# Waste Cooking Oil as Feedstock for Small-scale Biodiesel Production

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## ABSTRACT

Improper disposal of waste cooking oil is a growing problem in many urban countries along with hazardous and solid wastes. In this study, waste cooking palm oil (WCO) was used to produce alternative fuel resources such as biodiesel. The raw waste cooking oil was collected from a local chicken establishment of Tagum City, Davao del Norte. Through transesterification, potassium hydroxide (KOH) and sodium hydroxide (NaOH) were used as catalysts in two (2) different reaction times, 60 minutes and 120 minutes. Percentage volume yield was obtained. T-test was used to determine significant differences between the catalysts in 60-minute and 120-minute reaction time. The production of biodiesel from a low-cost WCO was successful. Research findings showed that the volume yield of biodiesel using NaOH and KOH within 60-minute reaction time were 36.5% and 70.17%, respectively. The biodiesel yield obtained using NaOH and KOH within 120-minute reaction time were 50.5% and 58.67%, respectively. T-test revealed a significant difference between NaOH and KOH catalysts within a 60-minute reaction time but no significant difference within 120-minute reaction time. It is recommended that policies must be locally adapted to enhance waste reduction.



***Keywords***: biodiesel, waste cooking oil, waste reduction, transesterification.

## INTRODUCTION

Fossil energy is the primary energy contributor globally for industrial, technological, social, and economic progress (Yildiz, 2018). Crude oil is the most abundant energy source among varieties of fossil fuels accounting for roughly 33.1%, followed by coal with 27.0%, natural gas with 24.2%, and others with 15.7% of fossil energy as of 2019. Despite its positive impact on global change, it has been the dominant source of air pollution, which results in the greenhouse effect and global climate crisis (Perera, 2017). In 2017, according to the Global Carbon Project (GCP), the annual $CO_2$ emission is largely contributed by Asia with 53% global emission, where China produces 10 billion tons a year, representing more than a quarter of the annual global emissions, followed by the USA in North America with 18% of global emissions. Africa and South Africa account for 3-4% global emission, relatively small in value. The Philippines has had a steady increase in $CO_2$ emission since 2011 with 83.53 million tons of $CO_2$, and in 2017, it reached 127.61 million tons of $CO_2$ (Le Quéré et al., 2018). The Fifth Assessment Report (2013) of the International Panel on Climate Change (IPCC), the perpetual

greenhouse gas emission will extend above the pre-industrial level. There was a recorded average increase of global temperature of 0.85˚C from 1880 to 2012, and the Arctic ice is continuously melting with 1.07 × 106 km² of ice loss per decade since 1979. In effect, polar ice will continuously melt and they predict that the sea level will rise 40 -63 cm by the end of the century (Quinn et al., 2013).

International organizations like the United Nations (UN) and the European Union (EU) suggest countries imposing policies to lessen carbon emission and reduce reliance on fossil fuels as energy system sources (da Silva, 2015; Ghazouani et al., 2020). The Philippines contributes 0.35% of the total CO2 emission globally however, it is one of the most affected countries to the effects of climate change. As a member state of the UN, the Philippines is committed to lowering the carbon footprint together with other member states convened in the Conference of Parties. The transportation sector was emphasized the highest on CO2 emission contribution compared to the manufacturing sector. This is due to the vulnerability of the Philippine economy from the effects of climate change (Durana, 2017).

The fossil fuel reserves are limited and expected to diminish until fully consumed (Owusu & Asumadu-Sarkodie, 2016). The concern on the depleting fossil fuel resource and the urgency of the global climate crisis has led the Environmental advocate to suggest the EU on banning crop-based fuels and resort to second-generation biofuels- biofuels made from wastes oils and algae, instead of the first-generation biofuels which are made from raw feedstock (Keating, 2019). The steady increase in global consumption of biofuel expects to consume 12% of coarse grain, 28% of sugarcane, and 14% of vegetable oil of the total global production of these crops by 2023. It implies that with the increase of biofuel consumption, food security is at risk due to competition of food and fuel over a limited land area (da Silva, 2015; Najeeb, 2021). As a result, alternative fuels have been widely developed for fossil fuel replacement (Reijnders, 2009). These alternative fuels include straight vegetable oils (SVOs), bioethanol, glycerol, hydrogen, Coal to Liquid technology (CTL), and biodiesel (Sangeeta, et al., 2014).

