WCEJ

WORLD CHEMICAL ENGINEERING JOURNAL

Journal homepage: http://jurnal.untirta.ac.id/index.php/WCEJ

The Effect of Operating Conditions on the Purification of Waste Cooking Oil over a Natural Zeolite Catalyst

Endang Suhendi[1] , Heri Heriyanto[1*], Mely Nur Avina[1] , Kharina Andriani[1]

[1]*Departement of Chemical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jenderal Sudirman Km 3, Kotabumi, Kec. Purwakarta, Kota Cilegon, Banten, Indonesia*

*Corresponding Author Email: heri.heriyanto@untirta.ac.id

ARTICLE HISTORY

Received 7 June 2022
Received in revised form 18 June 2022
Accepted 20 June 2022
Available online 25 June 2022

ABSTRACT

The waste of cooking oil is a danger to human health. The Heating of waste cooking oil at high temperatures will cause an increase in free fatty acid (FFA) and peroxide number in the oil. Therefore, waste cooking oil needs to be processed before being reused. This paper studies the effect of operation conditions on the purification of waste cooking oil over a natural zeolite catalyst. The stage of the purification process is despicing, neutralization, and bleaching process. The despicing process injected the steam to remove impurities. The effect of the mass flow rate of oil at 1.051; 0.456 and 0.139 Kg/s on FFA value was studied. After that, the neutralization and bleaching process. The Bleaching process was performed using zeolite adsorbent. The results show that the purification method of waste cooking oil decreases of the color of oil, free fatty acid, and peroxide value. In this study, the best performance of the despicing process at the mass flow rate of the oil is 0.139 Kg/s, a temperature of 60°C with 500 rpm stirring for the neutralization process and bleaching process of natural zeolite. The value of free fatty acid content (FFA) is 2.22 mg. KOH/mg fat, peroxide is 6.98 mekO_2/kg, color degradation is 66.93% and water content is 0.32% (w/w).

Keywords: *cooking oil, free fatty acid, oil, peroxide, waste*

1. INTRODUCTION

Cooking oil is one of the media for cooking and is widely used in the community because the price is relatively cheap and is often found in the market. The use of cooking oil is increasing both on a household scale and on an industrial or factory scale. The increasing consumption of cooking oil causes the cooking oil will become waste cooking oil which if not recycled will become waste, polluting the environment and threatening human health (Ernawati and Mufidah, 2016).

The cooking oil that has been used repeatedly can interfere the human health because the oil is heated repeatedly at high temperatures causing a decreased quality of the oil. It is due to damage by several processes such as the hydrolysis process, oxidation process, polymerization process, and browning reaction as a result of frying that has been done. (Rahayu, *et al*, 2014). The thermal oxidation process occurs when the oil is heated at a temperature above 180 ^{0}C (Marinova et al., 2012).

The physical appearance of the cooking oil will be changed when it is heated repeatedly such as an increased viscosity and the color of the oil becomes darker. So the fatty acid composition of the oil is changed (Nayak et al., 2016). The polar compounds contained in waste cooking oil consist of polymers, non-volatile cyclo compounds (the result of oxidation and mineral hydrolysis), and compounds dissolved during the frying process (Debnath, et al, 2012).

The decrease in the quality of waste cooking oil can be seen in the color of the oil which becomes darker and not clear, the aroma of the oil is less pleasant, the consistency of the oil is thicker, and the free fatty acid (FFA) content and high peroxide value. The amount of FFA content in the oil does not depend on the levels of linoleic acid and tocopherol (Aladedunye and Przybylski, 2013)

Cooking oil is considered suitable for consumption if the quality of cooking is standard of cooking oil. The quality standards of cooking oil are presented in Table 1.

