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Article

Analysis of the Effect of Boiling Time on Oil Yield Palm oil at PTPN IV Mayang Plantation

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ABSTRACT

The boiling process of fresh fruit bunches (FFB) at PTPN IV Kebun Mayang is carried out using a semi-automatic system using a horizontal steam pressure sterilizer. This study analyzed three boiling time programs, namely 85 minutes, 90 minutes, and 95 minutes, with a triple peak pressure system. The purpose of the study was to determine the most optimal boiling time to obtain the potential palm oil yield. The method used was a direct experiment with quantitative and qualitative observations of the potential of fresh fruit bunches (FFB) and oil yield. The results showed that the average RMS of the 85-minute experiment was 16.98%, the average RMS of the 90-minute experiment was 23.76%, and the average RMS of the 95-minute experiment was 19.44%. In conclusion, the 90-minute boiling time appears to provide the most balanced results. Boiling that is too short results in low yields while boiling that exceeds the optimum limit also tends to reduce the quality or amount of extractable yield.

1. Introduction

The palm oil industry is one of the strategic sectors in Indonesia that contributes greatly to the national economy through the export of Crude Palm Oil.(Pratama et al., 2025).The process of processing Fresh Fruit Bunches (FFB) into crude palm oil requires complex stages, where boiling (sterilization) is one of the most important stages.

At PTPN IV Kebun Mayang, the boiling process is carried out using a triple peak horizontal sterilizer system with gradual pressure (2.3 kg/cm², 2.5 kg/cm², up to 3.0 kg/cm²). Previous research has shown that the boiling time has a significant effect on the quality of the fruit and oil. Incomplete boiling at the sterilizer station will cause a decrease in the efficiency of the seed breaking process during thresher station.(Mahyunis et al., 2015).

According to Baldani and Ta'ali (2015), in(Lilis Masruroh, 2021)Based on their position, boiling machines are divided into two types: horizontal and vertical. Vertical boiling reduces factory maintenance costs because it eliminates the need for a lorry. Fresh fruit bunches (FFB) from the loading ramp are transported using a conveyor and then fed into the sterilizer. When the sterilizer is empty, the feeder chute rotates toward the sterilizer, opening the feeder gate. This allows fresh fruit bunches to flow in, filling the sterilizer.

The process of boiling fresh fruit bunches before further processing is aimed at(Benu et al., 2024; Oksya Hikmawan, 2019; Sitepu, 2011)and (Suandi, et al., 2016) in(Lilis Masruroh, 2021):

1. Deactivating or destroying enzymes and stopping fermentation, which can lead to the formation or increase of free fatty acids. Freshly harvested fresh fruit bunches (FFB) typically still contain the lipase enzyme, which acts as a catalyst in the formation of free fatty acids. In addition, fresh fruit bunches also contain the oxidase enzyme, which plays a role in the formation of peroxides, which are then converted into aldehyde groups. If the FFB is injured or bruised, the activity of the lipase and oxidation enzymes increases. If heated to temperatures above 50 °C, the enzymes become inactive. Therefore, boiling at high temperatures will stop the enzyme activity.
2. Freezing sap and proteins. Heating through boiling in the sterilizer station will freeze the sap contained in the fresh fruit bunches. Furthermore, the high temperature of boiling can freeze proteins.
3. Facilitates the removal of palm fruit from the bunch. To facilitate oil extraction, the palm fruit must be separated from the bunch. This separation occurs due to the hydrolysis of pectin at the base of the fruit. Boiling in the sterilizer station accelerates the hydrolysis of pectin. However, the hydrolysis of pectin in the stalk does not completely remove the fruit. Therefore, further threshing is required at the thresher station.
4. Soften the fruit flesh for easy mashing in the digester. Heating by boiling in the sterilizer station will cause the fibers in the skin of the oil palm fruit to loosen. This will make the subsequent processing in the digester easier.
5. Reducing the water content in the fruit increases the efficiency of palm kernel (nut) cracking. The boiling process at the sterilization station reduces the water content in the palm fruit and kernels through evaporation. This reduction in water content increases the efficiency of palm kernel cracking.
6. Conditioning the fruit flesh allows the oil cells to separate for extraction. The interaction of heat and the process of reducing water content causes the palm oil between the cells to clump together and have a lower viscosity. This makes the extraction process easier.
7. Simplifying subsequent processes: The boiling process in the sterilizer station helps release the fiber and seeds. Furthermore, boiling also helps remove the kernel from the shell. By separating the kernel from the fiber, and then the kernel from the shell, subsequent processes in the thresher and digester stations are simplified.
8. To achieve the boiling goal, a steam pressure of 3 bar is required with a boiling cycle of 60 to 70 minutes, and at a temperature of 120 to

