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Prototype of traditional mined crude oil distillation technology

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ABSTRACT

Crude oil or petroleum is a complex hydrocarbon compound consisting of carbon, hydrogen, and a small number of other elements such as oxygen, nitrogen, sulfur, and several metals including Fe, Na, Va, all of which are impurities. In Wonocolo there is a traditional oil mining relic from the Dutch era carried out by local residents. Oil from traditional mining is processed by residents into diesel fuel by simple distillation. Petroleum distillery equipment which is still simple has several drawbacks, namely the process is carried out openly, condenser heat transfer is not optimal along with the distillation process, and causes air pollution in the surrounding environment. This study aims to design a laboratory-scale distillation prototype that has the characteristics of setting the cooling water discharge in the condenser, the effect of time on the distillation capacity, and setting the boiler temperature on the prototype. The results of the prototype design for crude oil distillery have the following specifications; the capacity of the petroleum distillery process is 5000 ml in the boiler, the boiler material uses stainless steel 201. The condenser uses a shell and tube type with counter flow flow direction, with a number of tubes 12 with a diameter of 19 mm and a length of 500 mm.The prototype characteristics in the 3-7 discharge test have the highest heat transfer value at 7 liters/minute discharge, which is 210.8 W and the lowest is 50.19 W at 3 liters/minute discharge. Characteristics of distillation time at 174.48 minutes can produce 3486.67 ml of diesel oil with a kitchen temperature of 350 ^oC. The characteristics of the kitchen temperature control from 310 ^oC, 330 ^oC, 350 ^oC, 370 ^oC, and 390 ^oC, the highest diesel oil was 4350 ml at 390 ^oC and the lowest was 1670 ml at 310 ^oC.

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INTRODUCTION

Oil mining in Wonocolo is an old well mining that is a relic of the Dutch colonial era which is still carried out today. The oil mining process is carried out by lowering a pipe that is connected using a slink rope into the well, at the bottom of the pipe there is a valve that can be opened if pressed so that crude oil in the well can enter through the valve. The depth of oil mine wells is 200 - 400 m but miners only mine at a depth of 50 - 150 m, due to the limited capabilities of the tools used (Marwoto, 2012: 1-

5). Then the sling is pulled using the power of an old truck engine or diesel engine. Oil is removed from the pipeline through a valve at the bottom of the pipe and then flowed into a temporary holding pond to separate crude oil from water. The separation of water and oil is done by letting stand for a moment crude oil that is still mixed in water in the storage pond because of the difference in the specific period, the petroleum will be above the surface of the water. Miners take oil above the water level in temporary holding ponds.

Crude oil or crude oil is a mixture of hundreds of hydrocarbon components ranging from small methane, with only one carbon atom, to large component content of 300 or more carbon atoms (Treese, et al, 2015: 2-4) Crude oil that does not contain water is distilled. Distillation is the process of separating two or more components in a solution by utilizing differences in the boiling points of components (KEMENDIKBUD, 2014: 12-14). To get fuel oil in the form of diesel oil. The crude oil processing process is carried out using traditional refining equipment. The refining process is carried out by boiling crude oil on drums embedded in the ground. The boiling drum is initially left open, then the boiling drum is covered with a cover plate and then filled with soil. Then the oil boiling steam that passes through the drum cap hole is flowed into an iron pipe that passes through the water pool as oil condensation, at the end of the cooling pipe there is a reservoir of refined oil. Fuel for refining uses wood for distilleries far from the mine site and some use gas from wells at refineries near the mine site.

The root of the problem in this study is the refining of crude oil from traditional mines in Wonocolo, Bojonegoro regency. The problem is that distillation that is not optimal has an impact on air pollution in the form of hydrocarbons, H2S, CO2, and CO which are harmful to living things. Hydrocarbon gas consists of hydrogen and oxygen elements Hydrocarbon gas is carcinogenic, meaning it can cause cancer in humans. H2s gas is a colorless gas, heavier than air, highly toxic, corrosive and odorous. CO2 gas if it is in the ozone layer can cause global warming. CO gas in the environment can interfere with human health and can cause death (Sulistyono, 2015: 23-50). Another impact is the acquisition of inappropriate oil.