Table 1. Standard of Cooking Oil

Test Performance	Unit	Requirement
1. State		
1.1 Smell	-	Normal
1.2 Color	-	Normal
2. Water	%(b/b)	max. 0.15
3. Acid number	mg KOH/g	max. 0.6
4. Peroxide number	mek O_2/kg	max. 10
5. Oil	-	negative
6. linoleic acid (C18:3)	%	max. 2
7. Metal		
7.1 Cadmium (Cd)	mg/kg	Max. 0.2
7.2 Lead (Pb)	mg/kg	Max. 0.1
7.3 Lead (Sn)	mg/kg	Max. 40.4/250.0*
7.4 Mercury (Hg)	mg/kg	Max. 0.05
8. Arsenic (As)	mg/kg	Max. 0.1

(Source BSN SNI 3741:2013)

To be safe for consumption so the waste cooking oil must be fulfilled the requirements of the quality standards of cooking oil as presented in Table 1. Therefore, the study of waste cooking oil has been developed so that the waste cooking oil complies with applicable quality standards. Several studies have been carried out on the process of refining waste cooking oil with an adsorbent. Fauzhia et al (2019) studied the effect of tamarind seed adsorbent on the parameter waste cooking oil. The result shows several parameters reduce such as the absorbance value, free fatty acid content, and peroxide value. Fadila, et al (2019) studied with salak seed adsorbent. Octarya and Fernando (2016) investigated with activated charcoal adsorbent from bagasse.

In the purification of waste cooking oil, the most widely used adsorbent is zeolite. Zeolite has a distinctive structure, which is mostly channels and pores which cause zeolites to have a large surface area. Thus zeolite can be used for adsorption processes, ion exchange, and as a catalyst so that zeolites have the potential to purify waste cooking oil. The purpose of this paper is to determine the effectiveness of zeolite in the process of refining waste oil by visually analyzing the color of used cooking oil after adsorption using zeolite.

The refining process for waste cooking oil consists of several process stages, including the process of despicing, neutralization, and bleaching. Several factors can affect the results of oil refining, including the temperature and time of the process used, the pressure and amount of steam consumption, and the use of chemicals during purification (Febriana, 2017).

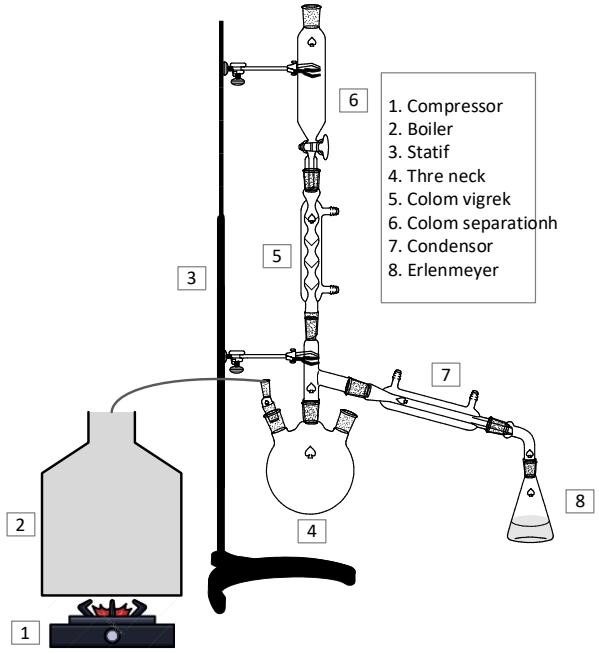

Fig. 1. Despicing Process Equipment

2. METHODS

2.1 Material

Waste cooking oil from household waste; NaOH, PP indicator, ethanol p.a. and zeolite from the Alam Bayah area, Banten Regency.

2.2 Equipment

The equipment is a vigrek column, boiler, decanter, three-neck flask, and condenser. The equipment for the despicing process is illustrated in Figure 1. Then the equipment for the neutralization process is an Erlenmeyer, measuring cup, hotplate magnetic stirrer, filter paper, and funnel. The equipment in the bleaching process is Erlenmeyer and filter paper. As for the use of supporting tools such as digital scales, pipettes, and thermometers. Equipment for the analysis of acid levels. Fat and peroxide value is a set of titration tools and measuring cups. Tools for water content analysis are porcelain dishes and ovens. The tool for spectrophotometric analysis is Uv-Vis genesis 10 spectrophotometry.

