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# Biofuel Production from Used Cooking Oil Using Pyrolysis Process

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***Abstract: This paper aims to evaluate the production of biodiesel from Waste Cooking Oil (WCO) using the Pyrolysis process with catalysts. The test rig used in the present study is designed and built in the lab specifically for this purpose. To investigate the effect of adding different types of catalysts with different concentrations on the quantity of hydrolyzed biodiesel. Noah and KOH catalysts with concentration of 0.5%, 1%, 3% and 10% by weight are used. Moreover, the effect of catalyst type on the energy consumption during the pyrolysis process is considered. The experimental results showed that the biodiesel produced by pyrolysis process form the Waste Cooking Oil has significant potential as an alternative source of biodiesel fuel. The addition of Noah catalyst with 1% concentration by weight provided the highest amount of hydrolyzed biodiesel and lowest energy consumption compared to adding KOH catalyst and without catalyst. Additionally, the experiments showed that the amount of biodiesel produced from the pyrolysis process is inversely proportional to the catalyst concentration.***
***Keywords: Bio fuel, Used Cooking Oil (WCO), Pyrolysis Process, Catalysts***

## I. INTRODUCTION

The Increasing demand of energy resources, environmental alarms due to the global warming problem and the increase of petroleum prices are the primary motivations to search for alternative fuels. The conventional sources of coal, oil and natural gas are decreasing dramatically and this negatively effects the continuous need of energy in the near future. In this perspective, significant attention has been given towards the green energy production from natural and renewable resources that are less harmful to human life. Biofuels are a recommended solution among the list of the alternative fuels these days. Biodiesel fuel is becoming among the most attractive fuels due to the fact that the feedstock such as vegetable oils and animal fats are renewable resources [1]. Biodiesel has essential cones to both environment and industry such as low dangerous emission, biodegradable, sustainability participant and improves the engine lubricity compared to traditional diesel [2]. Moreover, It has a higher Catani number, no sulfur, no aromatics and contains 10 - 11% of oxygen by weight [3]. However, using the crude vegetable oils as fuel or lubricant for Internal Combustion Engines (ICE) causes many problems due to its high viscosity [4]. Therefore, complicated chemical processes have to be carried out on the crude vegetable oils to convert it into a suitable form for industrial applications. Trans esterification processes with or without catalysts are the most common method of treating the vegetable oils and animal fats [1]. Although there are massive attractive reasons for using vegetable oils as feedstock of biodiesel production, many factors hamper this. For example, many farmers switch to plant their lands for biodiesel production instead of food production, hence the oil prices increase rapidly. Moreover, the cost of planting vegetable oils is usually higher than extracting the traditional diesel. Therefore, looking for an alternative source for producing biodiesel is becoming one of the major challenges in renewable and sustainable energy community. Waste Cooking Oil (WCO) as biodiesel feedstock is recently becoming an active topic for many researchers. This choice is reported as one of the best solutions to reduce the cost of biodiesel production since the cost of feedstock contributes approximately 70 - 95% of the whole biodiesel production cost [5]. Hence, the use of waste vegetable oils and non-edible oils received higher priority over the edible oils as a cheap course of biodiesel production. Massive amount of waste vegetable oil is collected each year from commercial and industrial sources in different countries, which it usually disposed into the sewage and rivers. For example, 65,000 : 80,000 tons in USA, 350,000 tons in Turkey and about 1.00 Million tons in China [6, 7]. These huge quantities of waste cooking oil bring many disposal problems all around the world by contaminating drinking water and choking of drainage. Therefore, the use of waste cooking oil as a source of bio fuel production will bring in many benefits to both the environment and industry. It was reported that the combustion of traditional fuels such as coal, petroleum products and natural gas are the main source of increasing the carbon dioxide concentration in the earth’s atmosphere, hence the global warming problem. On the other side, the combustion of bio fuels