The next problem is not optimal crude oil refining time. The impact of non-optimal refining time will lead to inefficient use of fuel for the refining process. It can also damage refining equipment. The next problem is that it is still rare or no one has researched the technology of refining crude oil from traditional mines in Wonocolo.

The purpose of this study is to obtain a form of crude oil refining that is specialized on a laboratory scale. Obtain prototype characteristics that include the effect of condenser water discharge on heat transfer efficiency. The effect of time on oil refining capacity. The effect of temperature on distillation results.

METHOD

The French method begins with the determination of needs and ends with a working drawing. The design stage of building a prototype of crude oil refining technology from traditional mining can be seen in figure 1

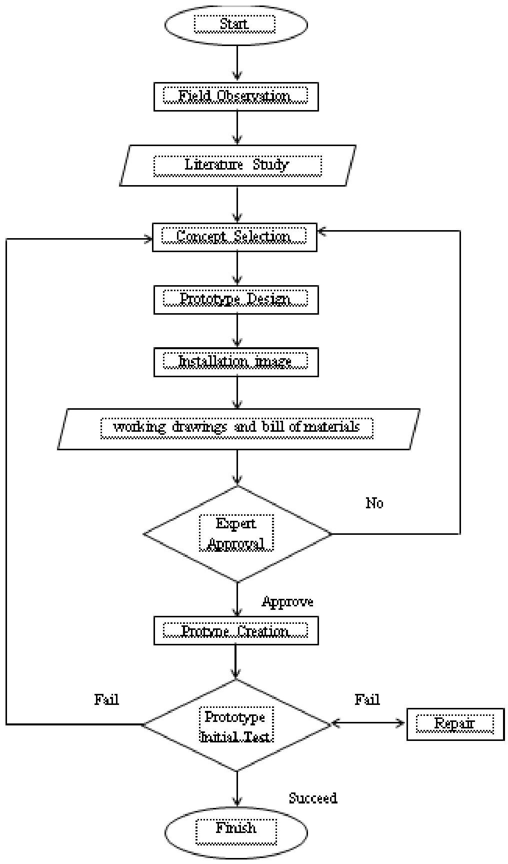

Figure 1. Design Flow Chart

Design

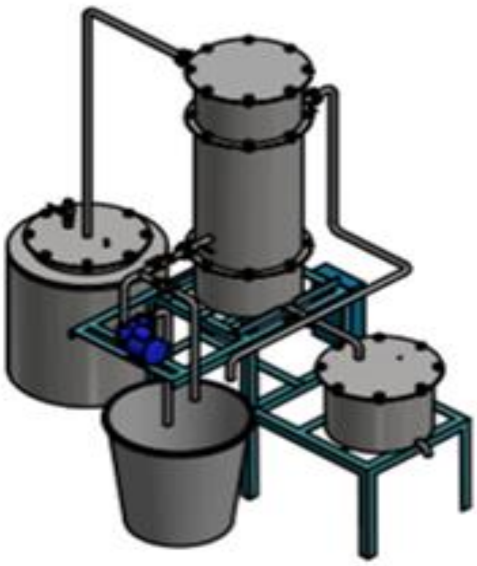

Figure 2. Crude Oil Refining Prototype Design

Boiler

Figure 3. Boiler

A boiler is a place to evaporate crude oil. The first thing in designing is to determine the draft pressure that the boiler can withstand. So that the calculation of the boiler body is carried out with equation 1:

$$t=\frac{P\ r_i}{S\ E-0,6P} \qquad \text{.................. (1)}$$

(ASME, 2007, & Callister, W. D., & Rewisch, D. G., 2010)

$$t=\frac{303\ 975\ Pa\times 0,15\ m}{103.10^6\ Pa\times 0,85-0,6\times 303\ 975\ Pa}$$

$$t=\frac{45\ 596,25}{87\ 367\ 615}$$

$$t=5,22\ .\ 10^{-4}\ m=0,522\ mm\approx 1,2\ mm$$

Condenser

Figure 4. Condenser

A condenser is a part of the distillation process that serves to condense steam, or to convert steam into a search by heat transfer. The condenser design process begins with calculations carried out with formulas. Then proceed with the design of the kondesnor design drawings used. Calculate the heat loss received by the fluid flow of water using (Incopera, dkk, 2007):

$Q_c = m_c c_{pc}(T_{co} - T_{ci})$.......................... (2)

The following is the calculation in designing the condenser, the working temperature targeted at the condenser as follows.

