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Heating Analysis Of Used Cooking Oil Refining Equipment Using Activated Charcoal With A Heating Element Capacity Of 20 Liters / Process

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ABSTRACT

Cooking oil that is used repeatedly is very harmful to health. The use of cooking oil repeatedly and continuously in the frying process will result in a degradation reaction, thereby reducing the quality of the cooking oil. Therefore, the purification of used cooking oil needs to be done with the aim of making use of consumable oil and to reduce the risks that can endanger health if using used oil repeatedly. The purpose of this research is to find out the heat energy produced by the band heater during the refining process of used cooking oil with activated charcoal. Knowing the effect of band heater power on the heating time of used cooking oil in the refining process. Changing the ratio of oil composition to activated charcoal to visual purification results. This research method uses a comparison between testing with numerical simulations using Ansys. Based on research, it is known that the greater the heating power used, the less time it takes to heat the oil up to 100^{o}C, the time needed for the process of refining used cooking oil is the fastest, namely for 2 hours 30 minutes with a composition of 80%: 20% with the heat flux used 5500 W/m^2, and which required a longer time of 4 hours 45 minutes with a composition of 60% : 40% with the heat flux used 3500W/m^2. Visually, the best purification results were obtained, namely with a composition of 70% used cooking oil and 30% activated charcoal with a yellow-orange color, while visually the poorer results were obtained with a composition of 80% used cooking oil and 20% activated charcoal with a reddish yellow color. Thus the composition ratio between used cooking oil and activated charcoal affects the results of the refining process, where visually the best composition ratio is 70% used cooking oil and 30% activated charcoal with a stirring speed of 120 rpm. The highest percentage of free fatty acid (BA) reduction in this study was 73.05% and the highest percentage of peroxide value (PV) reduction was 56.88%.

INTRODUCTION

In Indonesia, cooking oil is used as a staple ingredient in cooking. Cooking oil is one of the nine basic necessities of Indonesian society. Almost all households in Indonesia cook using cooking oil. The most widely consumed type of cooking oil in Indonesia today is palm oil. Cooking oil can be used as a medium for frying food, such as tofu, chicken and various other foods. The large amount of demand for fried food is an evidence of how much fried food is consumed by people of all ages. In frying, cooking oil functions as a heat-conducting medium, adds savory taste, adds nutritional value and calories in food ingredients (Ketaren, 2008). In its application in the community, many people use cooking oil repeatedly. Because it feels more economical when compared to throwing away the remaining cooking oil. However, there are many dangers that lurk if someone continues to consume food fried in used cooking oil. Cooking oil that is used repeatedly is very harmful to health. Repeated and continuous use of cooking oil in the frying

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process will result in degradation reactions that reduce the quality of cooking oil.

According to Julianus (2006) when viewed from its chemical composition, used cooking oil contains carcinogenic compounds, which occur during the frying process. So it is clear that the continued use of used cooking oil can damage human health because it contains carcinogenic compounds and as a result can further reduce the intelligence of the next generation. Repeated use of used cooking oil contains carcinogenic free radical substances such as peroxides, epioxides, and others. In animal experiments, consumption of food rich in peroxide groups causes intestinal cancer. The main deterioration of oil is due to oxidation events, one of which is the formation of peroxides and aldehydes. Peroxides and aldehydes can accelerate the process of developing rancidity and undesirable flavors in foodstuffs. Another parameter to determine the quality of fat or oil is the iod number. The iodine number is a number that indicates the number of double bonds in a fatty acid (oil). Unsaturated fatty acids can bind oxygen to their double bonds to form peroxides. The higher the peroxide number, the lower the quality of an oil.