130 ºC.

When oil palm fruit is boiled for too long, various problems arise that are detrimental to the production process. Over-boiling causes the fruit to become too soft, allowing the loose fruit (individual fruit) to easily detach from the bunch. While this may sound beneficial, it is actually dangerous because it can lead to significant oil loss. The oil dissolves in the condensate water produced during the boiling process, making it impossible to recover for the final product. Furthermore, overcooked fruit loses its physical structure and becomes charred, significantly reducing its oil content and lowering the quality of the resulting oil.

On the other hand, boiling too briefly also poses serious problems in the oil extraction process. Insufficient boiling time results in the fruit not fully ripening, leaving the flesh hard and difficult to process further. This condition makes it difficult to separate the loose fruit from the parent bunch, ultimately complicating the separation and processing process. As a result, processing machines must work harder to separate the fruit from the bunch, which can cause damage to equipment and increase operational costs. Most detrimentally, the resulting oil yield will not reach the maximum potential that should be obtained from the fruit, resulting in low production efficiency.

PTPN IV Kebun Mayang has a processing capacity of approximately 30 tons per hour using a horizontal sterilizer with a capacity of 10 trucks (approximately 25 tons of fresh fruit bunches). With such a large production capacity, boiling efficiency is crucial to reduce energy costs while maintaining oil quality.

Determining the correct boiling time not only impacts technical aspects, but also economic and environmental aspects, considering that excessive use of steam increases fuel consumption.

1. **Lorry**

A lorry is a tool used to store or transport fruit from the loading ramp to a horizontal boiling or sterilizer for boiling. The lorry's capacity is 2.5 tons of fresh fruit bunches (FFB). The amount that enters the sterilizer room at one boiling is 10 lorries.

Figure 1. Lori

2. **Capstand**

Capstand is a tool for pulling the lorry into the horizontal sterilizer room and removing the lorry from the horizontal sterilizer using a gearbox/electromotor.

Parts*cap stand*:

- Electromotor
- Clutch
- Gear box
- Rollerpuller
- sling rope

Figure 2. Capstand

3. **Transfer Carriage**

A transfer carriage is a device for moving lorries loaded with fresh fruit bunches (FFB) from the loading ramp to the loading ramp behind the loading ramp. A transfer carriage can move three lorries in a single operation.


Figure 3. Transfer Carriage

4. Boiling (Sterilizer)

*Sterilizer*is a pressurized steam vessel used to boil fresh fruit bunches (FFB) with steam. The steam used is wet steam with a pressure of 2.3 – 3.0 kg/cm2 and a temperature of 140 °C the number of active sterilizers is 2 in repair 1 (sterilizer) Horizontal shape and 31M long, with a capacity of 25 tons each (containing 10 lorries, a capacity of 2.5 tons/hour) using a triple peak boiling process with a steam injection and exhaust system regulated semi-automatically with operator supervision and assistance. The purpose of boiling is as follows:

A. Reduces the increase in Free Fatty Acids (FFA) because heating during boiling can kill the activity of enzymes that can increase FFA levels.

B. Makes it easier to release the fruit from the bunch during the threshing process.

C. Soften the fruit flesh to make it easier to separate the oil from the fruit flesh when pressed.

D. Reduce the water content of loose fruit

E. Reduces the water content in the seeds, making it easier to break the seeds in the ripple mill.


Figure 4. Horizontal sterilizer

Based on field conditions at PTPN IV Kebun Mayang, problems were found, namely the inconsistent potential for Palm Oil Yield in each processing cycle along with inconsistent boiling times.