Sixty per cent (60%) of energy is produced from fossil fuel in the Philippines. Primary diesel imports are from countries such as the United Arab Emirates (UAE) and Russia, where they provided 35% in 2013, according to U.S. Energy Information Administration (2014). Gasoline and diesel are the most common types of fuel imported in the country where alternative resources are produced within the country with its natural resources. Like any other country, the energy demand of the Philippines is increasing with time such that fuel consumption of the country will also increase (Mondal, 2018). Policies and programs have been imposed to address the demands of the biodiesel industry in the Philippines. The Biofuel act of 2006 (RA 9367) was passed into law to reduce the country's dependence on imported fuels. It includes the mandate to adopt sustainable and renewable local biodiesel and encourage investors to do so through incentives in producing and utilizing locally produced biofuel (Official Gazette of the Republic of the Philippines, 2007; Philippine Board of Investments, 2011).

Despite the law mandating the 10% minimum blend of bioethanol for all liquid fuels in the Philippines by the year 2011, there has been no recommendation from National Biofuel Board (NBB) for the Department of Energy (DOE) to increase its blend as specified on Section 5.2 of the said act. The 5% minimum bioethanol blend was not implemented in 2015 due to high coconut oil prices, which would lead to an increase of fuel in the market. The United Nations Conference on Trade Development (UNCTAD) identified the Philippines as "likely remains a net importer of fuel" since local oil companies have been importing ethanol from Thailand to

be consistent with the 10% ethanol blend requirement. It implies that the Biofuel Act of 2006 has not been able to meet its intended outcome (Olchondra, 2014; Corpuz, 2018).

In general, waste cooking oils (WCO) refers to a mixture of oils and fats used for cooking in food processing industries, fast food restaurants, and households (Raqeeb & Bhargavi, 2015). In most fast-food chains, oils are used to deep-fry foods like French fries and fried chicken (Zhang et al., 2012). As cited by Xu et al. (2020), Frying is done within the range of 160 to 200°C and is one of the oldest methods for food preparation. It is a complex process wherein a series of physical and chemical reactions occur, such as heat and mass transfer. Ideally, cooking oils should be used at a minimum temperature of 35˚C and in a maximum of 180˚C (Santos et al., 2013; De Alzaa et al., 2018) because cooking on low temperature would lead to an increase in fat uptake of fried foods (Brown et al., 2017). The rise of food establishments due to high human consumption increases considerable waste cooking oil. This could lead to uncontrollable disposal and may negatively impact the environment (De Feo et al., 2020; Goh et al., 2020). In this regard, instead of disposing of WCO, it is recycled to produce animal feeds, manufacture of soaps, and biodegradable lubricants (Panadare, 2015; Mannu et al., 2019). Several reports are found on the recycling of WCO to produce transportation fuel that are environmentally sustainable such as in Thailand (Pleanjai et al., 2009), Singapore (Chua et al., 2010), Mexico (Sheinbaum-Pardo et al., 2013), Portugal (Caldeira et al., 2015), Indonesia (Pasae et al., 2019). To date, current techniques for the treatment, recovery and conversion of waste oil has grown rapidly (Mannu et al., 2020) such as transesterification (Zhang et al., 2003; De Paola et al., 2009; Gashaw & Lakachew, 2014;) ultrasound-assisted transesterification (Carmona-Cabello et al., 2019), and hydrotreating (De & Luque, 2014; Wang et al., 2019).

The concern about energy supply has driven the transport industry to use vegetable oil as an alternative to petrodiesel (Li et al., 2012) then Europe began to improve and started the biodiesel industry in 1980 until it was commercialized in 1990 (Yarkasuwa et al., 2013). In 2005, the global production of biodiesel reached about 3,762 million liters where 85% is produced in Europe, 7% is produced in the USA and 8% is produced in some countries predominantly in China and Brazil (Goto et al., 2010).



Biodiesel is claimed to be a fast-growing alternative fuel in the world because of the number of benefits it holds towards the environment (Dincer, 2008). Analysis of particulate matter and carbon monoxide emission of biodiesel is found to be lesser (Rashid et al., 2010; Rubianto et al., 2013). Carbon monoxide and nitrogen oxide produce smog during hot days which causes respiratory illnesses to the public (Manisalidis et al., 2020). Biodiesel also provides sustainable, renewable, and cost-effective fuel which can compensate for the shortage of petroleum (Kumar et al., 2020). It offers a good economic impact and environmental effect in the coming future (Nunez, 2019).

