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Minimize Oil Losses in Palm Oil Mill through Optimization of Sludge Separator Performance

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ABSTRACT

One of the most important clarification station engine parts for reducing oil loss is the sludge separator. The sludge separator uses high-speed centrifugal force to capture any oil that is still adhered to the sludge. This study aims to improve the working performance of sludge separator to minimize oil losses through variations in feeding rate, oil under flow and temperature of flow rate. The experiment was conducted at one of the palm oil mills in Central Kalimantan, with a capacity of 45 ton/h. Variations in sludge separator feed rates: 23, 25 and 27 tons/hour. Oil underflow variations: 5%, 6%, and 7%. Feed temperature variations are: 90°C, 93°C, and 95°C. Feed temperature variations: 90°C, 93°C, and 95°C. Based on research that has been done, using bait rate of 23 ton/h, temperature 90 °C, and oil underflows 5%, resulting in oil losses of 0.54% – 0.61%. This study has managed to lower oil losses in the sludge separator by 0.11 % and shows the level of stability below the standard that has been determined.

1. INTRODUCTION

Palm oil fruit that has been harvested, should be transported quickly to the palm oil mill to be processed into crude palm oil (CPO). The quality of fresh fruit bunches (FFB) processed in palm oil mills is directly proportional to the quality and yield of CPO produced. The process of transporting FFB to the plant is carried out to avoid a decrease in CPO quality caused by oxidation and hydrolysis reactions (Basyuni *et al*., 2017; Faridah *et al*., 2015; Krisdiarto & Sutiarso, 2016). The processing of FFB into CPO through several stages, namely sterilization, threshing, digestion, pressing, and Clarification (Azeman *et al*., 2015; Hafiz *et al*., 2016; Mba *et al*., 2015; Vincent *et al*., 2014).

The result of the extraction process at the press station is the nut, fiber, and CPO. CPO was produced from the press station, then purified at the clarification station. Nut and fiber will be processed to produce kernels (Halim *et al*., 2016) Clarification station is the stage of purification and separation of CPO, water, sludge, and non-oil solid (NOS). The processing at the clarification station is useful to produce CPO according to standards and minimize oil loss. Generally, every ton empty fruit bunch (EFB) requires as much as a ton of steam, for operational purposes in each station, boiler, and domestic needs (Renjani *et al*., 2020).

Based on its physical nature, CPO consists of several phases that are difficult to separate using only one way. Therefore, the separation treatment of the oil phase, the NOS phase and the water phase are carried out with several stages. The separation of oil from other liquid fractions is carried out by filtration, sedimentation, evaporation, and centrifugation (Foong *et al*., 2018; Renjani *et al*., 2020).

In Figure 1, the FFB Processing process into CPO occurs at the clarification station. Precisely, the clarification station consists of oil processing (light phase) and processing sludge (heavy phase). Sludge processing at the clarification station minimised the loss of oil that is still attached to the sludge. One of the most important machines in the clarification station is the sludge separator. Sludge separator-serves to catching oils that are still attached to the sludge by centrifugal force mechanism. The light phase, which was successfully catching, was sent to the continuous settling tank (CST) for precipitation or separation process between oil and sludge. Sludge that comes out of the sludge separator is then sent to the fat pit for liquid waste treatment (Anyaoha *et al*., 2018; Dharmawati *et al*., 2017; Widyowanti *et al*., 2019).

Sludge separator one of an important machine in palm oil mills, as it is the final stage of the process of oil separation on sludge. Sludge separator is one of the operating units in palm oil mills for separation and recovery of oil in water. In palm oil mills, oil losses resulting from sludge separators are always fluctuate (more than 0.7%) and to cross standard limits. Oil losses that to cross the standard threshold are certainly a poor performance sludge separator.

Relevant research related to sludge separator is (Sabri *et al*., 2019) which identifies the probability of failure and reliability of sludge separator in palm oil mills. Critical components that often suffer damage from sludge separators are bearings, seal rings, nozzles, bowl discs, and worm gear. Concerning sludge separator (Ramirez & Collins, 2018) managed to maximize the catching oil of sludge through different types, concentrations, and ratios of surfactant applications.

Based on previous research, there has been no research related to minimization oil losses on sludge separator in palm oil mills. Novelty of this research is to maximize the working performance of sludge separator in palm oil mills, the impact of palm oil mill is to minimize oil losses during EFB processing. This study aims to improve the working performance of sludge separator to minimize oil losses through variations in feeding rate, oil under flow and temperature.