2.3. Purification Waste Cooking Oil

2.3.1 Despicing Process

The first stage is despicing process. In this process the waste cooking oil was contacted with steam, and then waste cooking oil is placed in a separatory funnel located at the top of the vigrek column and the steam flow from the boiler will enter through the bottom of the column. After that, the oil product was collected in a three neck flask. The variations process mass flow rate of oil are 1.051; 0.456; and 0.139 kg/s. The mass flow rate of the oil

is determined from the amount of oil at an interval of 1 minute. The despicing process continues until the oil in the separating funnel runs out. The oil resulting from the despicing process will then go through a separation process with water in the separator column (Hartono and Suhendi., 2020).

2.3.2. Neutralization Process

The neutralization process in refining waste cooking oil is carried out using the results of the oil sample in the despicing process. The weight of oil is 100 grams and put into an Erlenmeyer flask, then adds 5 ml of 17% NaOH solution into the Erlenmeyer and heats the sample at a temperature (28, 40 , 60, 90)^{0}C according to variations, as well as with variations of stirring at 500 rpm and without stirring, the process was carried out for 10 minutes, then the filtering process was carried out with filter paper (Hartono and Suhendi, 2020).

2.3.3. Bleaching Process

The weight of sample is about 100 grams from the neutralization used for bleaching process. Added the sample to erlenmeyer flask and mixed with 90 grams of zeolite adsorbent for 60 minutes, after that the sample was filtering by whatman filter (Hartono and Suhendi 2020).

2.4 Analysis

2.4.1 Analysis of Free Fatty Acid (FFA)

The oil from bleaching process was analyzed FFA value in LABKESDA Serang. The procedure of analysis FFA, firstly the weight of oil about 10 - 50 grams added to erlenmeyer and charged 50 mL of ethanol (95 % purity). Agitated for 30 minutes and then charged 3 -5 drops of phenolphthalein indicator (pp). After that, the titration of acid base with 0,1 N NaOH until a pink color is formed. The volume of NaOH was noted for calculation of FFA with as equation follow :

$$\text{FFA } (\%) = \frac{\text{V NaOH } \times \text{N NaoOH} \times \text{BM fatty acid}}{\text{weight sample of oil (gram)}}$$

2.4.2. Peroxide Analysis

Peroxide value was analyzed in LABKESDA Serang. The sample of oil from bleaching process was charged about 5 grams to erlenmeyer flask 250 mL and added of acetic acid 30 mL, chloroform and ethanol (95 %). Mix well for 30 minute and added 1 gram KI and continue agitated for 2 minutes. After that, the distilled water added about 50 mL, and then take out sample for tirated with the 0.02 N Na_2SO_3 standard until the yellow color disappeared. After that, adding of 1 mL starch solution 1 % and titrated with 0.02 N Na_2SO_3 standard until the blue color disapperaed. The volume of 0.02 N Na_2SO_3 was noted for calculation peroxide value with equation follow :

$$\text{Peroxide value} = \frac{\text{Vtiosulfat} \times \text{Ntiosulfat} \times 1000}{\text{weight sample of oil (gram)}}$$

2.4.3 Water Content Analysis

Weight of porcelain dish no sample weighed until constant of value. The value was noted. After that added sample as much as 5 grams in a dish and then heat at oven on 130 ^{0}C for 30 minute and then sample was cooled at desicator for 20 minute note the weight of sample. The value of weight sample losses equivalent the value of water content.

2.4.4 Spectrophotometric Analysis

Spectrometers are devices that are used to measure the spectra of the sample. Spectrophotometric was analyzed at LABKESDA Serang, with the Uv-Vis spectrophotometry genesis 10 and a wavelength of waste cooking oil before processing (Raw Material) which was 410nm. The method is carried out by stirring the sample evenly to make it homogeneous, then pouring the sample to be tested into the cuvette, then comparing the color of the oil sample with the standard color or the color used as a comparison, after that the absorbance value recorded on the Uv-Vis genesis spectrophotometry tool is obtained 10.