Based on the problem identification, it can be formulated that the main problem of this research is: (1) what is the effect of different boiling times (85, 90, 95 minutes) on palm oil yield; (2) which duration is the most optimal in maintaining a balance between yields.

The objective of this study was to quantitatively and qualitatively analyze the effect of varying boiling time on palm oil yield at PTPN IV Kebun Mayang. A literature review revealed a research gap on this topic. Most previous studies focused on boiling time ranges of 60–90 minutes, while analysis beyond 95 minutes is still relatively limited. Response Surface Methodology (RSM) optimization suggested that variations in duration and temperature need to be further explored according to the ripeness level of the fruit. This is relevant for the conditions at Mayang POM, which uses FFB with an average weight of 15 kg and 1,200 seeds per bunch.

This research also represents a tangible contribution from the students' Field Work Practice (PKL), where theoretical classroom learning is tested directly in the field through observation and experimentation. PKL provides an opportunity to examine real-world industrial problems and generate data-driven solutions. Furthermore, this activity strengthens the synergy between higher education and industry in improving the quality of education and the competitiveness of the Indonesian palm oil sector.

2. Literature Review

2.1. Palm Oil Industry and Its Economic Significance

Indonesia is the world's leading producer and exporter of Crude Palm Oil (CPO), contributing significantly to national foreign exchange earnings and agro-industrial growth. Pratama et al. (2025) confirmed that multiple macroeconomic factors, including production volume, land expansion, and world market prices, collectively shape the competitiveness of CPO exports from Indonesia, particularly from plantation-intensive regions such as East Kalimantan. The processing chain from Fresh Fruit Bunches (FFB) to CPO involves several interconnected stages, of which sterilization is considered one of the most critical determinants of final oil quality and yield efficiency. Inefficiencies at the sterilization stage propagate downstream, reducing threshing efficacy, digestion performance, and ultimately the oil extraction rate (OER) achieved in the mill.

2.2. The Sterilization Process in Palm Oil Milling

Sterilization is the process of applying high-pressure steam to FFB inside a sealed vessel to achieve several simultaneous biochemical and physical objectives. The sterilization process deactivates lipolytic enzymes, particularly lipase and peroxidase, which are responsible for the formation of Free Fatty Acids (FFA) and peroxide compounds in freshly harvested FFB. Zamanhuri et al. (2022), as cited in the study by Zamanhuri et al. (available in the UNSRI Chemical Engineering Journal), noted that steam heat during sterilization alters the protein structure within fruit cells and disrupts cell wall integrity, thereby facilitating oil separation during the pressing stage. In addition to enzyme inactivation, sterilization accelerates the hydrolysis of pectin at the pedicel of each fruit, enabling easier detachment from the bunch during the subsequent threshing process. The reduction of moisture content in the fruit kernel achieved during sterilization is also critical for improving the cracking efficiency of the ripple mill at later processing stages.

2.3. Sterilizer Types: Horizontal and Vertical Systems

Palm oil mills employ different types of sterilizers depending on their design, capacity, and operational requirements. The horizontal sterilizer, which is the most widely used type in Indonesia, processes FFB loaded onto lorries that are pulled into a cylindrical pressure vessel using a capstan winch system. Research by Upnyk University (2018) found that horizontal sterilizers are generally superior to vertical sterilizers in terms of minimizing potential oil extraction loss, based on evaluations of FFB ripeness, laboratory reports, and sterilization process data. In contrast, vertical sterilizers offer advantages in terms of reduced maintenance costs, as they eliminate the need for lorries and use conveyors to transport FFB directly into the vessel. A comparative study conducted at Universiti Putra Malaysia found that the microstructural analysis of sterilized fruit showed complete rupture of cell walls in vertically sterilized fruit, but that horizontal sterilizers remain more common due to their scalability and compatibility with existing lorry-based material handling systems.