The purification of used cooking oil can be done by adsorption using activated charcoal. Adsorption is the event of collecting molecules of a substance on the surface of another substance due to an imbalance and due to the attractive force between atoms or molecules on the surface of a solid. Adsorption is classified into chemical adsorption and physical adsorption, both of which are distinguished by the homogeneity of adsorbent and adsorbate, adsorption energy, reversibility, and adsorbent layer thickness. Some factors that affect adsorption are concentration, surface area, temperature, particle size, pH and contact time. Adsorption is selective, because only the solute or solvent is adsorbed. The amount of substance adsorbed depends on the concentration of the solute and the dependence of the amount of substance adsorbed on the equilibrium concentration is called the adsorption isotherm (Auliah, 2009). In general, adsorption is the process of separating certain components from one fluid phase (solution) to the surface of an adsorbing solid (adsroben). Separation occurs due to differences in molecular weight or porosity, causing some molecules to bind more strongly to the surface than other molecules. The conditions for the running of an adsorption process, namely: 1. The adsorbing substance (adsorbent), 2. The adsorbed substance (adsorbate), 3. Shaking time until the adsorption runs in balance. Adsorption can be classified into two types, namely chemical and physical adsorption. Chemical adsorption (chemisorption) is adsorption that occurs due to chemical forces and is followed by a chemical reaction. This type of adsorption results in the formation of chemical bonds, so that it is followed by a reaction in the form of a new compound. In chemisorption, the surface of the solid is very strong binding to gas or liquid molecules so that it is difficult to release again, so the chemisorption process is very small. Physical adsorption (physiosorption) is adsorption that occurs due to physical forces. The objectives of this research are:
1. Knowing the heat energy produced by the band heater during the process of refining used cooking oil with activated charcoal.
2. Knowing the effect of band heater power on the heating time of used cooking oil in the refining process.
3. Knowing the effect of the comparison of the composition of oil with activated charcoal on the results of visual purification and the results of the examination of the number of Free Fatty Acids (BA) and Peroxide Numbers (PV).

Some research that has been done before with the title "The Effect of Temperature and Adsorption Time on the Chemical-Physical Properties of Used Cooking Oil Purification Results Using Aren Pulp Absorbent and Bentonite" (Rahayu, L. H., & Purnavita, S. (2018).

EXPERIMENTAL METHOD

Experiment Setup

These experimental tests were conducted in compliance with established safety standards. Before the experimental test process begins, all conditions of the equipment sub-systems used are checked and confirmed to meet safety requirements.

Calculations on Used Cooking Oil Refining Equipment

Maximum Power of Band Heater

The band heater is an electric heating element used in the 20 liter/process capacity used cooking oil refiner. The band heater used measures 300 mm x 150 mm in diameter with a thickness of 6 mm.

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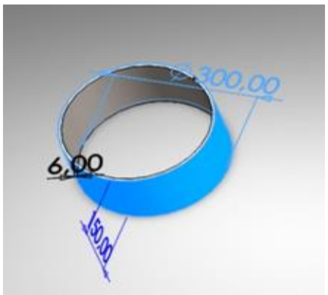

Figure 1. Band Heater

From figure 1. above the band heater on the used cooking oil refiner can be calculated theoretically to determine the maximum power in the band heater with equation 1. The following is the calculation of maximum power as equation 1.

$$P = Sl \,.\, A$$

Where Sl (Surface load) is the surface load on the Band Heater in units of W/m^2, A is the surface area of the Band Heater used in units of m^2.

Calculation of Conduction Heat Transfer

Conduction heat transfer is the heat transfer from the band heater to the tube. The tube size used is 300 mm x 500 mm with a thickness of 1.2 mm. The material used is stainless steel 304 (SS 304).

Figure 2. Stainless Steel Tube

Table 1. Thermal conductivity of stainless steel

Metal	Temperature (°C)	k (W/m°C)
Alumunium	0	202
	100	206
Brass (70 Cu, 30 Za)	0	97
	100	104
Nickel	212	59
Stainless steel (18/8)	0-100	15

Based on Table 1. can be calculated conduction heat transfer in stainless steel material with Equation 4.2. The following conduction calculations are like Equation 4.2.

$$Q = -\frac{kA}{\Delta x}\,(T_2 - T_1)$$

Where Q is the amount of heat flowing per second in units of J / s or Watt, k is the thermal conductivity of Stainless Steel in units of W / M^{o}C, A is the surface area of the tube used in units of m^2, T_2 is the temperature on the tube in units of ^{o}C, T1 is the temperature on the Heater in units of ^{o}C.