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does not cause any net increase in carbon dioxide concentration in the atmosphere; hence decrease the fear from global warming problem and crucial benefits into the environment. Biodiesel consists mainly of Methyl or Ethyl Esters of fatty acids that can be produced through esterification or a trans esterification reaction using acids or solid catalysts [8-11]. Nowadays, edible oils extracted from soybean, palm and sunflower are the main feedstock source of biodiesel, and hence the prices of these feed stocks increased dramatically. Consequently, the high prices of biodiesel compared to petroleum-based diesel represent the major obstacle of becoming wide spread. Motivated by these negative effects, seeking for a new alternative feedstock for biodiesel production is the main objective of the current project. Reducing the cost of feedstock sources is among the strategies of reducing the prices of biodiesel [12, 13]. Thus, production of biodiesel from waste cooking oil is one of the most beneficial ways to utilize it effectively and eliminating the disposal related problems [14]. Transesterification process has been approved by industry for many years as the best option of producing biodiesel from waste cooking oil [15, 16]. In that process, the high viscosity of triglycerides will be reduced and transferred into Methyl Ester and Glycerol using catalysts [17]. Although transesterification reaction is an economic method and environmental friendly, it relatively consumes high energy and saponification can occur [18-20]. A Long time ago, researchers investigated the use of heat with or without catalyst, in the absence of oxygen to produce petroleum form vegetable oil which is called pyrolysis process [21]. Compared to transesterification, the hydrolyzed fuel has similar chemical components to fuel produced from conventional fossil fuel [22]. Therefore, pyrolysis process has received a substantial amount of interest as it offers high quality produces [10, 23]. Based on the authors' review, producing biodiesel from Waste Cooking Oils (WCO) using pyrolysis process was not applied before. Therefore, the present study is aiming to apply and access the pyrolysis process for producing biodiesel from waste cooking oil. In addition, the effect of using different types of catalysts, its concentration and the temperature range on the hydrolyzed biodiesel is considered. The structure of this paper is as follows; first an introduction and historical review about bio fuel production and its benefits as an alternative fuel is presented. The description of the test rig and the equipment used in the biodiesel production is introduced next. Thereafter, the discussion of the parameters affected by the quantity and quality of produced biodiesel and summery of the research findings and future work are provided.

## II. EXPERIMENTAL TEST RIG

In the present research, the test rig used for producing biodiesel form the waste cooking oil using pyrolysis process was designed and built for this purpose. It consists of an oil tank with a cylindrical shape attached with circular electric heater, condenser, thermocouple connected with digital temperature controller, receiving adapter bend with vent and Plexiglas flask. The combination between the cylindrical tank and circular electric heater is mentioned here as the reactor. Figure 1 shows the CAD drawing of the cylindrical oil tank with dimensions in millimeters. It was made from stainless steel to avoid corrosion or any chemical reaction between the tank and WCO or any possible reaction with the produced biodiesel. Moreover, it was designed to withstand the high temperature that can reach to 500 ºC. The tank has a circular base of 190 mm diameter and 265 mm in height to hold 2 - 5 Liter of WCO during each run. The tank was completely isolated to minimize the heat losses.

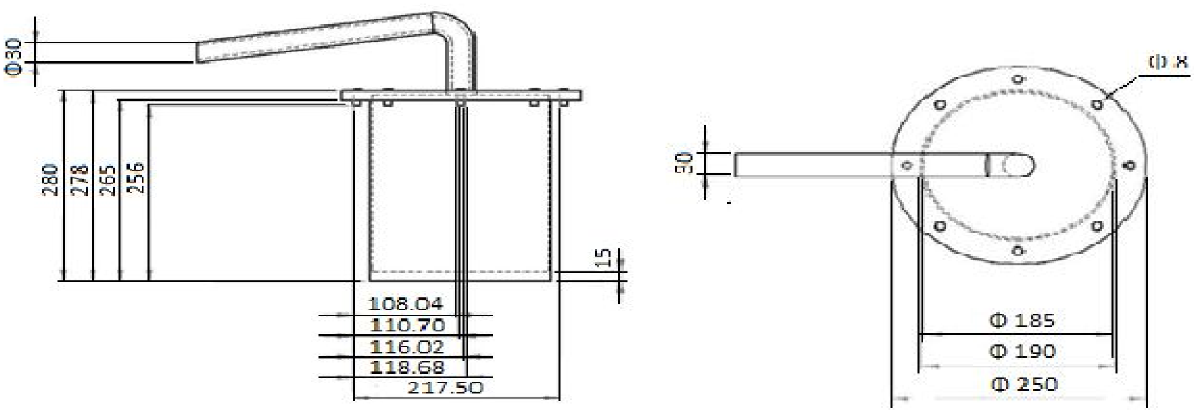


Figure 1: Cylindrical oil tank with dimensions in mm, (a) front view, (b) plan view.