3. RESULTS AND DISCUSSION

3.1 Despicing Process

The result of despicing process as presented in Figure 2.

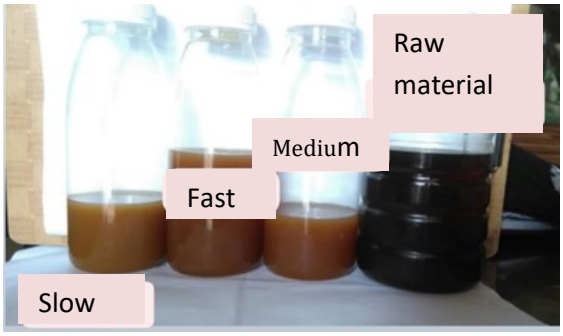

Fig. 2. The product oil of despicing process at different mass flow rate.

Figure 2 shows that the effect of despicing process on color of oil. The color of oil after despicing process is lighter compare without treatment despicing process. Furthermore, the effect of mass flow rate was studied. The result shows that at the mass flow rate faster then the color of the oil is darker. This is because when the mass flow rate of oil slows down then the amount of cetam will be contacted with the oil has a greater ratio. It is possibility of impurities dissolved in the steam will be greater, this causes the color of the oil to become brighter. In addition the effect of mass flow rate on FFA as presented in Table 2.

Table 2. FFA and Peroxide value at despicing process

Sample	FFA (mg NaOH/mg fat)	Peroxide (mekO_2/kg)
Raw material	15.30	10.94
1.051 kg/s	15.15	10.89
0.456 kg/s	15.10	10.86
0.139 kg/s	15.02	10.5

Table 2 shows the effect of mass flow rate on the value of peroxide and free fatty acid number. The value decreased as the mass flow rate of oil decreased. The FFA decreases higher at a mass flow rate of 0.133 kg/s oil about 1.8. Due to that at mass flow rate oil is slower then the time for contact between oil and steam is longer. So, the impurity compounds contained in the oil dissolve in the steam. Furthermore, the effect of the mass flow rate of oil on the value of the peroxide number was evaluated and the result shows the value decreases. The results show the effect of mass flow rate oil is decreased peroxide number. It decreases the highest at the mass flow rate of 0.139 kg/s oil is 4.02%. In the despicing process, the peroxide compounds on the carbon chain which is cut off due to frying become a short carbon chain. Short carbon chains will be more soluble in water than in non-polar solvents such as oil, where the difference in polarity can cause oil and water do not to dissolve in each other. So that the polar components contained in waste cooking oil samples are in the form of spices and herbs that are contained during the frying process will be dissolved in water. Finally, despicing process caused the value of peroxide number and FFA to decrease (Fauzhia, et al, 2019). Based on SNI 3741: 2013 the maximum limit of free fatty acid value is 0.6 mg NaOH/mg Fat, so waste cooking oil from the despicing process are not meet the quality standards of cooking oil. The effect of despicing process at different mass flow rates to spectrophotometric analysis is presented in Table 3.

Table 3. Data analysis of spectrophotometry on despicing process

Sample	Absorbance	Efficiency (%)
Raw material	3	-
Fast (1.051 kg/s)	2.875	4.17
Medium (0.456 kg/s)	2.857	4.77
Slow (0.139 kg/s)	2.813	6.23

Based on Table 3, the results of the spectrophotometric analysis in the despicing process with a wavelength of 410 nm there was a decrease in the absorbance value for each oil mass flow rate. The mass flow rate of oil affects the absorbance value, this is related to the amount of steam in contact with the oil. The mass flow rate optimum is 0.139 kg/s oil where the color degradated then causes a decrease in the absorbance value is 6.23%. The greater absorbance value of a solution then the solution is more turbid and the worse quality of the oil (Viantini, et al, 2015).

The variation of mass flow rate of oil in the despicing process to determine the effect on the quality of the oil produced, based on the physical appearance, free fatty acid number, absorbance and peroxide value. Finally, the mass flow rate of oil that produces the best quality is 0.139 kg/s.

