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Article

Impact of Thresher Drum Rotation in Removing Palm Fruit from Boiled Fruit Bunches (TBR)

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ABSTRACT

This study investigates the effect of thresher drum rotational speed on fruit release efficiency and fruit damage under real industrial conditions at a palm oil mill (PTPN IV Kebun Mayang). The research was conducted as a controlled field experiment using three drum rotation speeds: 20, 23, and 26 rpm. Quantitative measurements were performed on fruit release efficiency and residual fruit on empty bunches, supported by statistical analysis using ANOVA. The results show that increasing rotational speed improves fruit release efficiency but also increases fruit damage. At 20 rpm, the release efficiency was 97.03% with 2.97% residual fruit. At 23 rpm, the efficiency increased to 98.09% with reduced residual fruit (1.91%), representing the optimal balance between release effectiveness and damage. At 26 rpm, the highest release efficiency (98.48%) was achieved, but with significantly higher fruit damage due to excessive centrifugal force. These findings confirm the existence of a trade-off between mechanical detachment efficiency and fruit integrity. The study contributes to agro-mechanical engineering by linking rotational dynamics with detachment behavior and provides practical recommendations for optimizing thresher operation to improve crude palm oil (CPO) yield and quality.

1. Introduction

The oil palm (Elaeis guineensis Jacq) is a plantation commodity that plays a vital role in the national economy. The oil palm (Elaeis guineensis Jacq) is a tropical plant thought to have originated in Nigeria (West Africa), having first been discovered in the jungles of that country. Oil palm was first introduced to Indonesia in 1848, brought from Mauritius and Amsterdam by a Dutch citizen.(Aprilia Ega, 2020)The palm oil industry is a strategic sector in the Indonesian economy, primarily as a producer of crude palm oil (CPO), which is used in various food and non-food products. The palm oil processing process at the mill significantly determines the quality and quantity of the resulting crude palm oil (CPO). The process of processing fresh fruit bunches (FFB) to produce palm oil involves several work stations, one of which is the thresher station.

The thresher station has a vital function: separating the palm fruit from the boiled fruit bunches (TBR) after the boiling process. The efficiency of fruit removal at this station is directly related to oil yield. Successful boiling without proper thresher will result in high oil loss. Therefore, more thorough thresher operations are necessary, and it should be noted that thresher success also depends on the boiling process.(RIANDI A, 2024). Bunches that still contain excessive fruit can cause physical damage that reduces oil quality, especially free fatty acid (FFA) levels. The main tool used is a drum thresher, the performance of the drum thresher is greatly influenced by the applied rotation, because too low a speed can cause many fruits to be left on the bunch, while too high a speed can damage the quality of the fruit and reduce oil yield. Therefore, the rotation speed of the drum thresher is one of the important factors that need to be optimized.

Figure 1. Thresher Station*)*

Sterilized oil palm fruit bunches (FFB) are then transported using a hoisting crane and loaded into the bunch hopper. This equipment can lift approximately 5 tons per hoisting crane. There are two hoisting cranes available for the PTPN IV Kebun Mayang palm oil mill, with a capacity of 30 tons per hour (one operating and one standby).

Figure 2. Hoisting Crane

Speed or time of pouring boiled fruit bunches (TBR) on a hoisting crane (Hoisting Cycle Time / HCT):

$$HCT = \left(A \times \frac{60\, menit}{kapasitas\ pabrik}\right) \times B$$

Where:
A: Lorry capacity
B: Number of hoisting cranes in operation
Example:

$$HCT = \left(2{,}5 ton \times \frac{60\, menit}{30\ ton}\right) \times 1$$
$$= 5\frac{menit}{unit}/lori$$

Figure 3. Loading a TBR-filled truck into a bunch hopper using a hoisting crane.

*Bunch hopper*is a place where TBR is poured by a hoist crane operator(Napitupulu A, 2024).This tool isn't used to store TBR, but rather to maintain a continuous feed flow to the autofeeder unit. The body and floor plate can be tilted at an adjustable angle (usually 30° to 45°). The autofeeder's function is to move the TBR into a thresher or thresher, separating the loose fruit from the bunches, ensuring a smooth threshing process.

A thresher separates the loose fruit from the bunches by rotating and slamming them in a drum. The thresher is drum-shaped and has a capacity of 30 tons per hour.