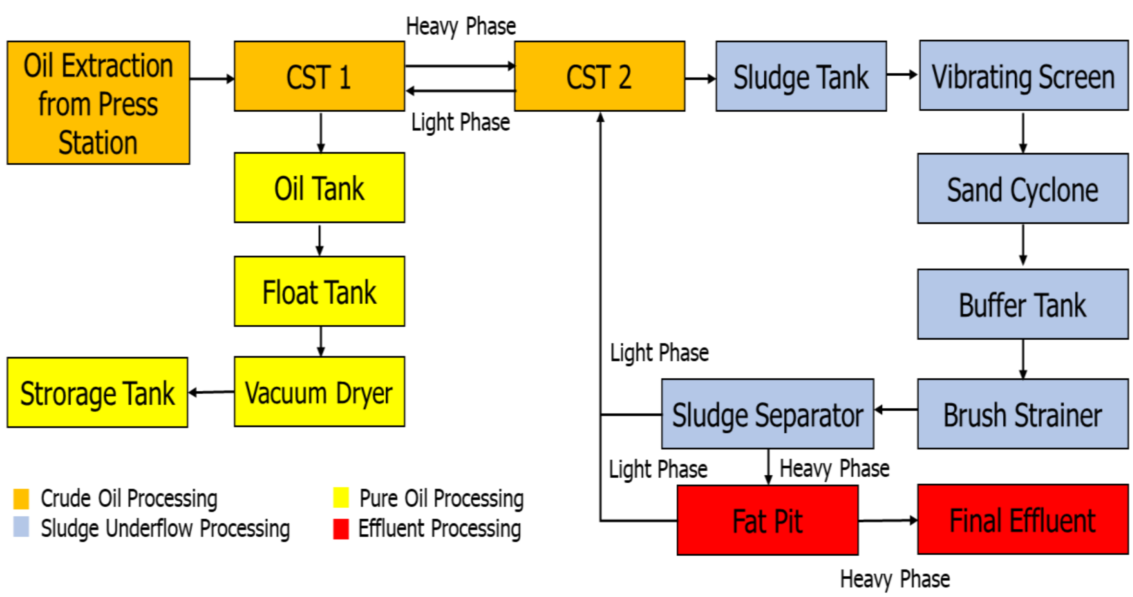

Figure 1. CPO processing at clarification station

2. MATERIALS AND METHODS

2.1. Material, Equipment, and Location

The research was conducted for three months at one of the palm oil mills of private companies in Central Kalimantan with a capacity of 45 ton/h. The equipment used in this research i.e., sludge separator GEA VDC 60-01-137 German, Centrifuge PLC 03 Taiwan, analytical scales Ohaus PA224 United States, oven Memmert UN30 German, and soxhlet extraction. The materials used are sludge underflow CST, heavy phase sludge separator, and n-Hexane. The research framework can be found in Figure 2.

2.2. Design of Experiment

The parameters observed in this study are: Oil under flow parameters used 5%, 6%, and 7%. Temperature variations feed 90°C, 93°C, and 95°C. Sludge separator feed rate: 23, 25, and 27 tons/h. Oil losses testing was conducted by extraction method and [20]. Potential oil losses are calculated based on a comparison between the performance results of the sludge separator before and after the experiment.

CST under flow oil level testing is conducted spinning test method using centrifuge PLC 03 to determine the percentage of oil, water, and emulsion contained in the underflow of CST. CST oil underflow of 10 ml is taken from the sludge skimmer in the CST, then inserted into the tube. The next stage inserts the tube into the centrifuge and performs the operation for 5 minutes, and after that remove it from the centrifuge. The sample will be separated according to the density of the fluid, then measure the composition of the fluid in percentage form (Juliano *et al*., 2012; Khalis *et al*., 2015).

2.3. Statistical Analysis

Sampling points are performed on under flow CST and heavy phase sludge separators, which are performed twice for one production process. Two hours after the operation, samples were obtained at a palm oil mill that was regularly working. The experiment was conduct used the Random Group Design (RGD) method. The method used to analyze the data in this study is quantitative data analysis through simple statistics. This study uses graph analysis method, as a method to analyze data changes (Renjani *et al*., 2020). An analysis of variance (ANOVA) was carried out to determine oil losses there was a significant difference in temperature of flow rate and oil underflow composition under different Feed flow rate. The difference was considered statistically significant at a 95% confidence interval ($p < 0.05$).