A circular shaped electric heater of 1400 Watt was attached to the oil tank to head up the WCO during the pyrolysis process. A transparent condenser with 29 mm bore and 800 mm length made from high-quality borosilicate glass is used. The condenser is connected to the reactor's pipe with a Teflon joint to prevent any possible leakage. A 2000 ml PYREX flask is used to collect the produced biodiesel during the process. K-type thermocouple with digital temperature controller was used to monitor and control the

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heating temperature during the pyrolysis process. Before running the test rig, the K-type thermocouple was calibrated and adjusted to minimize the error. In the calibration, the thermocouple reading was 99 °C when it was put in boiling water and it was -1 °C when it was put in a piece of ice at atmospheric pressure. Therefore, the error of the thermocouple used in the present study was approximately 1%. Figure 2 shows a schematic diagram of the test rig components and measuring devices used in the pyrolysis process of producing the biodiesel from the waste cooking oil.

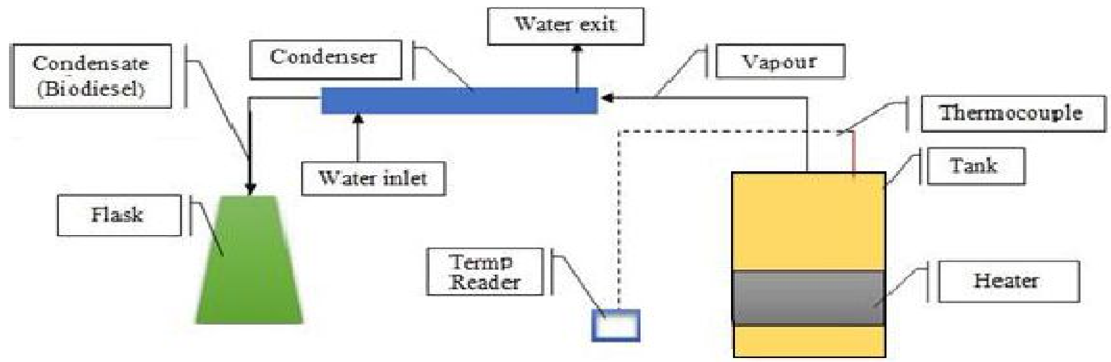


Figure 2: Schematic diagram for the test rig used in pyrolysis process of WCO.

## III. MATERIALS AND METHODS

In this study, waste vegetable oil is the feedstock of producing the biodiesel using pyrolysis process. One hundred liter of waste vegetable oil was collected from different restaurants in the local area. This amount of waste oils was collected from the fast food restaurants that use it in frying, since these places are a good and clean source of the used oils. Sodium Hydroxide (NaOH) and Potassium Hydroxide (KOH) were prepared to use as catalysts in the present study.

### *A. Pyrolysis Process*

In this process, the waste cooking oil is firstly filtered to remove all the residual solid particles beforeusing it in the reactor. The WCO was heated up to 50 °C to remove the water content and let the oil runs freely during the filtration process. A double layer of cheesecloth in a funnel is used in the filtration process. NaOH and KOH catalysts were prepared to study the influence of catalyst type bandits concentration on the properties of the produced biodiesel. This was achieved by carrying out a series of experiments using four values of NaOH concentration of 0.5%, 1%, 3% and 10 %. Figure 3shows the flow-chart of pyrolysis process of producing the biodiesel from WCO using two types of catalysts.