In 2007, the Philippines grasped the development of biofuels to attain future energy security, increase the farmer's income, and generate rural employment, according to the Philippines Biofuels Activities. Production of biofuels in the Philippines is currently limited to biodiesel where coconut oil is the primary feedstock. A total of 257 million liters of biodiesel per year were produced by seven (7) biodiesel plants in the country. In the same year, blending of coconut methyl ester (CME) in petrodiesel started upon the implementation of R.A. No. 9367 or the Biofuels Act of 2006 (Ison, 2019) in 2007. A minimum of one percent (1%) biodiesel by volume shall be blended into all diesel engine fuels, according to this act. B1 (1% biodiesel and 99% petrodiesel) has been successfully used by thousands of vehicles in the Philippines since 2002. It was increased to two (2) percent in 2007 and has remained at that level since.

The Philippine Department of Energy reported in 2012 that the biodiesel production for the Philippines reached 137.88 million liters. Its latest energy plan has recommended maintaining the current ethanol and biodiesel blends (10 and 2 percent, respectively) through 2019, and revisit blend targets through 2040 due to feedstock concerns and pricing (Corpuz, 2018). In 2011, the Philippine Board of Investments (BOI) created a program to support mechanisms to have an adequate supply of feedstock and adopt technologies that use alternative fuels such as biodiesel. A development plans and programs following a framework that covers feedstock, technology, and industry development, industry promotion, guidelines, and standards enforcement and evaluation, and industry promotion with financial support from the Land Bank of the Philippines (LBP) and the Development Bank of the Philippines (DBP) on renewable and agri-based energy source projects (Philippine Board of Investments, 2011). The statistics published by Statista Research Department (2019) shows the total biodiesel consumption in the Philippines from 2009 to 2017. In 2017, the total biodiesel consumption amounted to approximately 204 million liters, indicating a decrease of 14 million liters compared to 2016.

The most economical method of producing biodiesel is through transesterification (Nasreen et al., 2018). It is a process by which the triglycerides of oil react with an alcohol in the presence of a catalyst to form glycerol and esters (Refaat, 2010; Elkady et al., 2015; Mumtaz et al., 2017). The produced biodiesel is blended into diesel fuel for engines to utilize it (Brito-Cruz et al., 2014). To produce biodiesel, the main factor to consider is the feedstock (Mumtaz et al., 2017). Most feedstock studied for biodiesel production are edible oils (Sani et al., 2012). The significant edible oils used to produce biodiesel are soybeans, rapeseeds, canola, safflower, barley, coconut, copra, cotton seed, groundnut, oat, rice, sorghum, wheat, and winter rapeseed oil (Nomanbhay & Ong, 2017). Several studies have been carried out to synthesize biodiesel using different raw materials such as microalgae by Ahmad et al. (2011), Yanfen et al. (2012), Chen et al. (2018) and plant-based oils such Jatropha (Rashid et al., 2010; Lee et al., 2010; Siregar et al., 2015), canola oil (D'Cruz et al., 2007; Boz et al., 2013), palm oil (Ullah et al., 2014; Hidayatno et al., 2011; Choedkiatsakul et al., 2014), rape seed (Komers et al., 2002; Frondel & Peters, 2007; Chen & Chen, 2011; Ozturk, 2014) and sunflower (Thirumarimurugan et al., 2012; Mansourpoor, M. & Shariat, A., 2012; Naureen et al., 2015). Given these potential results, there have been no substantial reports on the relationship between potassium hydroxide (KOH) and sodium hydroxide (NaOH) as catalysts with the reaction time, quality and volume of the biodiesel produced.

Tagum City's effort to decrease its carbon emission is consistent with its commitment to reduce $CO_2$ emission. The local government has approved fourteen (14) environmental policies since 1990. In 2014, Resolution No. 567 was passed to mitigate carbon emission in the city which paved way for the establishment of waste-to-energy through pyrolysis in 2015 at Barangay San Agustin (Lim, 2014). However, there have been no reports on disposal of waste oils, treatment facilities for WCO, and permits to transport WCO to nearby cities where waste oils are used for treatment. Improper disposal of WCOs can substantially harm the environment. It can cause contamination of potable water and drastically drop the oxygen level affecting the freshwater ecosystem. Hence, this paper is presented as an attempt to yield biodiesel from waste cooking products using potassium hydroxide and sodium hydroxide as catalysts.