Figure 4. Drum Thresher

A drum thresher is a rotating cylindrical machine used to remove oil palm fruit from its bunches. This process typically occurs after the sterilization stage, where the bunches are softened using steam at a pressure of 2.5-3.0 kgm/cm2. The drum thresher's rotation speed is approximately 23 rpm. The drum is 4550 mm long, with a drum diameter of 1920 mm, and a shaft length of 5744 mm, with a shaft diameter of 152 mm.

Figure 5. Grid and Throwing Plate

The loose fruit will fall through the grating on the thresher drum to the under thresher conveyor, then forwarded to the bottom cross conveyor, then the loose fruit will be delivered to the fruit elevator. This grating plate has a thickness of ± 8 mm and a distance between the gratings of ± 50 mm. The throwing plate has a slope ranging from 13˚ to 15˚, usually in 12 pieces. Meanwhile, empty bunches will be taken to the empty bunch hopper.

The ripeness of the fruit significantly determines the strength of the fruit release. Optimally ripe fruit releases more easily after sterilization, while unripe fruit requires more impact energy, potentially increasing fruit residue in empty bunches. Field factors such as variations in harvest age, transportation speed to the factory, and waiting time on the loading ramp also influence the fruit release results.

The stability of the boiler's steam pressure affects the performance of the turbine or motor that drives the thresher. Decreased steam pressure causes a decrease in RPM and affects the threshing rhythm, while excessive pressure can increase the rotational speed and potentially result in greater fruit damage. Therefore, coordination between the boiler and thresher stations is crucial to maintain stable rotational speeds.

If the drum rotation speed is too high, throughput can be achieved, but fruit loss in empty bunches remains high even though the sterilization process is optimal. This occurs because the shelling time is less effective. Conversely, if the drum rotation speed is too low, the shelling time is too long, potentially increasing oil loss in empty bunches. This condition can also accelerate jamming and wear on the equipment.(Buana Marpaung, Ritonga, & Irwan, 2021).

Overall, thresher performance depends on the optimum combination of mechanical aspects, energy supply, fruit quality, and other operational parameters. Controlling rotation speed is central to efficient threshing management because it directly affects fruit release effectiveness and fruit damage levels, two key indicators of threshing quality.

Overall, thresher performance depends on the optimal combination of mechanical aspects, energy supply, fruit quality, and operational parameters. Among these factors, drum rotational speed plays a critical role because it directly influences the detachment mechanism of palm fruit through centrifugal force, gravity, and repeated impact between the bunch and the drum surface. Increasing rotational speed enhances centrifugal force, which facilitates fruit detachment; however, excessive speed may generate high impact energy and friction, leading to fruit damage and reduced oil quality.

Previous studies have mainly focused on thresher design, operational efficiency, and general process performance. For instance, Idowu et al. (2023) reported that thresher efficiency is influenced by storage time and throughput, while Malik Ali et al. (2017) emphasized the high utilization rate of the thresher station in palm oil processing systems. Other studies (Ansia, 2020; Buana Marpaung et al., 2021) highlighted the importance of machine reliability and operational control. However, these studies have not sufficiently explained the mechanical relationship between rotational speed, centrifugal force, and fruit detachment behavior under real industrial conditions.

In particular, there is still limited quantitative analysis that clearly demonstrates the trade-off between fruit release efficiency and fruit damage using field-based experimental data. Most existing works do not integrate mechanical interpretation with operational performance, making it difficult to determine the optimal rotational speed from an engineering perspective.

Based on field conditions at PTPN IV Kebun Mayang, several practical problems were identified, including incomplete fruit detachment, potential oil loss due to excessive mechanical damage, and the lack of optimal rotational speed control adapted to real operating conditions. These issues indicate the need for a systematic study that combines experimental measurement with mechanical analysis. Therefore, this study aims to:

1. Analyze the effect of thresher drum rotational speed (20 rpm, 23 rpm, and 26 rpm) on fruit release efficiency.
2. Identify the optimal rotational speed that balances maximum fruit release and minimum damage.
3. Provide engineering-based recommendations to improve thresher performance under industrial operating conditions.