3.2 Neutralization Process

The effect of temperature and agitation on oil quality in the neutralization process is presented in Figure 3.

(a) (b)

Fig. 3. Data Oil on Netralisasi Process (a) Agitation (b) No Agitation

Based on Figure 3, the temperature and agitation influence to color of waste cooking oil. Physically neutralization process oil has a lighter color than raw material oil and despicing process oil. With a stirring process of 500 rpm, it produces oil with a brighter color than oil without a stirring process.

Table 4. FFA and peroxide number on neutralization process

Remark	T (°C)	FFA (mg NaOH/mg fat)	Peroxide(mekO_2/kg)
neutralization (Agitation)	28	5.16	8.87
	40	4.51	7.86
	60	4.43	7.44
	90	4.29	7.43
neutralization (Without agitation)	28	7.49	8.91
	40	6.65	8.33
	60	6.61	7.91
	90	6.53	7.41

Table 4 shows the effect of agitation on the acid number. The acid number with a stirring process of 500 rpm has a lower acid number than without stirring. At a temperature of 60°C with a stirring process, there was a decrease in FFA levels of 70.50% but without agitation treatment, there was a decrease in FFA value is 55.99%. In the neutralization process, the stirring process important affects the free fatty acid content in the oil, because in the neutralization process a reaction occurs between free fatty acids and bases or other reagents. So that the soap formation process will occur. Therefore it is necessary to do a stirring process so that it is homogeneous, so that when given stirring treatment in the neutralization process, more NaOH reacts with acid, this causes a decrease in free fatty acid levels in the oil. Free fatty acids are the basis for knowing the age of the oil, the purity of the oil, and the degree of hydrolysis (Yustinah and Roasdiana, 2014).

Based on table 4, the temperature influences acid number. At higher temperature then the acid number is lower. So at higher temperature then the acid number is lower. Because at temperature is high then the FFA is decreased. An increase in temperature causes the movement of molecules, so that the reacting molecules will be faster and cause the collisions between particles to be even greater, so that the number of reacting bases will be even greater. The optimum temperature for the neutralization process is 60℃. At high neutralization, temperature requires more energy, so it is necessary to consider the use of a high temperature at a neutralization temperature is 90℃.

The decrease in peroxide value during the neutralization process is directly proportional to the decrease in FFA value. In the neutralization process at a temperature of 60oC with a stirring process, it decreased to 29.10%. The peroxide value is higher in cooking oil causing the damage to the oil to be higher. Cooking oil that is reused repeatedly using a sufficiently high temperature can cause changes in the chemical structure so that it can form a peroxide number (Fitriani and Nurulhuda, 2018). The use of NaOH solution can reduce the peroxide number because NaOH can react with waste cooking oil optimally, so it reduces the peroxide number. The aroma of the oil is not only influenced by impurities such as spices or food ingredients, but it is also influenced by the peroxide in the oil. In the neutralization process, peroxide compounds that have short carbon chains will dissolve in water and are bound to free fatty acids, so the peroxide content will also precipitate in the saponification process (Musyaroh and Hidayat, 2018). The decrease in the value of the peroxide number is related to the decrease in the level of FFA in the oil, so that when the value of FFA decreases, the value of the peroxide number in the oil decreases. The effect of temperature and agitation on absorbance is shown in Table 5.

Table 5. Data analysis of spectrophotometry on neutralization process

Remark	T (oC)	Absorbance	Efficiency (%)
neutralization (Agitation)	28	2.804	6.53333
	40	2.776	7.46667
	60	2.726	9.13333
	90	2.701	9.96667
neutralization (without agitation)	28	2.822	5.9333
	40	2.786	7.1333
	60	2.69	10.333
	90	2.73	9

The results show the effect of temperature and stirring of the spectrophotometric analysis in the neutralization process with a wavelength of 410nm showed a decrease in the absorbance value at each temperature both with 500 rpm stirring and without stirring. The absorbance value is related to the decrease in peroxide value and free fatty acid levels. This is because the reaction that occurs during the neutralization process causes precipitation, so the impurity particles are deposited during the neutralization process which causes the absorbance value to decrease. The optimum result is at a temperature of 60℃ with 500 rpm agitation, color degradation occurs in the despicing process oil with the color of the oil from the neutralization process of 3.1%.