Th_i = 350 °C = 623 K Tc_i = 25 °C = 298 K

Th_o = 270 °C = 543 K Tc_o = 70 °C = 343 K

The properties of water at 320 K are as follows

ρ = 988,50 kg/m^3

c_{pc} = 4182,5 J/kg K

k = 0,64 W/m K

μ = 5,5718 kg/ms

Pr = 3,63

m_c = 5 liter/minute = 0,082 kg/s

The properties of diesel fuel at 583 K are as follows

ρ = 420 kg/m^3

μ = 7 . 10^{-5} kg/ms

k = 0,03 W/mK

c_{ph} = 3300 J/kg K (Reitz,dkk, 2008)

Qh = Qc .... (3)

$Qc = m_c \cdot C_{pc} (T_{co} - T_{ci})$ ....(4)

Qc = 0,082 . 4182,5 (343-298)

Qc =342,9 (45) = 15430,5 W

The vapor flow rate on the condenser is calculated by the following equation

Qh = Qc ....(5)

$Q_k = m_h .l$ ....(6)

Q_k = 0,058 . 250 000

Q_k = 14 500 W

$Q_{tot} = Q_c + Q_k$ ....(7)

Q_{tot} = 15 430,5 + 14 500

Q_{tot} =29 930,5 W

Calculation of LMTD logarithmic mean temperature difference. Here's the equation for calculating the average temperature difference.

$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]}$ ....(8)

$\Delta T_1 = Th_i - Tc_o = 623 - 343 = 280\ K$

$\Delta T_2 = Th_o - Tc_i = 543 - 298 = 245\ K$

$$\Delta T_m = \frac{280\text{-}245}{\ln \frac{280}{245}}$$

$$\Delta T_m = \frac{35}{\ln 1{,}14}$$

$$\Delta T_m = \frac{35}{0{,}13}$$

$$\Delta T_m = 269{,}23\ K$$

$$P = \frac{Tc_o - Tc_i}{Th_o - Tc_i} = \frac{343 - 298}{543 - 298} = \frac{45}{245} = 0{,}18$$

$$R = \frac{Th_i - Th_o}{Tc_o - Tc_i} = \frac{623 - 543}{343 - 298} = \frac{80}{45} = 1{,}78$$

So, from the calculation above the P value is rounded to 0.2 and the R value is rounded to 2 then the Fc value seen from Figure 5 is 0.95.

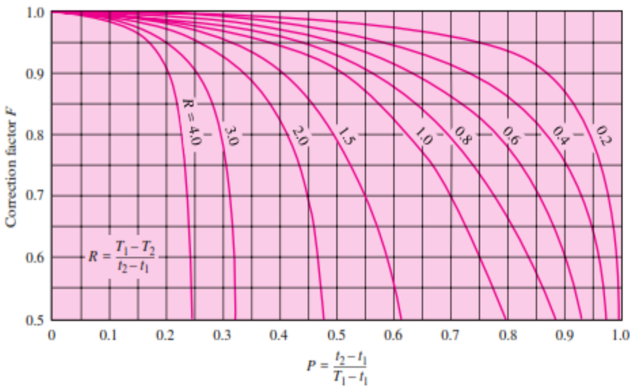

Figure 5. Graph Of Fc Correlation Factor (Holman, 2010)

Calculate the reynold number (Re) using the following equation

$$R_e = \frac{\rho_h\ v\ d_i}{\mu} \qquad \text{...............(9)}$$

$$R_e = \frac{420 \times 0{,}058 \times 0{,}017}{7\ .10^{-5}}$$

$$R_e = \frac{0{,}414}{7\ .10^{-5}}$$

$$R_e = 5\ 914{,}29$$

Counting Prandlt number

$$Pr = \frac{\mu \quad Cph}{k} \qquad \text{...............(10)}$$

$$Pr = \frac{7.\ 10^{-5} \times 3300}{0{,}03}$$

Pr= 7,7

Re > 4 x 103 so the flow is turbulent so to calculate the nuzelt number using the following equation (11).