2. Literature Review

The threshing stage is a critical unit operation in palm oil milling because it determines the effectiveness of fruit detachment from sterilized fresh fruit bunches and directly influences oil recovery and downstream processing performance. In industrial palm oil processing, mechanical separation after sterilization must achieve a balance between high fruit release and minimal fruit damage, because excessive damage may increase oil losses and reduce crude palm oil quality. Previous studies have shown that extraction efficiency and product quality are strongly affected by the effectiveness of fruit separation prior to pressing (Alhaji et al., 2024).

From an engineering perspective, fruit detachment in a drum thresher is governed by the interaction of centrifugal force, gravity, friction, and repeated impact between the bunch and the internal drum surface (Cahyadi, n.d.). As rotational speed increases, angular velocity increases, resulting in higher centrifugal force acting on the fruit, which facilitates detachment. However, excessive rotational speed also increases impact energy and friction, potentially damaging the mesocarp and kernel and leading to higher oil losses in subsequent processing stages (Buana Marpaung et al., 2021).

Previous studies have demonstrated that thresher performance is influenced not only by machine design but also by operational parameters. Idowu et al. (2023) reported that sterilization conditions and storage time significantly affect threshing efficiency and throughput capacity. Their findings showed that efficiency increased from 87.0% to 93.0% as storage time increased from 1 to 3 days, indicating that operational conditions strongly influence machine performance. Similarly, Malik Ali et al. (2017) emphasized that the thresher station has the highest utilization rate in palm oil mills, highlighting its importance in overall processing efficiency.

The role of pretreatment before threshing has also been widely discussed. Sterilization is not only a thermal process but also a mechanical conditioning step that affects fruit detachment behavior and oil quality (Thang et al., 2021). Proper sterilization weakens the bond between fruit and spikelet, reducing the energy required for detachment during threshing. Therefore, the performance of the thresher cannot be separated from upstream process conditions such as steam pressure, residence time, and fruit maturity.

In addition, fruit maturity significantly influences threshing efficiency. Balakrishnan et al. (2021) demonstrated that fruit detachment behavior varies depending on ripeness level, while Ruswanto et al. (2024) confirmed that ripe fruit is more easily detached compared to unripe fruit. This indicates that mechanical detachment is the result of interaction between machine dynamics and biological characteristics of the fruit bunch.

Furthermore, several studies have focused on the structural and design aspects of thresher machines. Mokhtar et al. (2019) used finite element analysis to evaluate the structural integrity of thresher components under operational loads, while Ologunagba and Ojomo (2011) developed palm fruit stripping machines to improve separation performance. Although these studies contribute to machine design and durability, they do not explicitly determine the optimal operational rotational speed under real industrial conditions.

Based on the reviewed literature, a significant research gap remains. Most studies focus on machine design, sterilization, or general efficiency, but limited research provides field-based quantitative analysis of drum rotational speed as a primary variable while integrating mechanical interpretation such as centrifugal force and impact behavior. Therefore, this study aims to address this gap by experimentally evaluating the effect of drum rotational speed on fruit release efficiency and fruit damage under actual industrial operating conditions.

3. Research Methodology

This study adopts a quantitative experimental approach conducted under actual industrial operating conditions at the thresher station of PTPN IV Kebun Mayang, which has a processing capacity of approximately 30 tons of fresh fruit bunches (FFB) per hour. The research design focuses on evaluating the effect of drum rotational speed on fruit release efficiency and fruit loss.

3.1 Research Variables

The variables used in this study are:

a. Independent Variable:
   Thresher drum rotation speed (RPM), with three variations include 20 RPM, 23 RPM, 26 RPM

b. Dependent Variable
   1. Weight of unstripped fruit remaining on empty bunches (kg)
   2. Percentage of fruit loss on empty bunches (%)

3.2 Experimental Procedure

Each rotational speed variation was tested with five repetitions (n = 5) to ensure data reliability and consistency. Samples of empty fruit bunches (EFB) were randomly collected after passing through the thresher unit.

Data collection was carried out using the following procedures:

1. Drum rotation speed measurements were carried out manually, by taking a video of the rotation of the thresher drum drive shaft.
2. Measurement of Unretained Fruit on Empty Bunches. Samples of empty bunches are taken after leaving the thresher, then the number of retained fruit is counted and weighed to determine the level of losses.
3. Use the observation data form to record the results of each experiment

Measurement accuracy was ensured using a calibrated digital scale (±0.01 kg accuracy).