In the neutralization process, variations in temperature and stirring are used to determine the effect on the quality of the oil produced, based on data on FFA content, peroxide number, absorbance value, and physical appearance of the oil, and taking into account the economic value of the oil refining process, temperature variations of 60 ^{0}C with a stirring process is the optimum variation in the neutralization process.

3.3 Bleaching Process

The effect of neutralization and bleaching processes are presented in Figure 5.

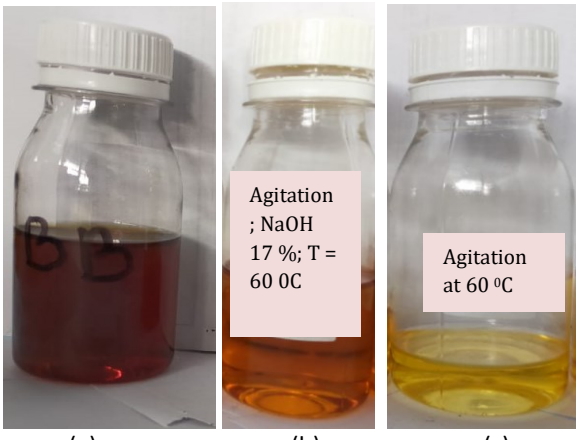

Fig. 4. (a) Waste cooking oil before treatment, (b) Waste cooking oil after neutralizer (c) Waste cooking oil after bleaching

Based on Figure 4, the effect of the neutralization and bleaching process to waste cooking oil was degraded color from darker to lighter. The effect of neutralization and bleaching processes on FFA are presented in Figure 5.

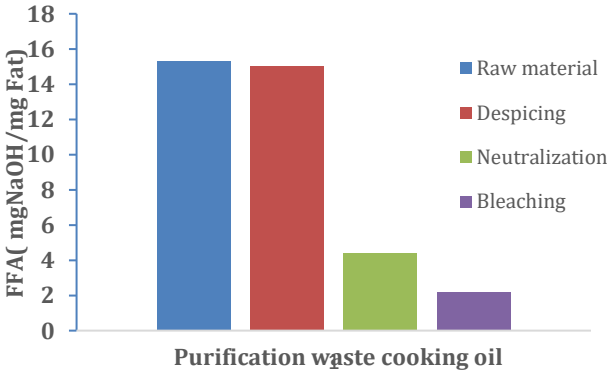

Fig 5. FFA value decreases after purification waste cooking oil

Figure 5 shows that the FFA value decreases after the waste cooking oil refining process. The FFA value after bleaching process is 2.22 mg NaOH/mg Fat and after neutralization process is 49.81%, when compared to oil in the raw material sample, the FFA value decreases by about 85.48%. In the bleaching process, natural zeolite was used as an adsorbent, the free fatty acid will be absorbed by the zeolite. In addition, the effect of neutralization and bleaching processes on peroxide numbers are presented in Figure 6.