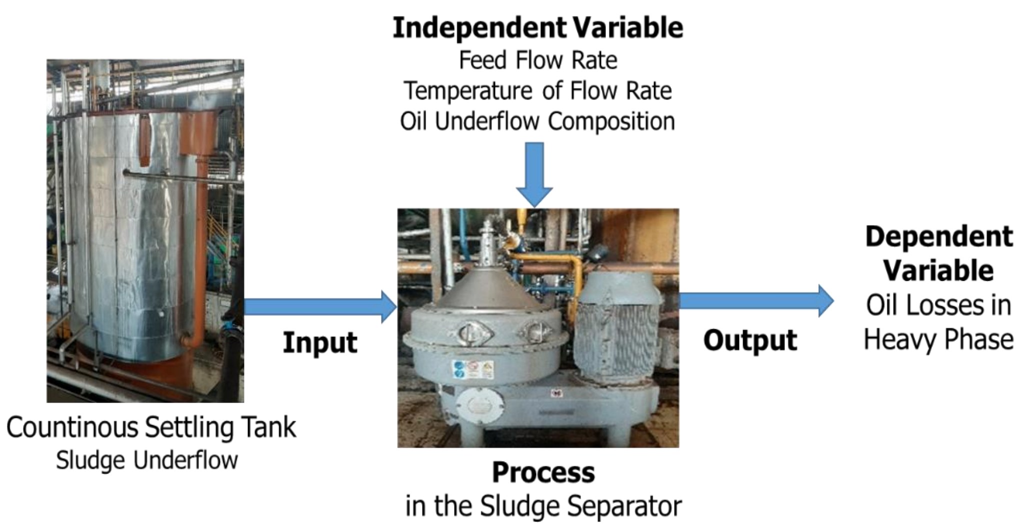

Figure 2. Research framework to maximize sludge separator performance

3. RESULTS AND DISCUSSION

3.1. Working Principle of Sludge Separator

Sludge separator with theoretical capacity of 30 ton/h, 6060 rpm rotation, standard feed rate of 25 ton/h, feed temperature given approximately 95°C, and oil losses standard of 0.70%. The working principle of sludge separator is by rotating the fluid at a high speed (Sabri *et al*., 2019). As a result of high rotation, light phase fluid weighing <1.0 N/cm^3 gathers in the center. Through a multilevel disk light phase that is in the middle of the sludge separator round, successfully quoted then sent to CST for further processing (Ramirez & Collins, 2018).

Sludge (heavy phase) which has a type weight of >1.0 N/cm^3 thrown into the wall bowl and out through nozzles. Heavy phase that comes out of the nozzle sludge separator, then enters the waste treatment process that is the fat pit pond. Maintenance sludge separator is done by washing the nozzle every 5 hours of operation every day, and periodically 2 times a week is done washing all parts of the sludge separator (Sabri *et al*., 2019). The image of sludge separator work scheme is presented in Figure 3.

Selection of sludge separator in the oil in water citation process because of its good working performance compared to centrifuge sludge. Between sludge separator and sludge centrifuge both use separation principle by centrifugation, but sludge separator utilizes much higher rotation speed. However, some considerations for using a semi-or sludge for palm oil mill require more electrical energy than centrifuge sludge.

3.2. The Effect of Feed Rate and Sludge Underflow Composition on Oil Losses

Sludge separator is a fluid mix separator machine using high speed disc and spin stacks. Fluids in the form of oil mixtures and sludges can be separated using a sludge separator. According to (Merkus & Meesters, 2016) large density differences in feed are an important factor in the separation process. CPO and sludge have different densities. CPO has a density of 0.91 kg/m^3 and sludge has a density of 1.1 kg/m^3 (Gong *et al*., 2013).

Figure 4 shows that a feed rate of 23 ton/h with the composition of underflow obtained makes the separator performance lighter and will get low oil losses. The amount of water content in the sludge underflow will help the separation process in the sludge separator because the more water, the lower the viscosity of the sludge. Low viscosity impacts the performance of the sludge separator to be light. However, the increase in the rate of CST underflow feeding resulted in increased oil losses.