## MATERIALS AND METHODS

This study followed strict compliance with the waste management protocol and biohazard precautionary measures provided under Section 11 of Republic Act (RA) 6969 (Toxic

Substances and Hazardous and Nuclear Wastes Control Act of 1990) and Section 22 of RA 9003 (Ecological Solid Waste Management Act of 2000). Proper bottling, labelling, and storage for WCO, distilled water (Di $H_2O$), KOH, NaOH, phenolphthalein, $H_2SO_4$, and ethanol, were made as part of the general safety measures for handling chemicals. Storage of the collected WCO was within the laboratory premises, where the experiment is conducted. All reagents and materials used were within the laboratory premises and were never transported elsewhere. All materials used in this study were disposed properly following the standard rules and regulations determined by the DENR under RA 9003.

The WCO samples were collected from a local chicken establishment in Tagum City, Davao del Norte, Philippines. Entry protocols were obtained prior the collection of samples from Country's Fried Chicken (CFC). WCO was stored in a plastic container and transported from the store to the Chemistry Laboratory of the University of Mindanao Tagum College, Mabini Street, Tagum City, Philippines.

The FFA content of WCO was determined by titration using phenolphthalein as an acid-base indicator (Banani, et al., 2015; Yusuff et al., 2018). This method was replicated thrice to get the average KOH volume (Alam et al., 2016). The acid value of WCO was taken using KOH as the titrant (Yusuff, Adeniyi, Olutoye, & Akpan, 2018; Luu, et al., 2014). The reference solution was prepared by dissolving 5.6 grams of KOH, diluted to 1L Di $H_2O$ with 50 ±0.05 ml in a titration set-up (Ebenaza & Vinoth, 2015). Phenolphthalein ($C_20H_{14}O_4$) indicator was prepared by dissolving 0.5g of phenolphthalein powder in 10 ml of ethanol and 50 ml of Di $H_2O$ (Ebenaza & Vinoth, 2015). 1 mL of WCO was mixed with 10 mL of ethanol and 2-3 drops of phenolphthalein solution were added into the mixture in each flask (Ebenaza & Vinoth, 2015). The reference solution was added drop by drop from the burette to the mixture until it turned into a light pink solution and the final reading was recorded. Phenolphthalein changes color from colorless to pink at a pH range of 8.3-10. The solution was tested with the use of pH paper to see if it fits the pH range which ensures that the titration process was completed. The same process of titration was repeated for two samples. The different values of titration were recorded ($T_1$, $T_2$, and $T_3$). The final value was calculated by taking the average of the three values (Alam et al., 2016). Acid value was calculated after the average volume of KOH was obtained. With the acquired acid value, the %FFA present in the oil can be determined. The percentage FFA in the sample is approximately equal to half the acid value and calculated using E2 (Banani et al., 2015). Since the %FFA of the oil was <2%, there is no need for the oil to undergo acid esterification process.

Base trans-esterification was conducted to convert the triglycerides to mono-alkyl esters on WCO (Venkateswarulu et al., 2014). During this process, the ethanol reacts with the fatty material of WCO in the presence of a strong base catalyst, usually NaOH and KOH with different concentrations (Udeh, 2017). The molar ratio of alcohol to oil was 12:1 to increase the yield of biodiesel obtained from WCO, filtered and re-filtered. Solution was heated at a range temperature of 110˚ to 120˚C (Joshi et al., 2017; Atadashi 2015) for 30 min to avoid moisture and for the removal of water (Bashir et al., 2018; Allah, 2016). The water content of WCO will cause soap formation and lead to low yield of biodiesel products (Saini, 2017). WCO was cooled up to 60°C after heating, a solution containing 1% (wt/wt of oil) of catalyst and 74mL of 95% ethanol were added and strenuously stirred with a magnetic stirrer. The two solutions were allowed to react separately for 60min and 120min (Degfie, Mamo, & Mekonnen, 2019) and the reaction temperature ranges from 55°C to 60°C (Gutierrez-Zapata et al., 2017; Saini, 2017). Mixture was carefully transferred in a separatory funnel and allowed to settle down at room temperature for 24 hours for the complete separation of raw biodiesel and