2.4. Triple Peak Sterilization System

The triple peak sterilization system is the standard operating method in most Indonesian horizontal sterilizer units, utilizing a three-phase steam injection and exhaust cycle to ensure uniform heat penetration throughout the FFB load. Each peak involves a progressive increase in steam pressure: the first peak removes air from the sterilizer vessel to allow effective steam contact, the second peak begins the thermal penetration of the bunch, and the third peak at the highest pressure completes enzyme inactivation and fruit softening. Benu et al. (2024) analyzed steam requirements for a triple peak sterilizer with a 40-ton/unit capacity and confirmed that precise pressure management across all three peaks is essential to ensure adequate sterilization without excessive condensate accumulation. The condensate produced during the triple peak process is a major pathway for oil losses, as oil from the mesocarp dissolves into the water vapor and condensate if sterilization duration exceeds optimal limits.

2.5. Effect of Boiling Time on Palm Oil Yield

Sterilization time is one of the most critical operational parameters in palm oil processing, with both under-sterilization and over-sterilization producing adverse outcomes on oil yield and quality. A study published in the Journal of Rekayasa Pertanian dan Biosistem (Oksya Hikmawan, 2019; Zamanhuri et al., 2024) found that, for overripe FFB conditions (25–26%), the optimal boiling cycle ranged from 90 to 100 minutes, yielding oil losses of only 0.78–0.98%; cycles longer than this increased oil loss progressively as more oil migrated from the mesocarp into the condensate water. Similarly, Sitepu (2011) established that a 90-minute boiling cycle at a pressure of 3.0 bar and temperature of 130–140°C represents a benchmark for steam requirement efficiency in a horizontal sterilizer, providing a balance between fruit softening and oil retention. A study conducted at a CPO plant in West Sumatra and published in the Jurnal Teknik Kimia UNSRI found that across sterilization time variations of 83 to 90 minutes, the longer the sterilization time, the greater the percentage of oil loss into condensate water, with the maximum allowable sterilization time calculated at 87.4 minutes under a 1.2% oil loss standard. Conversely, research by Thonglek and Kiatkittipong (as cited in Akademia Baru, 2021) demonstrated that FFB sterilized for up to 45 minutes at 1.5 bar showed fruit-bunch separation of 90.36% and CPO yield of 26.72% with FFA not exceeding 1.25%, confirming that insufficient sterilization time results in incomplete cell wall rupture and suboptimal oil extraction.

2.6. Free Fatty Acid Formation and Enzyme Inactivation

FFA content is one of the most critical quality parameters for CPO, with international standards typically requiring FFA levels below 5% for commodity-grade oil. The lipase enzyme present in freshly harvested FFB catalyzes the hydrolysis of triglycerides into FFA, particularly when the fruit mesocarp is bruised or damaged during harvesting and transport. Sterilization at temperatures above 50°C rapidly deactivates lipase activity, while temperatures reaching 130–140°C achieve complete enzyme denaturation within the sterilization cycle. The oxidase enzyme, which promotes peroxide formation and subsequent conversion to aldehyde compounds, is similarly deactivated during high-temperature sterilization, thereby preventing rancidity and quality degradation in the extracted oil. Mahyunis et al. (2015) demonstrated that incomplete boiling at the sterilizer station directly reduces the efficiency of seed breaking at the thresher station, confirming the cascading effect of sterilization quality on downstream processing performance.

2.7. Research Gap

Most prior studies on sterilization time optimization have focused on boiling cycles in the range of 30 to 90 minutes, with limited investigation of the performance differences between 85, 90, and 95-minute programs under a semi-automatic triple peak system. The Response Surface Methodology (RSM) approach applied by Yulianti et al. (2021) in the context of virgin palm oil production highlighted that interactions between sterilization temperature and duration must be evaluated in relation to FFB characteristics, including bunch weight and ripeness fraction, for optimization to be meaningful. At PTPN IV Kebun Mayang, where FFB averages 15 kg per bunch with approximately 1,200 seeds, the specific time range of 85–95 minutes in a horizontal triple peak sterilizer with semi-automatic control has not been empirically analyzed, representing the gap that this study addresses.