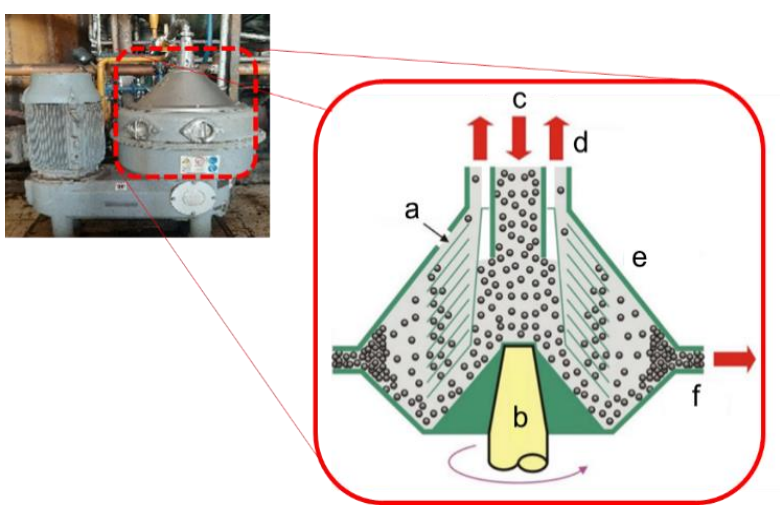

Figure 3. Catching oils scheme on sludge separator: a. conical disc stack; b. bowl drive;
c. feeding; d. centrate; e. imperforate bowl; f. nozzle discharge
Source: Merkus &Meesters (2016) has been modified

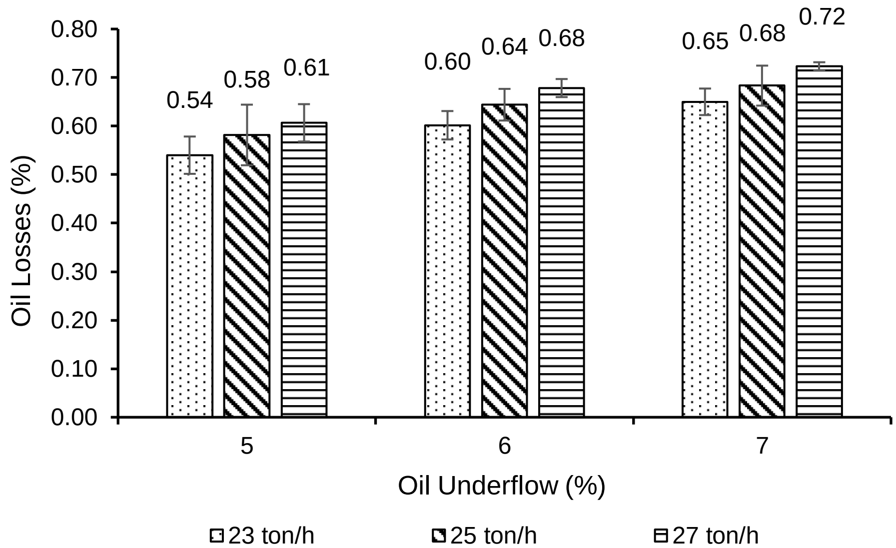

Figure 4. Oil losses on sludge separator against change in feed rate

The data showed that at a feed rate of 25 ton/h, the lowest oil losses obtained at oil under flow 5% which is 0.58%±0.03 light phase content contained in the sludge. But at a feed rate of 25 ton/h has more oil losses than at the rate of separator feed 23 ton/h that is with an average oil loss of 0.54%±0.05. This can be due to the different composition of feed and the lower rate of the given feed. Sludge separator on feed 23 ton/h resulted in a lighter separator workload compared to feed rate 25 and 27 ton/h.

The high oil losses at a feed rate variation of 27 ton/h, indicating that the large amount of fluid entering the sludge separator makes its performance to be not maximal. If the sludge separator does not work properly, which causes the amount of oil losses in water to increase and is a loss for the palm oil mill. Oil losses that occur during the palm oil processing process is a major problem and has the potential to cause a large loss of profit (Foong *et al*., 2018).

Based on the results obtained, if the oil under flow obtained is low, then the loss of oil obtained in the sludge separator will be low. The amount of oil underflow is influenced by the long-term deposition factor of oil skimmer arrangement in CST, and the administration of delusional water. In addition, the feed rate of the Sludge separator is small (23 ton/h), hence the oil loss on the sludge separator is low. So, before the separation process is done by separator must control oil under flow on CST and feed rate Sludge Separator.

The ANOVA test's findings on the relationship between of the sludge separator feed rate and the oil in oil under flow to the oil losses of the sludge separator's oil losses F count > F table, then variations in sludge separator feed rate and oil in sludge separator has a significant. The F-value was obtained at 0.01, which means P-value < value (a) 0.05, then the treatment had a significant.