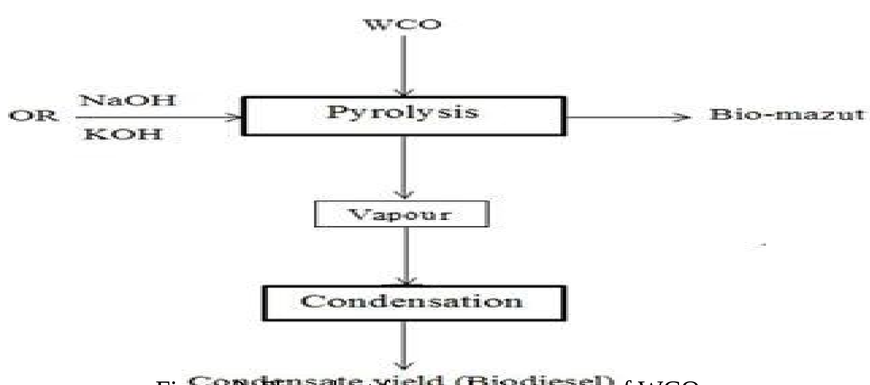


Figure 3: Flow chart for pyrolysis process of WCO

The reaction time for pyrolysis process spends between 3 to 6 hours with temperature range of 200-400 °C. The reaction temperature in the reactor was measured by the thermocouple and the reading was displayed on the digital temperature controller. At each run, 1.5 to 2 Liters of waste cooking oil was put inside the reactor where the pyrolysis process takes place. When the reaction complete, the produced biodiesel vapor from the reactor was condensed and collected in the receiving flask, which has a yellowish color. The high viscous and black residuals from the paralyzed WCO precipitate in the reactor's bottom, which is usually called as bio-mast. Figure 4 shows a sample of the filtered WCO before the pyrolysis process (a) and the final biodiesel product (b)


(a) (b)

Figure 4: Sample of filtered Waste Cooking Oil (a) and the Pyrolysis biodiesel (b)

## IV. RESULTS AND DISCUSSION

### A. *Influence of Catalyst Type on the Paralyzed WCO*

The influence of catalyst type on the amount of produced biodiesel from the pyrolysis process was investigated and the results were reported in this section. Sodium Hydroxide (Noah) and Potassium Hydroxide (KOH) are the two catalysts that were added to the WCO during the pyrolysis process. The pyrolysis process was performed firstly without adding any catalysts for comparison. The process with and without catalysts was carried out at the standard atmospheric pressure and the temperature range of 200 - 400 °C. The catalyst concentration of both NaOH and KOH was kept the same at 1 %by weight. Figure 5 shows the effects of using a catalyst on the quantity of pyrolysis biodiesel compared to the obtained quantity without adding a catalyst.

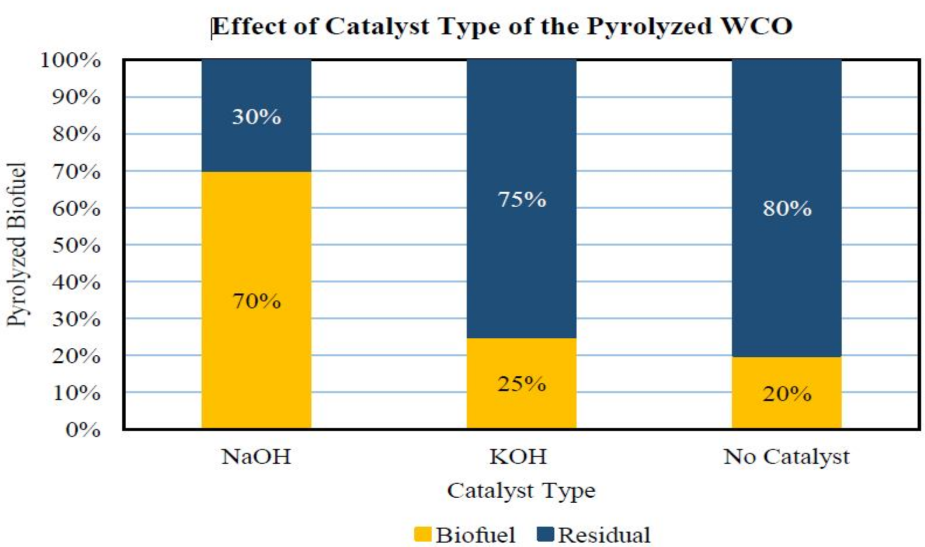


Figure 5: The quantity of Pyrolysed biodiesel with and without adding catalyst.