3. Research Methodology

3.1. Research Type and Design

This study employed a mixed methods research design that integrates quantitative and qualitative approaches within a single investigation. According to Creswell and Creswell (2018), a mixed methods approach allows researchers to collect and analyze both numerical data and descriptive observations, thereby producing a more comprehensive understanding of the phenomenon under study. Sugiyono (2023) further asserts that the combination of quantitative and qualitative methods strengthens research validity by providing complementary perspectives on the same research problem. In the context of this study, quantitative data were obtained through measurement of palm oil yield (RMS), while qualitative data were collected through systematic sensory observation of the physical characteristics of fresh fruit bunches (FFB) after sterilization, including visual attributes such as fruit color, surface texture, and degree of softness of the fruit flesh. This dual data collection strategy ensures that both the measurable outcomes and the observable physical changes associated with different boiling durations are documented and analyzed.

3.2. Population and Sample

The population of this study comprised all production cycles of FFB boiling conducted at PTPN IV Kebun Mayang using a horizontal triple peak sterilizer system during the research period. Sudaryono (2021) defines a research population as the entire set of objects or subjects that possess characteristics relevant to the research objectives, while a sample is a representative subset selected from that population. Sampling in this study was purposive, with five bunches of FFB selected per treatment variation, chosen based on criteria of representativeness in terms of weight (approximately 15 kg per bunch), fruit diameter (approximately 30 cm), and number of loose fruit per bunch (approximately 1,200 seeds). A total of five trials were conducted for each of the three boiling time variations (85, 90, and 95 minutes), resulting in 15 experimental units overall. Data collection was carried out from August 7 to September 2, 2025. The selection of this sample range aligns with industrial observations reported by Benu et al. (2024), who noted that FFB characteristics, including bunch weight and fruit density, directly influence sterilization efficiency and oil yield outcomes.

3.3. Research Instruments and Data Collection Techniques

Data collection was conducted using two complementary instruments: a measurement protocol for quantitative RMS calculation and an observation checklist for qualitative physical assessment. For quantitative data, each sterilized FFB sample was transported to the laboratory for analysis of the following parameters: weight of fresh fruit bunches (FFB), weight of boiled fruit bunches (TBR), weight of empty bunches (TANKOS), weight of loose fruit (fallen fruit), and composition of fruit flesh, seed, kernel, and shell obtained from a 1,000-gram loose fruit subsample. Boiling time was monitored using the semi-automatic sterilization control panel installed on the horizontal sterilizer unit at PTPN IV Kebun Mayang, as described by Mahyunis et al. (2015) in their study of sterilization effects on oil palm seed properties. For qualitative data, trained observers evaluated the physical condition of the boiled fruit after each trial using a standardized observation checklist. Observations recorded the color change of the fruit exocarp (from orange-red to darker hues), the firmness or softness of the mesocarp when compressed manually, the ease of fruit detachment from the bunch, and the presence of any signs of over-processing such as charring or excessive moisture loss. These qualitative indicators are consistent with the physical criteria identified by Oksya Hikmawan (2019) and Sitepu (2011) for evaluating sterilization effectiveness in palm oil processing. Emzir (2020) notes that qualitative observational data in mixed methods research must be systematically structured and recorded contemporaneously with quantitative measurements to ensure methodological coherence and triangulation validity.

3.4. Data Analysis Procedures

Quantitative data were analyzed using a two-factor ANOVA with replication (ANOVA: Two-Factor With Replication) in Microsoft Excel to determine whether boiling time had a statistically significant effect on RMS potential, with a significance level of alpha = 0.05. Palm oil yield (RMS) was calculated using the formula derived from the Fossnir analysis, which determines the proportion of oil in the loose fruit relative to the total FFB weight processed. This computational approach is consistent with standard laboratory yield analysis procedures applied in Indonesian palm oil mills, as described by Lilis Masruroh (2021). Qualitative observational data were analyzed descriptively by categorizing the physical attributes of each boiling treatment and identifying patterns across the five trials per treatment. According to Creswell and Creswell (2018), in a convergent mixed methods design, quantitative and qualitative results are compared and integrated during the interpretation phase to produce a unified set of conclusions. This integrated analysis approach strengthens the overall reliability of the findings by corroborating numerical yield outcomes with direct physical evidence of sterilization quality, as similarly demonstrated by studies on micro-structural changes in palm fruit during sterilization.

