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Operative Effect of Zeolite Catalyst in Biofuel Production

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Abstract
Global plastic production and its accumulation in landfills have increased over the years due to the wide applications of plastic in commercial units. The methods of recycling and energy recovery have been some of the alternatives that have been developed for the management of plastic waste. The paper aims to solve the problem of getting rid of plastic waste in safe and environmentally friendly ways, as well as exploiting it to obtain a source of energy. The pyrolysis technique was used using an operative catalyst. A reactor was designed with a thermal heat source and the oil condensation was done on a water container. Factors affecting biodiesel production yield are studied, including the amount of catalyst used, temperature, and reaction time. The physicochemical properties of the biodiesel produced were determined, such as the density by using the Anton Paar Density device method (ASTM D4052), the flash point by using the Stanhope-Seta Flash Point Tester device method (ASTM D93), and the pour point by using the HK-3535 Pour Point Tester device method (ASTM D97). At the optimum conditions of the experiment, it was achieved the highest yield of 57%wt/wt with a conversion rate of 98% at 1:100%wt of catalyst to the raw material at a temperature of 275°C, where the process takes 80 minutes. The liquid product had been found to be feasible as diesel fuel.
Keywords: Biodiesel characterization, Biofuel, Pyrolysis, Recycling Plastic Waste, Zeolite.

1. Introduction

Energy ultimatum is increasing continuously due to rapid growth in the population and industrialization development. The development of energy sources is not keeping pace with spiraling consumption. Even developed countries are not able to face the increase of this problem. The major energy ultimatum is supported by traditional energy sources such as coal, oil, natural gas, etc. [1][2]. Two major problems that every country is facing with these conventional fuels are its exhaustion and the deterioration of the environment. Since there are currently no safe, affordable, and low-carbon large-scale energy alternatives, the world will continue to struggle with these two energy issues until we broaden these options. The connection among energy required and greenhouse gas emissions is the energy issue that garners the greatest attention. [3, 4, 5]

Plastic significantly influences several areas of our existence for the better such as healthcare, construction, packaging, electronics, automotives, and many more. Increasing the growing global population effect on increasing the demand for commodity plastics. [5]. Since most of the plastics were thrown out after single use, Plastic garbage was becoming alarmingly abundant in the environment each year. In Europe, the trash stream received 25 million tonnes of plastic in 2012 [6]. Six major polymer kinds account for over 70% of global manufacturing (PET or PETE), (HDPE), (PV), (LDPE), (PP), and (PS) the so-called commodity plastics [5-7]. As the world's capacity to deal with the rapidly rising output of disposable plastic goods overwhelms it, plastic pollution has emerged as one of the most urgent environmental challenges. Plastic pollution is more pronounced in developing Asian and African nations where rubbish collection services are typically inadequate or nonexistent [8, 9]. But the industrialized world also has issues with adequately collecting used plastics, particularly in nations with poor recycling rates. The COVID-19 epidemic is having an impact on the fight against plastic pollution

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since throwaway masks, gloves, and other protective gear usage is on the rise. Plastic, however, does not automatically make something hygienic or secure [10, 11]. According to the data, 38% of plastic garbage was still dumped in landfills, 26% was recycled, and 36% was used for energy recovery [6].

Plastic garbage can be turned into energy sources using a number of effective waste management strategies. Many researchers picked pyrolysis because it can yield a lot of liquid oil, up to 80 weight percent, at a modest temperature of about 500 ºC [13]. Pyrolysis is the thermal degradation of long-chain polymer molecules into simpler, smaller molecules. The procedure calls for short-term, extreme heat and an oxygen-free surroundings [14] . Oil, gas, and char are the three main byproducts of pyrolysis and are valuable to the manufacturing and refining sectors of the economy. Slow pyrolysis, quick pyrolysis, and flash pyrolysis are the three main types of pyrolytic reactions, which are distinguished by the biomass's processing duration and temperature [14, 15].