Figure 6. Empty Janjangan

Figure 7. Kubota brand digital scale

Figure 8. Loose Fruit Left on the Fruit Bunch

Figure 9. Process of Retrieving Berondol from Jankos

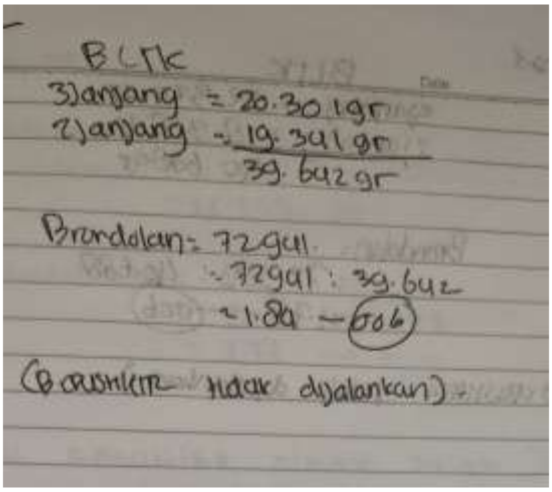

Figure 10. Jankos Analysis Results

3.3 Control Variables

To ensure experimental consistency, several parameters were controlled during data collection:

a. Type and condition of fresh fruit bunches (FFB)
b. Sterilization conditions (steam pressure and duration)
c. Feeding rate into the thresher
d. Machine configuration and operating condition

3.4 Data Analysis

Quantitative data was analyzed using comparisons between RPM variations to determine the relationship between rotational speed and thresher performance indicators. The analysis included:

a. Fruit release efficiency (%)
b. Level of losses on empty fields
c. Identification of optimum rotation based on the balance between release effectiveness and minimization of fruit damage.

Qualitative data were analyzed descriptively to understand field factors that contributed to yield variations, such as boiler pressure drop, differences in FFB size, and mechanical condition of equipment.

The data was analyzed by calculating the percentage of fruit release using the formula:

$$Loss\ brondol\ dari\ jankos(\%) = \frac{Berat\ loss\ brondol}{Berat\ jankos} \times 100$$

Statistical analysis was performed using Analysis of Variance (ANOVA) with a significance level of 95% ($\alpha = 0.05$) to determine the effect of rotational speed on fruit loss. Mean values and standard deviations were calculated to evaluate data variability.

3.5 Mechanical Consideration

The theoretical rotational speed of the drum can be estimated using the following empirical equation
(Main, 2023):

$$putaran\ drum(N) = \frac{40 \times \sqrt{\frac{(D-d)}{2}}}{D-d}$$

Where:
.

N : Drum rotation (rpm)
D : Drum diameter (m)
d : TBS Diameter (m)
40 : Empirical constant number

4. Results and Discussion

4.1 Results

Field observations revealed significant variation in the effectiveness of removing oil palm fruit from the boiled fruit bunches (TBR) at three tested thresher drum rotation speeds: 20 rpm, 23 rpm, and 26 rpm. The data showed that the higher the drum rotation speed, the lower the percentage of fruit remaining in the empty bunches

Table 1. Analysis of losses of remaining loose fruit in empty bunches that have been thrown at 20 rpm, 23 rpm and 26 rpm

ROUND	DATE	JANKOS WEIGHT (gr)	WEIGHT OF THE FRUITS (gr)	%BERONDOL TERPAP JANKOS
20RPM	07-Aug	39736	1168	2.94%
	August 10th	41080	1195.2	2.91%
	August 13th	39540	1170	2.96%
	August 16th	36997.5	1155	3.12%
	August 19th	36165	1063.5	2.94%
23RPM	08-Aug	38685	757.86	1.96%
	August 11th	39642	729.41	1.84%
	August 14th	39775	717,999	1.81%
	August 20th	38664	811.94	2.10%
	August 23rd	40886	768.65	1.88%
26RPM	09-Aug	40664	601.82	1.48%
	August 12th	40688	723.89	1.78%
	August 15th	40688	723.89	1.78%
	August 21st	36573	512.02	1.40%
	August 24th	40348	484.17	1.20%

From the data in the table above, I will conduct a quantitative test using the ANOVA Test: Two-Factor With Replication to see the impact of each rotation (rpm) on the loss of empty bunches.