$$Nu=0{,}023\ Re^{0,8}Pr^{0,4} \qquad ....(11)$$

$$Nu=0{,}023\times 5\ 914{,}29^{0,8}\times 7{,}7^{0,4}$$

$$Nu=0{,}023\times 1\ 041{,}17\times 2{,}3$$

$$Nu=55{,}1$$

Calculate the coefficient of heat transfer by convection on the condenser with the following equation.

$$h_i=Nu\frac{k}{d_i} \qquad ....(12)$$

k = 16,3 W/mK

h_i = Nu . k / d_{in} = 55,1 . 16,3 / 0,017 = 52 831,2 W/m^{2}K

h_o = Nu . k / d_{out} = 55,1 . 16,3 / 0,019 = 47 270 W/m^{2}K

Calculates the total heat transfer coefficient by using the following formula.

$$U=\frac{1}{\frac{1}{h_i}+\frac{A_i\ln(^{r_o}/_{r_i})}{2\pi k d_o}+\frac{A_i}{A_o}\frac{1}{h_o}} \qquad ....(13)$$

$$U=\frac{1}{\frac{1}{h_i}+\frac{\pi d_i\ln(^{r_o}/_{r_i})}{2\pi k d_o}+\frac{\pi d_i}{\pi d_o}\frac{1}{h_o}}$$

$$U=\frac{1}{\frac{1}{52\ 831{,}2}+\frac{\pi\ 0{,}017\ \ln(^{0,0095}/_{0,0085})}{2\ \pi\ 16{,}3\ .\ 0{,}019}+\frac{\pi\ 0{,}017}{\pi\ 0{,}019}\frac{1}{47\ 270}}$$

$$U=\frac{1}{1{,}9\ .\ 10^{-5}+\frac{0{,}05\ \ln(1{,}1176)}{1{,}9}+\frac{0{,}05}{0{,}06}2{,}1\ .\ 10^{-5}}$$

$$U=\frac{1}{1{,}9\ .\ 10^{-5}+\frac{0{,}01}{1{,}9}+0{,}83*2{,}1\ .\ 10^{-5}}$$

$$U=\frac{1}{1{,}9\ .\ 10^{-5}+526{,}3\ .\ 10^{-5}+1{,}8\ .\ 10^{-5}}$$

$$U=\frac{1}{530\ .\ 10^{-5}}=188{,}7\ W/m^2K$$

Calculates the surface area of total heat transfer by using the following equation.

$$A=\frac{Q_{tot}}{U\ Fc\ \Delta Tm} \qquad ....(14)$$

$$A=\frac{29\ 930{,}5}{188{,}7\times 0{,}95\times 269{,}23}$$

$$A=\frac{29\ 930{,}5}{48\ 276{,}1}$$

$$A=0{,}62\ m^2$$

Total condenser pipe length

$$L = \frac{0,62}{\text{Inner pipe circumference}} \quad \text{................(15)}$$

(Mustaqim, 2015)

$$L = \frac{0,62}{0,11}$$

L=5,6 m = 6 m

The sum of condenser pipes with a shell height of 0.5 m.

$$n = \frac{\text{total length of pipe}}{\text{high shell}} = \frac{6\text{ m}}{0,5\text{ m}} = 12 \quad \text{……........(16)}$$

Prototype Testing

Prototype testing was carried out by cooking 5 liters of crude oil in a boiler. Then set the thermostate at boiler temperature of 350 oC, in accordance with atmospheric distillation standards in the industry. The refining process is carried out until the diesel oil yield stops dripping from the temporary reservoir. When diesel oil is no longer out of the temporary reservoir, the prototype testing process ends. After initial testing, a review of the characteristics of the prototype was carried out.

RESULTS AND DISCUSSION

Figure 6. Crude Oil Refining Prototype

The design of crude oil refining prototypes on a laboratory scale uses the principle of simple distillation, and the method used is batch destillation. This prototype design has dimensions of height 1471.8 mm, width 961.8 mm, length 1566.6 mm. The heat source uses a tube type heater with a power of 4500 W. The power cable used for heater installation is a fiber type cable with a size of 2.5 mm. Using a pump to circulate condenser cooling water, water circulated approximately 50 liters, 30 liters in the condenser, and 20 liters in the reservoir. The following are the specifications of the components of the crude oil refining prototype.

