Upper | t                 | Sig. (2-tailed) |
|-----------------|----------------|-----------------|--------------|--------------|-------------------|-----------------|
| 0.0685          | 0.0498         | 0.0067          | 0.0552       | 0.0818       | 10.290<br>(df=55) | 0.000           |

The results of the Paired Samples T-Test are presented in Table 4. The test produced a mean difference of 0.0685, a t value of 10.290 at 55 degrees of freedom (df), and a significance value (Sig. 2-tailed) of 0.000. Because the significance value was less than 0.05, H<sub>0</sub> was rejected and H<sub>1</sub> was accepted, indicating a statistically significant difference in the mean CPO moisture content before and after the increase in the number of nozzle holes and the change in nozzle-hole diameter.

These results are consistent with the study by Yuselin [4] at PT Letawa, which demonstrated that changing the nozzle diameter in a vacuum dryer could reduce the moisture content to an average of 0.21%, corresponding to a 23% reduction. The reduction obtained in the present study, namely 23.6% to an average of 0.221%, is close to that finding, reinforcing the conclusion that reducing the nozzle-hole diameter to produce a finer oil spray yields consistent results. A nozzle with 9 holes of 7 mm diameter produced a relatively coarse oil spray, resulting in a smaller contact surface area between the oil droplets and the vacuum chamber, so that the water in the oil did not have sufficient opportunity to evaporate optimally. Increasing the number of holes to 10 and reducing the diameter to 6 mm increased the spray pressure, producing a finer oil mist and a more uniform flow distribution throughout the vacuum chamber, thereby allowing water to evaporate more effectively.

Although the average results showed a positive trend, some post-modification data still had moisture contents above 0.25%, with a maximum value of 0.367%. This indicates that nozzle design is not the only factor affecting CPO moisture content. Other operational factors, such as retention time in the continuous settling tank (CST), oil temperature before entering the vacuum vessel, and the volume of the vacuum tank that maintains stable pump suction, also influence the effectiveness of the drying process. Therefore, in

addition to implementing the new nozzle design, these operational parameters should continue to be monitored to ensure that the CPO moisture content is consistently maintained below the company quality standard.

#### **4. Conclusion**

Based on the results of this study, it can be concluded that: (1) the average CPO moisture content before modification, using a nozzle with 9 holes and a diameter of 7 mm (August–early October 2025), was 0.290%. After the nozzle was modified to 10 holes with a diameter of 6 mm (October–December 2025), the average moisture content decreased to 0.221%. (2) Increasing the number of holes and changing the diameter of the vacuum dryer nozzle had a significant effect on reducing the moisture content of CPO ex vacuum dryer at PT Inti Indosawit Subur PMKS Buatan Dua, as demonstrated by the Paired Samples T-Test with a significance value (Sig. 2-tailed) of 0.000 ( $<0.05$ ), resulting in rejection of  $H_0$  and acceptance of  $H_1$ . The modification effectively reduced CPO moisture content by 23.6%.

#### **5. Acknowledgments**

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#### **7. Conflict of Interest**

The authors declare that there is no conflict of interest in this study.

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