glycerol (Chinni et al., 2015; Wicaksono et al., 2019). Raw biodiesel from phase I have undergone washing for purification (Rahadianti et al., 2018). FAEE was separated from the glycerol, a warm Di $H_2O$ (approx. 50°C) was carefully added, and the volume of the water was 50% of the total volume of the raw biodiesel (Bashir et al., 2018). Washing of the impure biodiesel was continued until the pH neutrality (7.25) was obtained (Udeh, 2017). Purified biodiesel was dried to remove the excess amount of water from washing (Gupta et al., 2014; Bateni et al., 2017). The biodiesel was removed from the separatory funnel into a 250 ml beaker and placed on the top of a hot plate magnetic stirrer. The solution was slowly heated at a range temperature of 100°C to 110°C (Arenas et al., 2021) for 30 min until the cloudiness gradually disappeared as the water evaporated. Biodiesel was allowed to cool down and transferred to a ±1.0 ml graduated cylinder for measurements.

For the analysis of data, the biodiesel yield from transesterification was calculated. Percentage volume yield (Abbah et al., 2016) is calculated using this equation:

$$Yield = \frac{produced\ biodiesel\ (mL)}{amount\ of\ used\ oil\ (mL)}\ x\ 100$$

The average ($\bar{x}$) volume yield by catalyst within 60-min and 120-min reaction time was calculated. T-test was used to determine if there is a significant difference between the catalysts within 60-min and 120-min reaction time at $p<0.05$ (Kim, 2015).

## RESULTS AND DISCUSSION

In this study, biodiesel production by transesterification of waste cooking oil with 95% ethanol was studied in a homogeneous catalyst system. The optimal conditions for transesterification were an ethanol/oil molar ratio of 12:1, NaOH and KOH amount (1% wt/wt of oil) with a range temperature of 55-60°C. In order to study the effects of the mixture catalyst on the biodiesel production yield, the mixture of the KOH and NaOH was mixed in an equal molar ratio of 1:1 with the same amount of WCO and alcohol. The biodiesel was produced successfully from low-cost waste cooking oil using the KOH and NaOH as catalyst.



The average yield of KOH is slightly higher compared to NaOH. The mean volume yield of NaOH is 36.5% while KOH is 70.17% in a 60-min reaction time. Presented in Figure 3 is the volume yield by the two catalysts within 60-min reaction time. The average yield of the product using NaOH and KOH as catalysts are 36.50 ±0.05 mL and 70.17 ±0.05 mL, respectively (Figure 1).

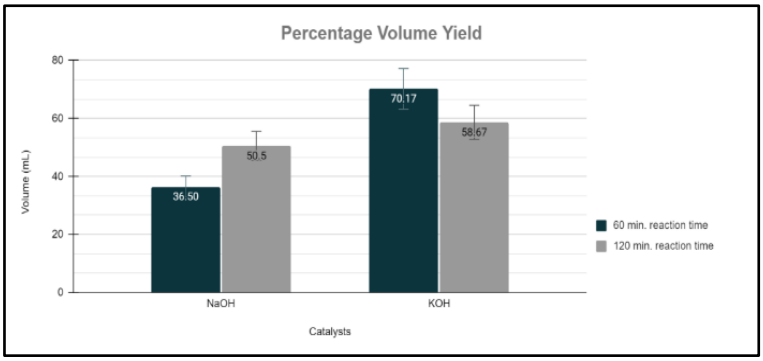


Figure 1. Percentage volume yield catalyst at 60-minute and 120-min reaction time.