Calculation of Heat Transfer by Convection

Convection heat transfer is the heat transfer that occurs in a substance accompanied by the transfer of particles from the substance. Convection generally occurs in fluids (liquids and gases). The fluid to be used in this research is used cooking oil with a volume of 20 liters or equivalent to 16 kg. Convection heat transfer can be known by the following equation 3:

$$Q = h\,A\,\Delta T$$

Where Q is the heat flowing per second in units of J/s or Watt, h is the convection heat transfer coefficient in units of W/m^2.^{o}C, A is the fluid surface area in units of m^2, ΔT is the temperature change in units of ^{o}C.

Calculation of the Amount of Caloric Required to Heat Oil

The fluid to be used in this study is used cooking oil with a volume of 20 liters or equivalent to 16 Kg. To calculate the amount of heat needed to heat cooking oil from 28^0 C to 100^0 C, specific heat data is required as shown in Table 2 below.

Table 2. Specific Calorific Value Table

No	Nama Zat	Kalor Jenis	
		J/kg°C	Kkal/kg°C
1.	Alkohol	2.400	550
2.	Air	4.200	1.000
3.	Minyak Goreng	2.200	580
4.	Gliserin	2.400	580
5.	Raksa	140	30

To calculate the amount of heat required to heat cooking oil from 28^0 C to 100^0 C can be done using the following Equation 4:

$$Q = m\, c\, \Delta T$$

Where Q is the amount of heat flowing per second in units of J/s or Watt, c is the specific heat of cooking oil in units of J/kg°C, ΔT is the temperature change in units of °C.

Data Collection Technique

Data collection techniques are carried out by planning for the analysis of heaters in cooking oil refining equipment using active charcoal with a capacity of 20 liters / process. Performed with several stages, namely: Literature, Observation, and Testing Methods.

The variables used in this study are divided into two, namely:

1. Independent variables
   a. Heat flux with values of 3500, 4500, 5500 W/m^2
   b. Stirrer rotation with values of 80, 100, and 120 rpm
   c. Composition with the ratio of 80%: 20%, 70%:30%, and 60%:40%.
2. The dependent variable is cooking oil temperature.

Data Processing

Data collection methods can be done by doing calculations manually and by testing methods on the used cooking oil refining equipment. But before doing calculations, tests, and simulations there are several steps that must be prepared from the beginning, namely as follows:

A. Literature study where this goal is to obtain information related to the research material what parameters are taken in the used cooking oil refining equipment.
B. Conducting tests to obtain data related to the time required to heat used cooking oil to a temperature of 100oC.
C. The test data obtained in this step can be done by manual calculation based on the test data and then compared with the simulation results.
D. Data analysis
E. Conclusion

RESULTS AND DISCUSSION

CFD Simulation Results

CFD simulation in this study uses Ansys Student R22 numerical modeling.

1. Temperature

The figure below is the simulation result of heat distribution at the 8700th second that has been simulated on the used cooking oil refining tube with three different heatflux variations.

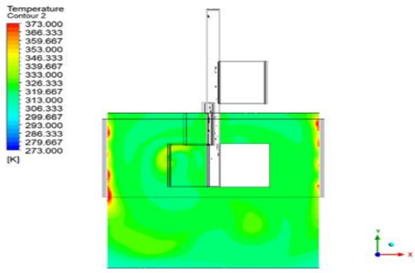

Figure 3. Visualization results of heat flux temperature 3500 W/m^2

From Figure 3, it can be seen that the heat distribution in the heat flux 3500 W/m2 at the 8700th second, looks dominated by green which means the temperature is around 339 K.

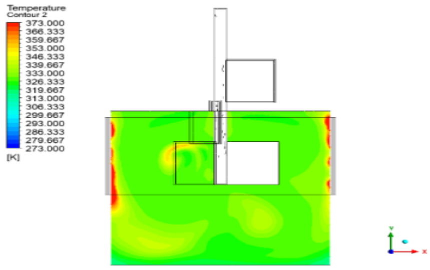

Figure 4. Visualization results of heat flux temperature 4500 W / m2

In Figure 4, it can be seen that the heat distribution in heat flux 4500 W/m^2 at the second to 8700, looks dominated by yellowish green which means the temperature is around 347 K.