3.3. The Effect of Feed Rate and Underflow Temperature on Oil Losses

Palm oil processing process, temperature is one of the determining factors of success in obtaining yield. The right temperature, impacting the stability of the FFA, facilitates the separation process, and produces minimum oil losses (Vincent *et al*., 2014). Based on its working principle, sludge separator serves to quote oil in water or emulsion oil in water (o/w), i.e. oil granules are spread into water granules. In the type of oil in water emulsion, oil is the dispersed phase while water is a dispersion medium (Akbari & Nour, 2018). The form of emulsion is caused by several factors, namely: two liquids that do not dissolve each other (Immiscible); the occurrence of stirring process (agitation), the presence of emulsifying agent; and the temperature of the processing process is too low. So, if the emulsion concentration in the oil increases, the oil losses will increase (Hariyatno *et al*., 2021).

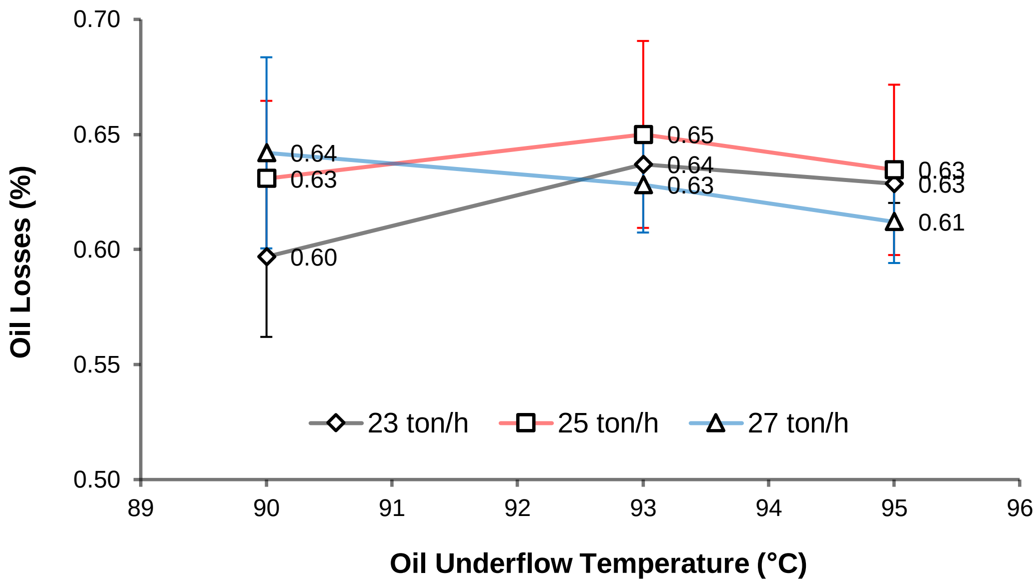

Figure 5. Oil losses on sludge separator against feed temperature

Standard oil losses on sludge separator were below 0.7%. Based on Figure 5 shows that the performance of the sludge separator is already at its best in separating oil in water. However, it is necessary to know the right temperature for optimal palm oil mill operation. Temperature is optimal to produce the lowest oil losses for sludge separator operations that is at a feed rate of 23 ton/h and a temperature of 90°C. At that rate and temperature obtained oil losses by an average of 0.60%±0.02.

This study showed that the change in the temperature of the feed given to the sludge separator did not provide enough evidence as a significant factor of success in separating emulsions. The temperature range used does not differ much and is still within the temperature range suggested by (Salhin *et al*., 2013) and the quality of FFB processed daily varies, resulting in still fluctuating oil losses (Andrew *et al*., 2017). When viewed from the physical properties of heavy phase feed to sludge separator, temperature affects density and viscosity. High viscosity can generally facilitate the separation process. High viscosity sludge separator feed can be obtained by increasing the temperature on the buffer tank. 7.

The increase in oil losses at 93°C occurs because the emulsion used as feed for sludge separator is still high, making it difficult to separate. The use of temperatures that are too high is suitable for separation but also has a negative impact, namely triggering oxidation reactions, polymerization and thermal degradation, which causes changes in physical properties such as CPO to burn, causes crust in heating, and losses during sale due to decreased quality of CPO produced (Renjani *et al*., 2020; Shehu *et al*., 2019).