The percentage yield of NaOH (50.50%) is slightly low compared to KOH (58.67%) in a 120-min reaction time. As shown in Figure 3, the volume yield of the biodiesel product within 120min. The average yield of the product using NaOH and KOH as catalysts are 50.50 ±0.05 mL and 58.67 ±0.05 mL, respectively. During the process, it was observed that the transesterification reaction was very slow as oils and alcohols are not completely miscible without mixing. Chozhavendhan et *al.* (2020) stated that the increase in stirring speed will shorten the reaction time and increase the conversion. Ideally, the maximum mixing speed for 60-minute and 120-minute reaction time is 600 revolutions per minute (rpm) (Mashkour et al., 2016). Yield of biodiesel could be influenced by the stirring speed. This parameter was not determined due to the insufficiency of laboratory equipment such as the chemical agitator, hence agitating was made manually. Basically, agitating the solution is necessary to promote the transesterification reactions to take place (Trejo-Zaragga et al., 2017). A related study from Alamsyah et al. (2010) produced a yield of 80% biodiesel using a blade agitator reactor within 60-min reaction. A 97.3% conversion of triglycerides that matched with the EN biodiesel standards was achieved by Hosseine et al. (2012) using a helical ribbon-like agitator. Meanwhile, a maximum yield of 49% biodiesel that met the quality standard of Standard Nasional Indonesia (SNI) was attained using a static mixer with a mechanism of agitator blades (Rahmat et al., 2013). A bench reactor with a mechanical agitator was used by Colombo et *al.* (2017) to obtain a yield of 96% biodiesel.

Biodiesel conversion also depends on the concentration of the catalyst. It was observed that utilizing a high concentration of catalysts resulted in the formation of soap thus reducing the yield of the biodiesel production. In addition, above 1% amount of catalyst was found to be difficult to eliminate during washing of the impure biodiesel. According to Changmai et *al.* (2020) using vegetable oil with low FFA content as a feedstock in making biodiesel, a small amount of catalyst (<0.5%) is needed.

*Volume yield by catalyst within 60-minute reaction time*

Analysis of volume yield by catalyst using T-test showed that there is a significant difference (at p>0.05) within a 60-min reaction time as presented in Table 3. The results of this study showed KOH had higher results compared to NaOH. Table 1 showed the significant difference on volume yield of biodiesel by catalyst, and when analyzed by 60-min reaction time, NaOH showed a significant ($p < 0.05$) result compared with KOH.

Table 1. Significant Difference on Volume Yield by Catalyst (60-minute reaction time)

| Catalyst | Mean | SD | t-value | p-value |
|---|---|---|---|---|
| **NaOH** | 36.50 | 15.31 | -4.717 | 0.001* |
| **KOH** | 70.17 | 8.45 | | |

*$p < 0.05$

This finding could be attributed to the nature of the NaOH as an alkali catalyst. According to Efavi et al., (2018), a higher concentration of NaOH will lead to the triglycerides forming soap thereby, reducing the yield of the biodiesel production. Nevertheless, Gnanaprakasam (2013) referred NaOH as the fastest catalyst among other alkali catalysts. Ejikeme et al. (2010) found out that NaOH requires low temperature and less reaction time and converts oil to biodiesel directly. Also, Kawentar & Budiman (2013) and Nasreen et *al.* (2018) pointed out that NaOH

is the most preferable catalyst for biodiesel production due to its low temperature and atmospheric pressure requirement, and high conversion rate in lower reaction time than any other alkali catalysts. However, Hossain & Mazen (2010) stated that there are no clear explanations between NaOH and KOH as good catalysts, instead, emphasizing that based on several studies, performance of different catalysts are dependent on the oil used. For this research work, the oil used is palm oil collected from a local fried chicken store. The result of this study is similar to the findings of Gumahin et *al.* (2019) which conclude that KOH gives the highest yield of biodiesel at 60-min time reaction with a maximum yield of 93%. Karabas (2013) also concludes that the optimum reaction time using KOH is 60min, which provides 98% biodiesel from canola oil. Saleh & Kulkarni (2014), using KOH catalyst, showed that the biodiesel yield and conversion obtained were higher than using NaOH. This is due to the formation of soap during the reaction, nevertheless, with KOH catalyst, less soap formation was obtained. However, with catalyst concentration higher than 1%, the ester content available for the conversion decreased due to soap formation. Anisah et *al.* (2018) obtained 56.60% of biodiesel using NaOH at a 12:1 molar ratio of alcohol to oil within 60-minute time reaction. It was observed that the optimum reaction time has been achieved within 60 minutes. However, Efavi et *al.* (2018) suggested that the suitable reaction time for NaOH is somewhere between 90 min to 120 min. It also shows that the excess reaction time at about 150 min will lead to a reduction in the product yield due to the backward reaction of transesterification thus, resulting in losing some of the esters available for the conversion.