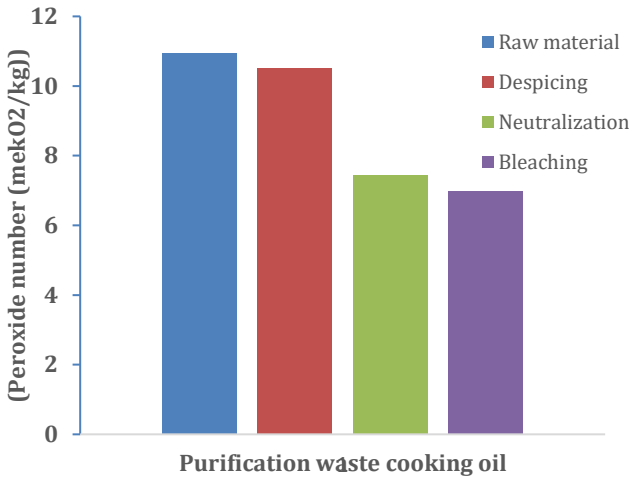

Fig. 6. Peroxide number decreases after treatment

Based on Figure 6, the peroxide value decreases after treatment neutralization and bleaching. After the bleaching process decrease to 6.20% and if compared with raw material decreased to 36.20%. It is due to the adsorption process, during the bleaching process the natural zeolite will absorption of carbon compounds. Furthermore, the effect of the neutralization and bleaching processes on the spectrophotometric analysis is presented in Figure 7.

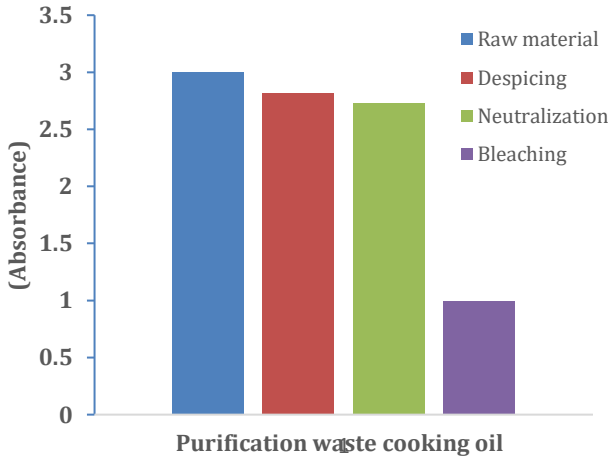

Fig. 7. Decreases of absorbance after treatment

Based on Figure 7, the effect of treatment (despicing, bleaching) on the spectrophotometric analysis is decrease of color and absorbance value of the oil. Decreasing absorbance values after despicing and bleaching were 63.61%, and 66.93%, respectively. It is due to the physical adsorption process with the zeolite which was composed of pores with a surface area capable of absorbing the compounds and impurities contained in the oil. The occurrence of the physical adsorption process is due to the difference in potential energy on the surface of the adsorbent with the adsorbed substance (adsorbate) involving the Van der Waals force (intermolecular force) which takes place continuously (Fauzhia, et al, 2019).

4. CONCLUSION

The purification method of waste cooking oil can degrade the color of the oil, and reduce free fatty acid and peroxide value in the oil through the despicing and neutralization process. The optimum of despicing process are variations in the mass flow rate is 0.139 kg/s oil, 60°C temperature and stirring and 500 rpm stirring as well as natural zeolite adsorbent bayah. The properties of the resulting oil have an FFA content of 2.22 mg NaOH/mg Fat, a peroxide value of 6.98 mekO2/kg, an absorbance value of 0.992, and water content of 0.32% (w/w). The results of the purified waste cooking oil have met the quality standard of cooking oil, while the free fatty acid content has not met the quality standard of cooking oil.

5. ACKNOWLEDGMENTS

The authors express gratitude to Mr. Mahfud who have helped the research process and testing the results.

6. REFERENCES

Aladedunye, F.A. & Przybylski, R. 2013. Frying Stability Of High Oleic Sun Flower Oils As Affected By Composition Of Tocopherols Isomers And Linoleic Acid Content. *Food Chem*. 141, 2373–2378. DOI: 10.1016/j.foodchem.2013.05.061

Badan Standarisasi Nasionan SNI 3741:2013.