Test Analysis of the Effect of Cooling Water Discharge on the Effectiveness of Heat Transfer

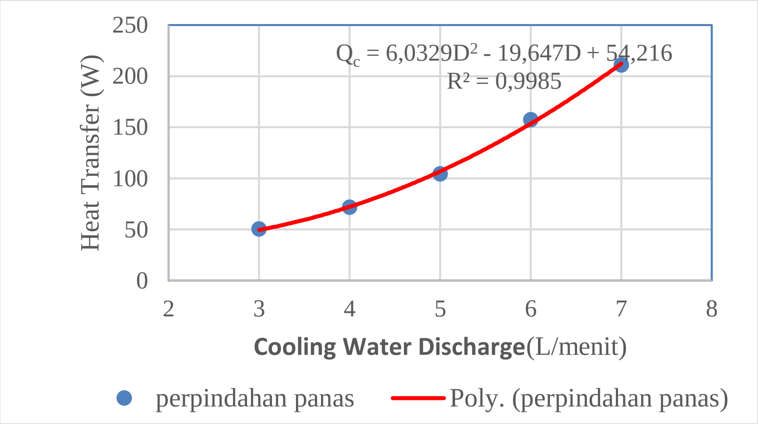

Figure 1**.** Results of the Effect of Cooling Water Discharge on the Effectiveness of Heat Transfer

Figure 1 shows that the discharge of cooling water to the heat transfer efficiency in the condenser of the crude oil refining prototype produces the following graph of the quadratic function.

$$Q_c = 6{,}0329D^2 - 19{,}647D + 54{,}216$$

Information:

Qc = Heat split received by cooling fluid (W)

D = Cooling water discharge (liters / minute)

The quadratic function equation shows the value of heat transfer obtained from the distillation process if one of the variations in cooling water discharge is entered in the equation. The effect of cooling water discharge on condenser heat transfer efficiency from prototype distillation can be known how strong the correlation with the interpretation value R^2. The R^2 value of graph 1 obtained 0.9985 can be concluded that the effect of the relationship of refining time on the oil capacity of distillation is significant.

Analysis of the Effect of Refining Time on the Oil Capacity Obtained

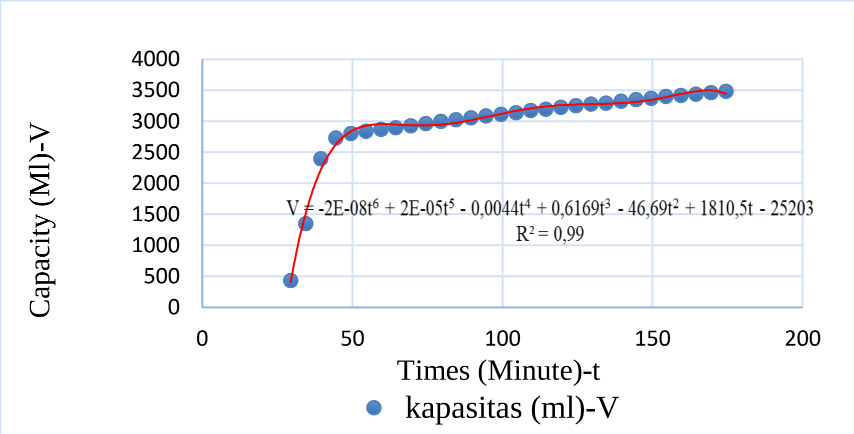

Figure 2**.** The result of the effect of refining time on the oil capacity obtained

Figure 2 shows that the distillation time to the amount of distilled oil capacity obtained produces the following graphs of the quadratic function.

$V = -2E\text{-}08t^6 + 2E\text{-}05t^5 - 0{,}0044t^4 + 0{,}6169t^3 - 46{,}69t^2 + 1810{,}5t - 25203$

information

V = oil capacity (ml)

t = distillation time (minutes)

The quadratic function equation shows the volume of oil obtained from the distillation process if one time is entered in the equation. The effect of refining time on the yield capacity of oil obtained from distillation can be known how strong the correlation with the interpretation value R2. The value of R2 on the effect of time on the yield capacity of oil from distillation graph 2 is obtained 0.99, it can be concluded that the effect of the relationship of refining time on oil capacity from distillation is significant.