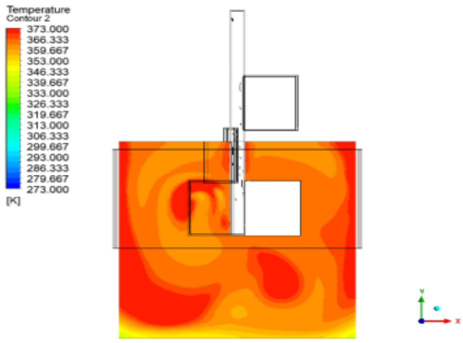

Figure 5. Visualization results of heat flux temperature 5500 W/m^2

In Figure 5, it can be seen that the spread of heat in the heat flux 5500 W/m^2 at the second to 8700, looks dominated by the color orange to red which means the temperature is around 367 K.

Table 3. Simulation results of the time required to heat oil to 100°C

No	Heat Flux (W/m²)	Kecepatan Pengaduk (rpm)	Waktu
1	3500	120	3 jam 46 menit
2	4500	120	3 jam 17 menit
3	5500	120	2 jam 26 menit

From Table 3, the simulation results of the time required to heat oil to 100°C can be poured into a graph of the heat flux used.

Figure 6. Comparison graph of the time required to reach 100°C

From Figure 6, it can be seen that heatflux 5500W/m2 has a faster time in reaching a temperature of 100oC and the slowest is heatflux 3500W/m2.

2. Velocity

The figure below is the result of velocity that occurs in the used cooking oil refining tube. Velocity that occurs in the used cooking oil refining tube occurs in the stirrer in the tube.

Figure 7. Visualization of velocity in simulation

From Figure 7, it can be seen that the speed of stirring used cooking oil is evenly distributed and the rotation is smooth, which can be seen from the regular lines.

Testing Results

Table 4. Comparison of test time with simulation

No	Heat Flux (W/m²)	Kecepatan Putaran (rpm)	Waktu (s)	
			Pengujian	Simulasi
1	3500	120	14820	13570
2	4500	120	11520	11830
3	5500	120	9000	8760

From Table 4, a comparison graph of test and simulation results can be made in Figure 8 below.

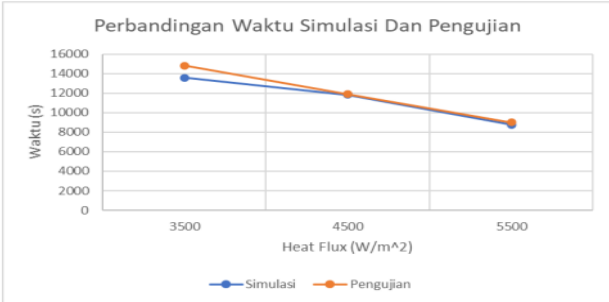

Figure 8. Comparison of Simulation Time with Testing

Based on Figure 8, it can be seen the difference between testing time and simulation time. From the comparison of the results of the test time and the results of the simulation time, the deviation can be found in Table 5 below.

Table 5. Deviation of test results with simulation results

No	Heat Flux (W/m²)	Presentase Deviasi
1	3500	8,43%
2	4500	2,69%
3	5500	2,67%

In Table 5, it can be seen the deviation of the test time results with the simulation time results where the largest deviation is 10.95% at a heat flux of 3500 W/m² and the smallest deviation is 0.42% at a heat flux of 4500 W/m².

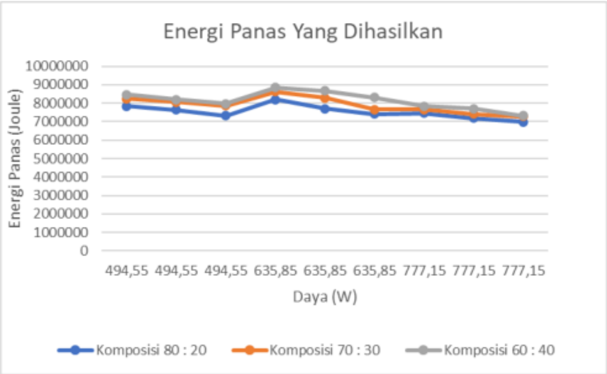

Figure 9. Heat Energy generated

Based on Figure 9, it can be seen the heat energy generated by the band heater in the process of refining used cooking oil. The effect of power on heating time during the refining process, the greater the power used the faster the heating process is carried out. The composition between used cooking oil and activated charcoal also affects the heating time from 30 to 100°C. The heat energy generated by the band heater during the process of refining used cooking oil with the largest active charcoal is 8622.126 kJ and the lowest is 6994.350 kJ.