4. Results and Discussion

4.1. Results

Table 1. Potential Palm Oil Yield in the 95-Minute Experiment

Information (gr)		**95 Minute Trial**				
		1	**2**	**3**	**4**	**5**
Fresh Fruit Bunches (FFB)		14360	15760	15460	10650	17170
Boiled Fruit Bunches (TBR)		11790	13760	14250	8680	15050
Empty Bunches (TANKOS)		2570	2000	1210	1970	2120
Falling apart		6180	8180	8760	4990	8150
Meat Fruit (taken 1000g of loose fruit)		823	738	703	749	730
Seed		177	262	297	251	270
Core		61	91	103	87	94
Shell		116	171	194	164	176
Fossnir	L	61.41	54.22	59.07	59.03	51.89
	A	20.7	14.9	14.51	22.26	25.89
	N	17.89	25.88	26.42	18.71	22.22
Palm Oil Yield (RMS)		20.25%	19.26%	22.02%	19.21%	16.48%

From the table above, the following results are obtained:

Palm Oil Yield Formula (RMS):

$$RMS = \left(\frac{Berat\ daging\ buah\ rata-rata}{1000}\right) \times L(dari\ fossnir\ rata-rata) \times \left(\frac{Berat\ berondolan\ rata-rata}{Berat\ TBS}\right) - 1{,}50$$

$$RMS\ 95\ menit = \left(\frac{748{,}6}{1000}\right) \times (57{,}124) \times \left(\frac{7252}{14680}\right) - 1{,}50 = 19{,}44\%$$

Table 2. Potential Palm Oil Yield in the 90-Minute Experiment

Information (gr)		90 Minute Trial 1	2	3	4	5
Fresh Fruit Bunches (FFB)		13640	13050	147730	13890	17700
Boiled Fruit Bunches (TBR)		11900	11250	13070	11960	14860
Bunch Empty (TANKOS)		1740	1800	1660	1930	2840
Falling apart		6960	6820	7270	8110	9320
Meat Fruit (taken 1000g of loose fruit)		775	715	788	688	728
Seed		225	285	212	312	272
Core		83	38	72	106	92
Shell		142	202	139	206	180
Fossnir	L	59.48	65.78	61.47	73.16	65.16
	A	22.99	17.84	18.44	10.49	22.43
	N	17.53	16.38	20.09	16.35	12.41
Palm Oil Yield (RMS)		22.02%	23.07%	22.33%	27.88%	23.47%

From the table above, the following results are obtained:

Palm Oil Yield Formula (RMS):

$$RMS = \left(\frac{Berat\ daging\ buah\ rata-rata}{1000}\right) \times L(dari\ fossnir\ rata-rata) \times \left(\frac{Berat\ berondolan\ rata-rata}{Berat\ TBS}\right) - 1{,}50$$

$$RMS\ 95\ menit = \left(\frac{738{,}8}{1000}\right) \times (65{,}01) \times \left(\frac{7696}{14610{,}6}\right) - 1{,}50 = 23{,}76\%$$

Table 3. Potential Palm Oil Yield in the 85-Minute Experiment

Information (gr)		85 Minute Experiment 1	2	3	4	5
Fresh Fruit Bunches (FFB)		12690	19850	22240	12460	17700
Boiled Fruit Bunches (TBR)		10840	16240	17390	10700	14860
Empty Bunches (TANKOS)		3510	5730	7060	3120	4310
Falling apart		6520	8690	9080	5760	9320
Meat Fruit (taken 1000g of loose fruit)		686	676	729	769	728
Seed		314	324	271	235	272
Core		74	131	120	80	92
Shell		240	193	151	155	180
Fossnir	L	59.34	54.84	44.15	48.25	65.16
	A	23.35	22.04	29.86	29.59	22.43
	N	17.31	23.11	25.99	22.16	12.41
Palm Oil Yield (RMS)		19.41%	14.72%	11.64%	15.65%	23.47%