Analysis of the Effect of Temperature on the Results of Refining Crude Oil from Traditional Mining

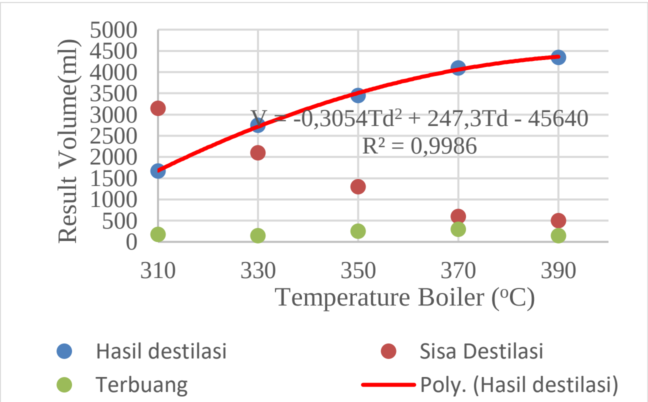

Figure 3**.** The Results of the Effect of Temperature on the Refining of Crude Oil from Traditional Mining

Figure 3 shows that the temperature of the kitchen against the amount of oil obtained produces the graph of the quadratic function as follows.

$$V = -0{,}3054Td^2 + 247{,}3Td - 45640$$

information:

V = Volume of oil obtained from distillation

Td = Kitchen temperature

The quadratic function equation shows the volume of oil obtained from the distillation process if one of the temperature variations in the equation is inputted. The effect of variations in kitchen temperature on oil results obtained from distillation can be known how strong the correlation with the interpretation value of R2. The R2 value on the influence of temperature variation on oil yield from distillation graph 3 is obtained 0.9986, it can be concluded that the effect of the relationship of temperature variation on oil yield from distillation is significant.

Design Validation by Experts

Validation of the design design of the prototype of refining crude oil from traditional mining was carried out by design and energy experts lecturers in Mechanical Engineering, Semarang State University. Design validation data is obtained by providing a form that has 6 assessment indicators, namely, design, construction, use, suitability, performance, and product. Based on the first expert assessment, the design indicators are rated as good. Construction indicators of crude oil refining prototypes are considered good. Indicators of the use of prototypes for laboratory scale are considered good. Indicators of design suitability and prototype design results are well valued. The performance indicators of the prototype are considered good, and the product indicators or results of the crude oil refining prototype are rated good.

CONCLUSION

The design results of the crude oil refining prototype with the following specifications: the boiler has specifications of stainless steal 201 material, working capacity of 5 liters of crude oil, maximum capacity, 21 liters diameter 300 mm, height 300 mm, working temperature 30 – 400 oc; condenser has specifications of stainless steal material 201diameter 300 mm, height 850 mm, tube diameter 19 mm, shell height 500 mm, tube height 500 mm, number of tubes 12, hot fluid temperature 35 – 310 oc, cold fluid temperature 35 – 44 oc, circulating water volume 25.8 liters; The shelter has specifications of stainless material Stell 201, volume 15.5 liters, diameter 300 mm, height 220 mm; The frame has specifications of iron material l, thickness 2 mm, overall height 581 mm, overall length 860 mm, overall width 700 mm; tube-type heater with a power of 4500 W; water pump with a power of 125 W; type K thermocouple; thermostate; autonics tcn4s-24r, ssr mgr 60 A; water reservoir volume 20 liters; Flow Meter 5 GPM.

The characteristic results of crude oil refining prototypes specifically for laboratory scale are as follows: The effect of the relationship between cooling water discharge and efficiency in heat transfer is significant. The results showed that the greater the water discharge, the greater the heat transfer value, the greatest heat transfer value occurred at a discharge of 7 liters / minute with a value of 210.8 W. The influence of the relationship between distillation time and the oil capacity obtained was significant. The results showed the characteristics of the crude oil refining prototype began to produce diesel oil at 24.48 minutes with a boiler temperature of 217 oC. The resulting oil began to flow from minutes 24.48 to 59.48. Then drip until the distillation process is complete. The effect of the relationship between distillation kitchen temperature and oil yield is significant. The results showed that the greater the temperature used, the greater the volume of oil obtained. The most oil is obtained at a temperature of 390 oC which is 4350 ml, while the least at a temperature of 310 oC is 1670 ml.

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