Comparison with Literature

Comparison of curve verification for the percentage decrease in the results of Acid Numbers (BA) and Peroxide Numbers (PV) obtained from a process between the research conducted by the author with the title "Heating Analysis on Used Cooking Oil Refining Equipment Using Activated Charcoal with a Heating Element Capacity of 20 Liters / Process" by the journal with the title "Effect of Temperature and Adsorption Time on the Chemical-Physical Properties of Used Cooking Oil Refined Using Aren Starch Pulp Absorbent and Bentonite" (Rahayu, L. H., & Purnavita, S. (2018), obtained the following comparison results:

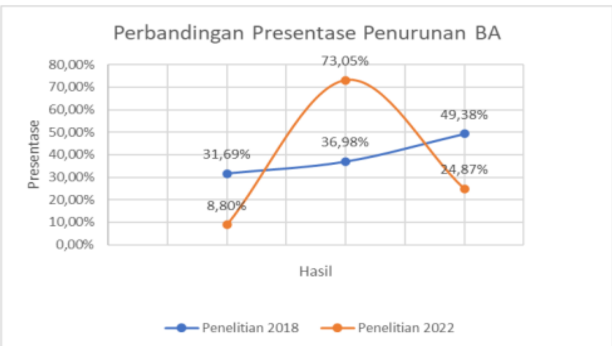

Figure 10. Comparison of BA Decrease Percentage

Based on Figure 10, it can be seen that the percentage of the decrease in Free Fatty Acid Numbers (BA) in the research of Rahayu, L. H., & Purnavita, S. (2018), the highest percentage is 49.38% and the lowest is 31.69%. In this study (2022), the highest percentage was 73.05% and the lowest was 8.80%.

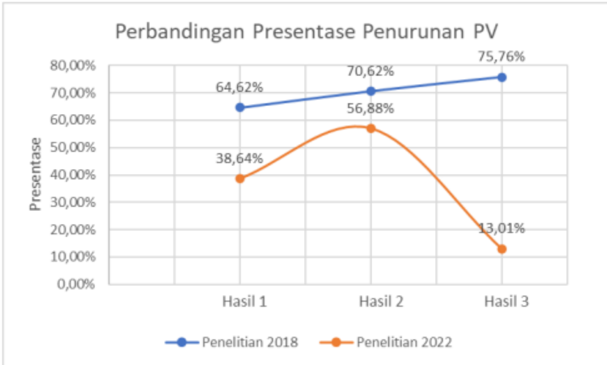

Figure 11. Comparison of PV Decrease Percentage

In Figure 4.27, it can be seen that the comparison of the percentage of PV reduction in research by Rahayu, L. H., & Purnavita, S. (2018), the highest percentage is 75.76% and the lowest is 64.62%. In this study (2022), the highest percentage is 73.05% and the lowest is 13.01%.

CONCLUSION

Based on the results of data analysis and discussion, the following conclusions can be drawn:

1. The heat energy generated by the band heater during the process of refining used cooking oil with activated charcoal is the highest at 8622.126 kJ and the lowest at 6994.350 kJ.
2. The effect of band heater power on the heating time of used cooking oil in the refining process is the fastest heating time at 779 W power and the longest heating time at 499.55 W power.
3. The composition ratio between used cooking oil and activated charcoal affects the results of the refining process, where visually the best composition ratio is 70% used cooking oil and 30% activated charcoal with a stirring speed of 120 rpm.
4. The percentage decrease in free fatty acid number (BA) was the highest in the study of 73.05% and the percentage decrease in peroxide number (PV) was the highest at 56.88%.

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