From the table above, the following results are obtained:

Palm Oil Yield Formula (RMS):

$$RMS = \left(\frac{Berat\ daging\ buah\ rata-rata}{1000}\right) \times L(dari\ fossnir\ rata-rata) \times \left(\frac{Berat\ berondolan\ rata-rata}{Berat\ TBS}\right) - 1{,}50$$

$$RMS\ 95\ menit = \left(\frac{717{,}6}{1000}\right) \times (54{,}34\%) \times \left(\frac{7874}{16988}\right) - 1{,}50 = 16{,}98\%$$

4.2. Discussion

Waktu	TBS	TBR	Tankos	Berondolan	Daging Buah(diambil dari 1000 gr)	Biji	Inti	Cangkang	L %	A %	N %	RMS %
95 Menit	14360	11790	2570	6180	823	177	61	116	61,41	20,7	17,89	20,25069
	15760	13760	2000	8180	738	262	91	171	54,22	14,9	25,88	19,26887
	15460	14250	1210	8760	703	297	103	194	59,07	14,51	26,42	22,02973
	10650	8680	1970	4990	749	251	87	164	59,03	22,26	18,71	19,21598
	17170	15050	2120	8150	730	270	94	176	51,89	25,89	22,22	16,48017
90 Menit	13640	11900	1740	6960	775	225	83	142	59,48	22,99	17,53	22,02164
	13050	11250	1800	6820	715	285	38	202	65,78	17,84	16,38	23,07954
	14773	13070	1660	7270	788	212	72	139	61,47	18,44	20,09	22,33719
	13890	11960	1930	8110	688	312	106	206	73,16	10,49	16,35	27,88872
	17700	14860	2840	9320	728	272	92	180	65,16	22,43	12,41	23,47785
85 Menit	12690	10840	3510	6520	686	314	74	240	59,34	23,35	17,31	19,41499
	19850	16240	5730	8690	676	324	131	193	54,84	22,04	23,11	14,72944
	22240	17390	7060	9080	729	271	120	151	44,15	29,86	25,99	11,64042
	12460	10700	3120	5760	769	235	80	155	48,25	29,59	22,16	15,65253
	17700	14860	4310	9320	728	272	92	180	65,16	22,43	12,41	23,47785

Figure 5. RMS Potential in the Three Independent Variables

From the data in the table above, I will conduct a quantitative test using the Anova Test: Two-Factor With Replication to see whether the boiling time has a significant effect on the RMS potential.

Table 4. Annova: Two Factor With Replication

SUMMARY	TBS	TBR	Tankos	Berondolan	Daging Buah	Biji	Inti	Cangkang	L %	A %	N %	RMS %	Total
95 Menit													
Count	5	5	5	5	5	5	5	5	5	5	5	5	60
Sum	73400	63530	9870	36260	3743	1257	436	821	285,62	98,26	111,12	97,24544	189909,2
Average	14680	12706	1974	7252	748,6	251,4	87,2	164,2	57,124	19,652	22,224	19,44909	3165,154
Variance	6079550	6509230	240230	2551870	2018,3	2018,3	249,2	849,2	15,40438	23,95857	15,52613	4,050885	27642895
90 Menit													
Count	5	5	5	5	5	5	5	5	5	5	5	5	60
Sum	73053	63040	9970	38480	3694	1306	391	869	325,05	92,19	82,76	118,805	191421,8
Average	14610,6	12608	1994	7696	738,8	261,2	78,2	173,8	65,01	18,438	16,552	23,76099	3190,363
Variance	3366892	2012570	233380	1074830	1748,7	1748,7	660,2	1023,2	27,5376	25,04627	7,67512	5,65882	27076681
85 Menit													
Count	5	5	5	5	5	5	5	5	5	5	5	5	60
Sum	84940	70030	23730	39370	3588	1416	497	919	271,74	127,27	100,98	84,91522	225074,9
Average	16988	14006	4746	7874	717,6	283,2	99,4	183,8	54,348	25,454	20,196	16,98304	3751,248
Variance	18814270	9531180	2671130	2628380	1402,3	1302,7	624,8	1290,7	70,81157	15,43653	28,71748	20,87238	36269922
Total													
Count	15	15	15	15	15	15	15	15	15	15	15	15	
Sum	231393	196600	43570	114110	11025	3979	1324	2609	882,41	317,72	294,86	300,9656	
Average	15426,2	13106,667	2904,67	7607,33333	735	265,2667	88,2666667	173,93333	58,82733	21,18133	19,65733	20,06437	
Variance	9382074	5592995,2	2714912	1860463,81	1656,28571	1637,924	519,209524	972,35238	54,35499	28,45483	20,73429	17,14422	