Debnath, S., Rastogi, N.K., Krishna, A.G.G. & Lokesh, B.R. 2012. Effect of frying cycles on physical, chemical and heat transfer quality of rice bran oil during deep-fat frying of poori: An Indian traditional fried food. *Food Bioprod*. Process. 90, 249–256. DOI:10.1016/j.fbp.2011.05.001

Ernawati I. H, and Mufidah S. 2016. Penurunan Asam Lemak Bebas pada Minyak Goreng Bekas menggunakan Ampas Tebu untuk Pembuatan Sabun. Jurnal Integrasi Proses, 6(1), 22-27 DOI: http://dx.doi.org/10.36055/jip.v6i2.656

Fadila, Ihwan, Anam, S. 2019. Mutu Minyak Jelantah dengan Adsorben Biji Salak (Salacca Zalacca (Gaertn,)Voss) Menggunakan Parameter Bilangan Peroksida dan Asam Lemak Bebas. *Jurnal Farmasi Galenika*, (2): 124 – 131. DOI : 10.22487/j24428744.2019.v5.i2.10070

Fauzhia, Hariati, Jura, M. Rama Ningsih, Purnama, 2019. Pemurnian Minyak Jelantah Menggunakan Biji Asam Jawa. *Jurnal Akademika Kimia,* 8(1): 50-58. doi: 10.22487/j24775185.2019.v8.i1.2744

Febriana. W., Susanti and Arif M. 2017. *Pemakaian Steam pada Proses Pemurnian Minyak Kelapa Sawit*. Fakultas Sains dan Teknologi: UIN Sultan Syarif Kasim Riau

Fitriani and Nurulhuda. 2018. Pemurnian Minyak Goreng Bekas menggunakan Adsorben Biji Alpukat Teraktivasi. *Jurnal Pendidikan Matematika dan IPA.Pendidikan Kimia FKIP* :Universitas Muhammadiyah Pontianak, 9(2),65-75. DOI: 10.26418/jpmipa.v9i2.26770

Hartono R., and Suhendi E. 2020. Pemurnian Minyak Jelantah dengan Menggunakan Steam pada Kolom Vigrek dan Katalis Zeolit Alam Bayah. Jurnal Integrasi Proses, 9(1), 20-24.
DOI: http://dx.doi.org/10.36055/jip.v9i1.7912

Marinova, E.M., Seizova, K.A., Totseva, I.R., Panayotova, S.S., Marekov, I.N. & Momchilova, S.M. 2012. Oxidative Changes In Some Vegetable Oils During Heating At Frying Temperature. Bulg. Chem. Commun. 44, 57–63.

Musyaroh and Hidayat, Nur. 2018. Pengaruh Lama Waktu Pengadukan dan Konsentrasi NaOH pada Proses Pemurnian Minyak Goreng Superworm (Zophobas morio). *Jurnal Teknologi dan Manajemen Agroindustri*, 2:81 – 88. https://doi.org/10.21776/ub.industria.2018.007.02.2

Octarya, Zona Fernando, Adhitya. 2016. Peningkatan Kualitas Minyak Goreng Bekas Dengan Menggunakan Adsorben Arang Aktif dari Ampas Tebu Yang Diaktivasi dengan Nacl. *Jurnal Photon*, Program Studi Pendidikan Kimia UIN SUSKA Riau.
https://doi.org/10.37859/jp.v6i02.494

Nayak P.K., Dash K., Rayaguru K., Krishna K. R. 2016. Physio-chemical changes during repeated frying of cooked oil: a review, J. Food Biochem. 40, 371–390, https://doi.org/10.1111/jfbc.12215

Rahayu L. H., Purnavita S., Sriyana H., 2014. *Potensi Sabut dan Tempurung Kelapa Sebagai Adsorben Untuk Meregenerasi Minyak Jelantah*. Akademi Kimia Industri : Santo Paulus. Semarang

Viantini, Frima, and Yustinah. 2016. Pengaruh Temperatur Pada Proses Pemurnian Minyak Goreng Bekas Dengan Buah Mengkudu. *Jurnal konversi,* 4(2), 53-62.
DOI: https://doi.org/10.24853/konversi.4.2.53-62

Yustinah and Rosdiana, 2014. *Pengaruh Konsentrasi Asam Sitrat Terhadap Penurunan Bilangan Asam dan Kepekatan Warna Minyak jelantah Melalui Proses Adsorpsi'* Jurusan Teknik Kimia : Universitas Muhammadiyah Jakarta. DOI: https://doi.org/10.24853/konversi.3.1.%25p