The results of ANOVA test with a comparison of feed rate and sludge separator feed temperature obtained F count 0.83 and F table 5.14, meaning that F count <F table, then the treatment has no significant effect. The F-value was 0.47 which means that the P-value > value (α) was 0.05, so the treatment had a significant.

3.4. Analysis of Sludge Separator Operational Time on Feed Rate

Sludge separator with theoretical capacity of 30 ton/h. Based on the rate of feed used, actual capacity can be obtained at feed rates of 23 ton/h, 25 ton/h, and 27 ton/h. If the palm oil mill operates within a day then the potential of sludge production is 53% or as much as 424 ton sludge/day with 800 tons of FFB.

The feed rate of sludge separator is 23 ton/h, then sludge separator process sludge as much as 460 ton/day (for 20 h operations). Based on these results, the sludge separator feed rate of 23 ton/h has been able to reach the palm oil mill processed throughput in a day. Based on the processing of sludge 424 ton/day, the sludge separator with a feed rate of 23 ton/h process sludge with enough time 19 hours.

Similarly, the sludge separator feed rate is 25 ton/h and 27 ton/h. Based on the processing of sludge 424 ton/day, the feed sludge separator 25 ton/h is able to process sludge with a time of 17 hours and feed sludge separator 27 ton/h with a time of 16 hours. Based on the results of sludge processing calculation on the overall variety of feed (23, 25, and 27 ton/h), categorized as the rate of recommended as the standard processing operation in the sludge separator. However, when connected between the feed rate and oil losses, using a feed rate of 23 ton/h becomes an operational standard recommendation and able to adequately process sludge per day.

3.5. Potential of Oil losses

Oil losses are inevitable from a process of processing agricultural materials, including the process of palm oil processing. However, oil losses can be minimized in order to reduce losses. Oil losses that occur in palm oil mills include those in condensate sterilizers, EFB, unstripped bunches (USB), fiber press, oil losses at clarification station (Andrew *et al*., 2017).

Based on observations made (Figure 6) shows trend oil losses after using feed rate of 23 ton/h, temperature 90°C, and oil underflow 5%, resulting in oil losses of 0.54-0.60%. Before this research, oil losses in the sludge separator showed fluctuations and did not meet the expected standards.

The amount of oil losses obtained after improvisation, has given an indication that oil losses have been controlled, and do not exceed the standard (< 0.7%) that has been determined. Oil losses after feeding changes, CPO temperature, and oil underflow, decreased on average by 0.11%. Through this experiment the performance of sludge separator can be suggested as the standard operation of sludge separator in palm oil mills.

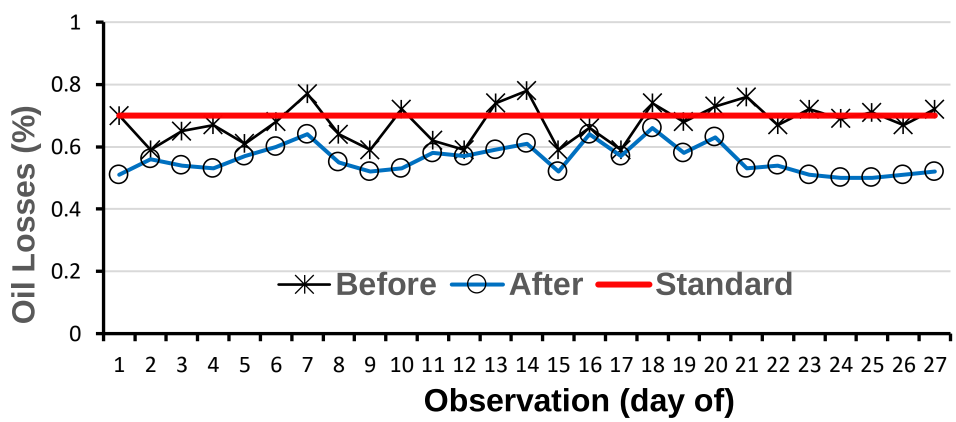

Figure 6. Oil losses sludge separator after and before research

4. CONCLUSIONS

The optimal condition for separator sludge operation is to use a feed rate of 23 ton/h with oil underflow of 5% to produce the lowest oil losses of 0.54%. The optimal temperature in lowering oil losses is 90°C. The use of feed rate of 23 ton/h, temperature of 90°C, and oil underflow of 5%, resulted in oil losses of 0.54–0.61%. The advantage of this study is that it has managed to reduce oil losses in the sludge separator by 0.11% and shows a stable level below the standard threshold.

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