As it can be seen from figure 4, 70 % from the whole waste cooking oil in the reactor was converted into biodiesel when NaOH catalyst with 1 % concentration by weight was added and the rest (30%) was collected from the reactor’s bottom as bio-mazut. In addition, only 25 % of biodiesel was obtained from the pyrolysis process of the waste vegetable oil when KOH catalyst with 1 % concentration by weight was added and the high parentage (75 %) was bio-mazut. The minimum quantity of biodiesel (20 %) obtained when the process was carried out without catalyst.

### B. *Influence of Catalyst Concentration on the Pyrolysed WCO*

In this section, the effect of catalyst’s concentration that was added to the waste cooking oil during the pyrolysis process is studied. As discussed in the previous section, the NaOH catalyst provided the maximum amount of the parolee Serbiadiesel, hence the effect of catalyst concentration is investigated using NaOH catalyst only. Four values of NaOH concentration by weight of 0.5 %, 1%, 3% and 10 % are used in this study. The pyrolysis process with these conditions was carried out at the standard atmospheric pressure and at temperature range of 235 - 310 °C. Figure 6 shows the amount of biofuel produced from the pyrolysis method with using different values of NaOH catalyst concentration and without using any catalysts (0.0 % NaOH).

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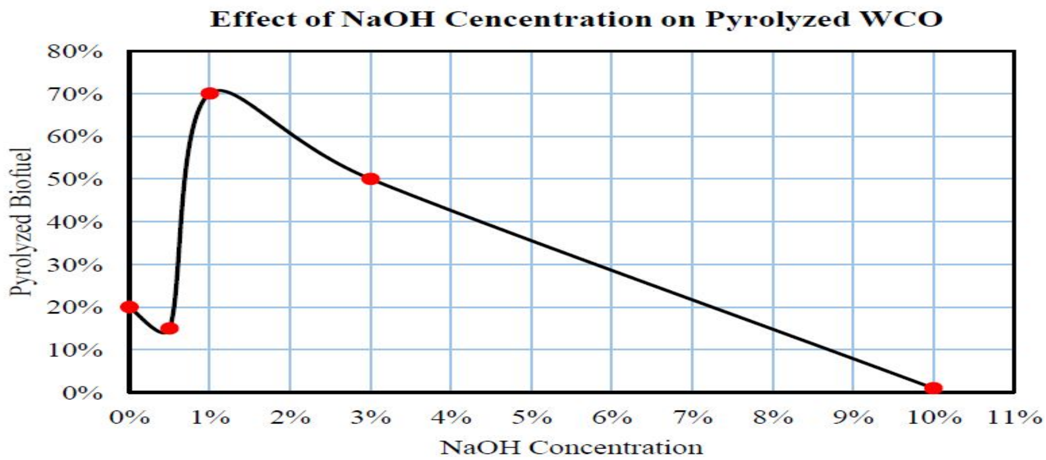


Figure 6: The quantity of Pyrolysis biodiesel with different values of NaOH concentration

As might be seen in figure 5, the addition of NaOH catalyst with 1 % by weight provided the maximum quantity of pyrolysis biodiesel from the pyrolysis method. Moreover, the experiments showed that the amount of biodiesel produced from the pyrolysis process is inversely proportional to the catalyst concentration.

*C. Influence of Catalyst Type on Pyrolysis Temperature Range*

The temperature range of the pyrolysis process is considered one of the most important parameters to measure the energy consumption. Figure 6 illustrates the relation between the type of added catalyst and the amount of energy consumed while carrying out the pyrolysis method. To investigate this parameter, the experiments were carried out using NaOH and KOH catalysts with 1% concentration by weight and without catalysts. Evidently, the type of catalyst strongly affects the temperature range of the pyrolysis process, hence the energy consumption. Figure 7 shows that the temperature range applied for the process was 235 - 310 °C, 275 - 400 °C and 150 - 340 °C when Na OH catalyst used ,KOH catalyst added and without catalyst, respectively. Additionally, it can be concluded that the usage of 1% concentration by weight of Na OH catalyst does not only produce the highest quantity of Pyrolysed biodiesel, but also achieves the highest rate of energy saving during the process.