Table 3. Fruit Release Efficiency at Variations in Thresher Drum Rotation

Drum Rotation (rpm)	Release (%)	Fruit Remains (%)
20	97.03	2.97
23	98.09	1.91
26	98.48	1.52

Table 2. Anova Test: Two-Factor With Replication

Anova: Two-Factor With Replication

SUMMARY	TANGGAL	BERAT JANKOS (gr)	BERAT BERONDOLAN (gr)	%BERONDOL TERHADAP JANKOS	Total
20RPM					
Count	5	5	5	5	20
Sum	229410	193518,5	5751,7	0,148703949	428680,3487
Average	45882	38703,7	1150,34	0,02974079	21434,01744
Variance	22,5	4191989,7	2568,428	7,13818E-07	465827592,3
23RPM					
Count	5	5	5	5	20
Sum	229421	197652	3785,859	0,095841713	430858,9548
Average	45884,2	39530,4	757,1718	0,019168343	21542,94774
Variance	38,7	843821,3	1359,251056	1,3766E-06	477070376
26RPM					
Count	5	5	5	5	20
Sum	229426	198961	3045,79	0,076382101	431432,8664
Average	45885,2	39792,2	609,158	0,01527642	21571,64332
Variance	38,7	3259278,2	12859,62527	6,31027E-06	481714840,2
Total					
Count	15	15	15	15	
Sum	688257	590131,5	12583,349	0,320927763	
Average	45883,8	39342,1	838,8899333	0,021395184	
Variance	30,45714286	2600597,436	60673,42928	4,24171E-05	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	210867,5455	2	105433,7727	0,152214733	0,859216741	3,190727
Columns	27030596009	3	9010198670	13008,02346	7,83417E-70	2,798061
Interaction	3799445,348	6	633240,8913	0,914209849	0,492961371	2,294601
Within	33247905,62	48	692664,7004			
Total	27067854227	59				

The ANOVA test data above shows that rotation significantly affects the number of fruit bunches remaining on empty bunches. This is evidenced by the sample P-value of 0.05, which is 0.05>0.0000859216741.

However, increasing drum speed also affected the level of fruit damage. Furthermore, observations also noted operational impacts on plant efficiency. At 23 rpm, material flow was more stable, energy consumption was relatively efficient, and oil losses were lower than at 26 rpm. While 26 rpm resulted in higher release rates, it left residues in the form of broken nuts and mesocarp that adhered to the fiber, potentially increasing losses at subsequent stations (pressing and clarification).

4.2 Discussion

The results of this study confirm that the rotational speed of the thresher drum is a key factor in the process of removing oil palm fruit. Mechanically, the higher the drum rotational speed, the greater the centrifugal force generated, making it easier for the fruit to be released from the bunch. However, too much force can cause excessive friction, which damages the fruit's structure.

At 20 rpm, the fruit release rate reached 97.03%, with 2.97% remaining fruit and relatively low fruit damage. Increasing the speed to 23 rpm resulted in an optimal release rate of 98.09%, with a reduction in retained fruit to 1.91%. This indicates an optimal point where the mechanical energy provided is sufficient to separate the fruit without causing significant damage. At 26 rpm, the fruit release rate reached its highest value of 98.48%, but was accompanied by increased fruit damage.

If the drum rotation speed is too high, throughput can be achieved, but fruit loss in empty bunches remains high even though the sterilization process is optimal. This occurs because the shelling time is less effective. Conversely, if the drum rotation speed is too low, the shelling time is too long, potentially increasing oil loss in empty bunches. This condition can also accelerate jamming and wear on the equipment..The standard operating drum rotation range of 21-23 rpm is the ideal condition for a factory with a capacity of 30 tons of fresh fruit bunches (FFB)/hour. Thus, 23 rpm can be categorized as the optimum operating point with a balance between effective release and minimizing fruit damage. Factors such as clean grates, placement of throwing knives and regular drum cleaning are very important to minimize fruit losses, especially when overfeeding or improper rotation.