At different temperatures, transesterification may occur depending on the alcohol used and the type of catalysts (Taufiq-Yap et al., 2011). Temperature influences the reaction rate which can be anchored to the theory of chemical reaction kinetics. Arnaut et. al. (2006) mentioned in their book that this theory is affiliated to the theory of collision which explains how the reaction rates of molecules are affected by the temperature. Lower (2020) stated that for a chemical reaction to occur, temperature is needed as a source of energy. Thus, as the temperature of a solution increases, the more the molecules collide and react with one another. This causes the reaction to move faster. However, the temperature range maintained during the conduct of this study was 55-60 °C using a bulb thermometer for the reason to prevent the alcohol from evaporating. According to Refaat (2010), Allah & Alexandru (2016), Istiningrum et *al.* (2017), and Saini (2017), the temperature for the reaction should not exceed the boiling point of any alcohol to avoid evaporation of alcohol. In a related study by Abbah et *al.* (2016) using methanol, increase in temperature results in decreased yield of biodiesel due to evaporation. As cited, temperature increase results in increasing fraction of molecules with high speed, thus, high kinetic rate. According to Degfie et *al.* (2019), the optimum temperature is 50°C which increases biodiesel yield at 96% while higher temperature (70°C) decreases yield to 74% yield within 90-min reaction time.



*Volume yield of biodiesel by catalyst within 120-minute reaction time*

T-test results from data on biodiesel yield within a 120-min reaction time showed no significant difference on volume yield by catalyst and the reaction time. Table 2 showed no significant difference on volume yield of biodiesel by catalyst when analyzed by 120-min reaction time. This finding is contrary to Efavi et *al.* (2018) which showed that the yield and the concentration of the catalyst for biodiesel production are directly proportional. This means that as the rate of reaction is enhanced, the higher will be the yield. According to Simpen et *al.* (2020), fatty acid ethyl esters production was faster in reaction time of 60 minutes, and then the reaction declined when equilibrium was reached. Along the process, the two opposing reactions equalize at equilibrium, resulting in a constant concentration of the reactants and products (Brown et al., 2017).

Table 2. Significant Difference on Volume Yield by Catalyst (120-minute reaction time)

| Catalyst | Mean | SD | t-value | p-value |
|---|---|---|---|---|
| NaOH | 50.50 | 21.18 | -0.916 | 0.397 |
| KOH | 58.67 | 5.32 | | |

*p < 0.05

For most chemical reactions, the longer the reaction time, more interaction of molecules occurs yielding to high results. However, expanding the reaction time in this process does not affect fatty acid ethyl esters yield when the equilibrium is attained, which concurs with the results of this study. The findings of this study are related to the findings of Anisah et. al. (2018) which obtained 60-80% conversion at an increasing molar ratio of 1:3, 1:6, 1:12, and 1:15 with 1% catalyst within 90-, 120-, and 150-min reaction time. They found out that the conversion rate was stable with these increasing molar ratios and reaction time. They concluded that accelerating the reaction time will not increase the conversion result. This is probably due to the transesterification reaction as a reversible process in which the conversion of reactants to products and products to reactants happens at the same time, as defined by Castillo-Gónzalez et *al.* (2020). This infers that adding more time when the reaction equilibrium is reached does not affect the volume yield unless adding excess alcohol to maintain a forward reaction yielding to more biodiesel. Although the average yield in this study showed slightly higher results with KOH, it is evident that the transesterification reaction equilibrium occurs in a 60-minute reaction time (Anikeev & Ermakova, 2012; Trejo-Zarraga et al., 2017).

## CONCLUSIONS

Biodiesel from waste cooking oil, particularly palm oil, is obtained by transesterification process using two (2) different catalysts, sodium hydroxide (NaOH) and potassium hydroxide (KOH), with corresponding reaction time of 60 minutes and 120 minutes. Catalysts play an essential role in converting triglycerides into mono-alkyl esters by increasing the reaction rate. On the other hand, the reaction time allowed the transesterification process to produce a high-quality biodiesel with high yields. In summary, research findings from this study showed that production of biodiesel from low-cost WCO was successful. Volume yield of biodiesel using NaOH and KOH within 60-minute reaction time were 36.5% and 70.17%, respectively. The biodiesel yield obtained using NaOH and KOH within 120-minute reaction time were 50.5% and 58.67%, respectively. T-test revealed a significant difference between catalysts NaOH and KOH within a 60-minute reaction time but no significant difference within 120-minute reaction time.

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