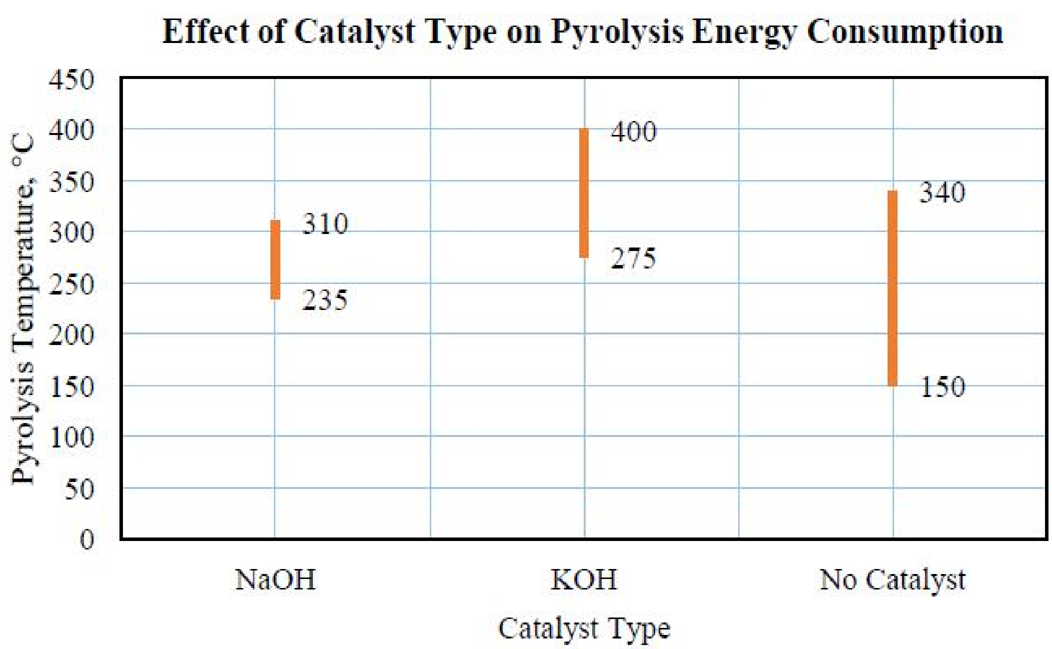


Figure 7: Effect of catalyst Type on the amount of energy consumption during pyrolysis process

## V. CONCLUSIONS

In the present work, a test rig was designed and built for the purpose of bio fuel production from the waste cooking oil using pyrolysis process. An amount of 100 litre of waste cooking oil were collected from different restaurants and processed before using it in bio fuel production. The effect of using different catalysts (NaOH, KOH) with different concentrations by weight (0.5%, 1%, 3% and 10%) were investigated and compared to the process without catalysts. The experimental results showed that when NaOH catalyst was added to the process with concentration of 1% by weight; the highest amount of biodiesel was produced. The obtained amounts of pyrolysed bio fuel from the original WCO during the pyrolysis process were 70%, 25 % and 20% when NaOH, KOH catalysts were used and when no catalyst was added, respectively. NaOH catalyst with 1 % concentration by weight provided the lowest amount of energy consumption for the pyrolysis process compared to KOH catalyst at the same concentration or in case of carrying out the process without adding catalysts. Samples of the pyrolysed biodiesel will be tested in the laboratory and quality parameters and chemical analysis will be investigated such as glycerin content, flash point, cloud point, oxidation stability and metal content. Then, experimental work will be carried out to investigate the performance, emission and combustion characteristics of a diesel engine fuelled by blends of this biodiesel and comparing the results of the same engine fuelled completely with petroleum based diesel.

## VI. ACKNOWLEDGEMENTS

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