The practical implication of this finding is the need to control the drum rotation speed within the optimal range (23 rpm). If the rotation speed is too low, many fruits are left on the bunch, reducing yield. Conversely, if the rotation speed is too high, oil loss increases due to seed breakage and mesocarp damage. Therefore, drum speed regulation directly impacts production efficiency and the quality of crude palm oil (CPO).

This research was conducted only at a single mill at PTPN IV Kebun Mayang with a specific processing capacity, so the generalizability of the results to other mills with different capacities is limited. Other factors such as fruit moisture content, bunch age, boiler energy supply stability, fruit size, and drum construction design have not been analyzed in depth. Therefore, further, more extensive research is needed to strengthen the validity of the findings.

The data can be presented with line charts and bar charts as follows.

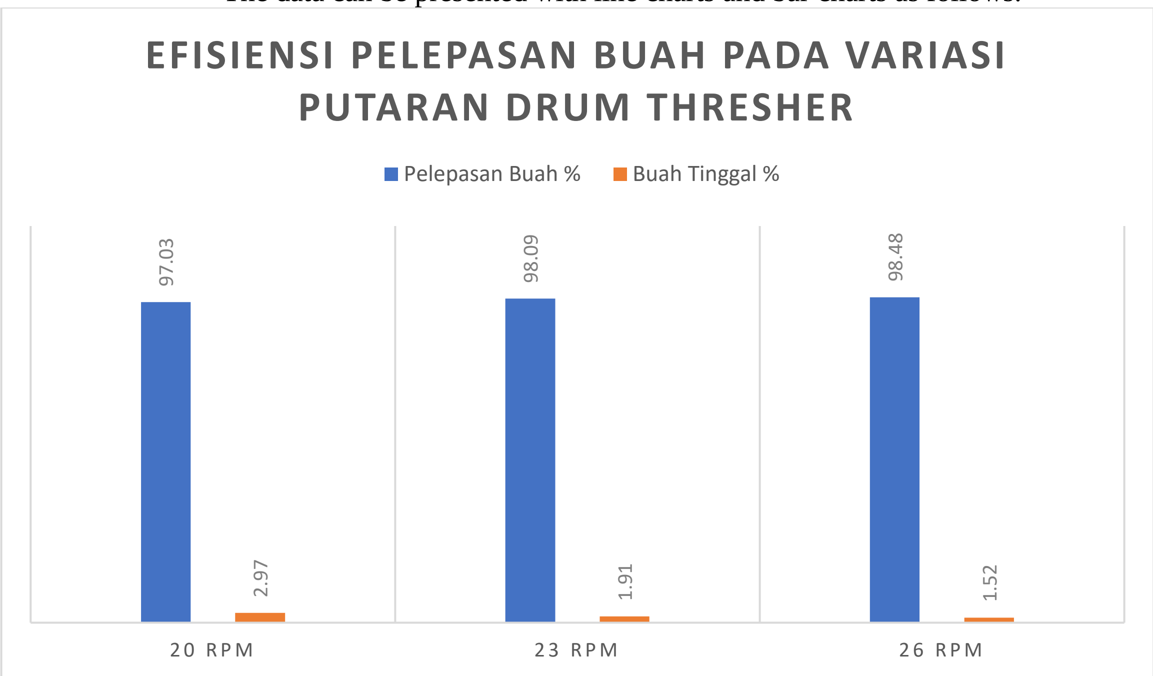

Figure 11. Fruit Release Efficiency at Variations of Thresher Drum Rotation with Bar Chart

5. Conclusion

Based on the research results, it can be concluded that:

1. The rotation of the thresher drum has a significant effect on the effectiveness of releasing oil palm fruit from the boiled fruit bunches (TBR).
2. 23 rpm rotation is the optimal point with a fruit release efficiency of 98.09%, with 1.91% remaining fruit.
3. Speeds below 20 rpm cause a lot of fruit to be left behind, while speeds above 26 rpm cause increased fruit damage and oil loss.
4. Machine maintenance and design significantly impact operational performance. Cleanliness of the gratings and positioning of the throwing knives, as well as preventing overfeeding, are key to preventing fruit loss.
5. Optimizing the rotation speed of the thresher drum is an important strategy in increasing the yield of crude palm oil (CPO) at PTPN IV Kebun Mayang.

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