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	13174681	2	6587341	4,25533387	0,01601339	3,058928
Columns	5,11E+09	11	4,6E+08	299,959783	2,3301E-93	1,855696
Interaction	37685406	22	1712973	1,10655764	0,34650508	1,616709
Within	2,23E+08	144	1548020			
Total	5,38E+09	179				

The ANOVA test data above shows that the duration of time significantly influences the potential for Palm Oil Yield (RMS). This is evidenced by the 0.05>P-value of 0.01601339.

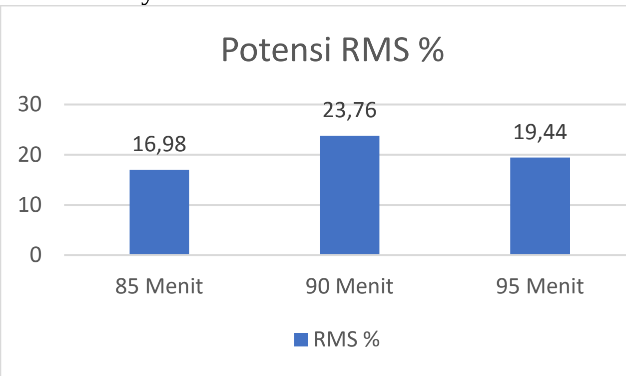

Figure 6. RMS Potential % Bar Chart

Based on experimental data, boiling for 85 minutes yielded an average palm oil yield of 16.98%. This figure indicates that even with such a short boiling time, the oil extraction process from fresh fruit bunches did not achieve optimal results. This could be due to the incomplete softening of the fruit flesh, resulting in much of the oil remaining bound within the fruit cells and not being fully extracted.

At 90 minutes of boiling, there was a significant increase in palm oil yield, averaging 23.76%. This 6.78% increase compared to 85 minutes of boiling indicates that the additional sterilization time had a positive impact on the oil extraction process. The longer boiling time allowed for more complete softening of the fruit flesh, allowing for easier rupture of the oil cells and more efficient oil extraction.

Interestingly, after 95 minutes of boiling, the palm oil yield actually decreased to 19.44%. While still higher than after 85 minutes, it represents a 4.32% decrease compared to the 90-minute boiling. This phenomenon suggests that excessively long boiling times can negatively impact the quality and quantity of the resulting oil, likely due to degradation or damage to oil components due to excessive heat exposure.

The practical implications in the field are significant. The results of this fieldwork experience can provide advice to Mayang PKS operational management that the 90-minute program could serve as a sound standard operating procedure (SOP) for optimizing CPO quality.

From an academic perspective, this research fills a local gap. Previous studies have focused on the general timeframe (45–60 minutes). This research provides a specific qualitative and quantitative analysis of the 85–95 minute timeframe, which has not been widely discussed locally.

The limitations of the study are acknowledged. The limited sample size and single location require further investigation into factors such as the influence of fruit fraction (ripeness), pressure, and other supporting stations. The internship also provides a hands-on learning approach. Students involved not only collect data but also understand the technical dynamics of boiling and quality parameters.
which is closely related to industry, providing added value to education.

5. Conclusion

The analysis concluded that boiling time significantly impacts palm oil yield potential, with an optimum value of 90 minutes. Boiling times that are too short result in low yields, while boiling times exceeding the optimum limit also tend to reduce the quality or yield of extractable oil.

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