In the Middle East. The employment of catalysts that might be a mixture of zeolite, clay, alumina, and silicates in various quantities was concentrated on the conversion of plastic waste for fuel production in order to reduce the amount of solid waste for landfills and lower CO2 emissions. Moreover, it would decrease the high demand for fossil fuel products. Additionally, compared to conventional diesel and gasoline use, the carbon emissions created by this new fuel are 93% lower [17]. Researchers examined catalytic pyrolysis using activated natural zeolite in a reactor with three levels of the separator used to perform catalytic pyrolysis of HDPE and mixed waste plastic (PS) for liquid fuel using ZAA zeolite as a Catalyst [18] [19 There is a lot of research that focuses on the types of convertible plastics. All kinds of plastic waste except for PET and PVC were reviewed, which could cause corrosion and piping problems. It generally produces about 70-80% liquid and 5–10% gas. Solid waste and pollutants like liquid products contain naphtha and other ingredients that are likely to be reprocessed at a fraction of their higher economic value, like gasoline [20].

Hence, the purpose of this research is to discuss a modern way of solving the problems due to the existence of plastic waste on a large scale around the world and disposing of it safely while also addressing the global energy crisis. Therefore, the objective of the project will be achieved by converting plastic waste, especially polypropylene, using the pyrolysis process and zeolite as a catalyst, optimizing the optimum conditions for this process, calculating the biodiesel yield under these optimum conditions, and analyzing the produced biodiesel and comparing it with standard diesel and standard biodiesel. In the future work, Biodiesel obtained from plastic waste using zeolite as a catalyst could be combined with fossil fuels with certain proportions in the diesel engine without any modification in the engine. the engine thermal efficiency and the emissions could be characterized using the blended diesel and biodiesel.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Polypropylene

Due to its presence in large quantities, the used material polypropylene was collected from household waste and analyzed.

2.1.2 Zeolite

The catalyst used is zeolite, which was brought from Sigma Aldrich with the composition shown in Table (1).

Table (1) The Composition of zeolite

SiO_2	50-65%
Al_2O_3	18-22%
Fe_2O_3	2-3%
Cao	15-18
MgO	2-5%
Na_2O	1-2%

2.2 Experimental setup

To decrease the size and enhance the surface area, the specimen was divided into little pieces. As shown in figure (1), The catalyst was mixed with the plastic specimen. Then they were placed in the reactor. The reactor is a stainless-steel container with a 22.5 cm diameter and a 35 cm height. Through pipes with a half-inch diameter, 30 cm long, and 70 cm broad, connected to a condenser, a container containing water to condense the gas rising from the combustion process is connected to the reactor.

The heat source was activated, and the reactor's oxygen was subsequently drained. The process of pyrolysis began after the oxygen was discharged over time. On the water's surface, the oil is produced, and through the openings in the container, the process's accompanying gas escapes. The temperature was determined. Using a thermometer After the procedure is complete, the oil is separated by a separating funnel, then cleaned with hot water several times to get rid of any contaminants and dried in an oven.

In order to obtain the highest oil yield, the following variables were studied: the reaction of the catalyst's weight percentage to plastic waste at 2.5:100, 2:100, 1.5:100, and 1:100; the reaction of temperature to plastic waste at 100, 150, 200, 250, and 275 °C; and the reaction of time to plastic waste at 20, 40, 60, and 80 minutes. An equation accustomed to compute the mass yield of the produced biodiesel (1).

Mass yield%= (weight of liquid biodiesel)/(weight of plastic waste)*100 Eq. (1) [21].

2.3 Characterization of biodiesel produced.

The physicochemical properties of the produced biodiesel were characterized at Suez oil processing company such as density, viscosity, flash point, pour point, distillation and cetane index. Using an Anton Paar Density meter instrument and the ASTM D4052 technique, the density was measured at 15 °C. Using a Stabinger Viscometer equipment and the ASTM D7042 technique, the viscosity was determined at 40 °C. Utilizing a Stanhope-Seta Flash Point Tester instrument, the ASTM D93 technique was used to measure the flash point. The HK-3535 Pour Point Tester equipment was used to measure the pour point according to ASTM D97 standards. Using a PAC Distillation testing apparatus, the distillation was measured in accordance with ASTM D86 [20, [4].

3. RESULTS AND DISCUSSION

3.1 Characterization of raw material

Ash, moisture, fixed carbon, volatile matter, and fixed carbon are all components of polypropylene. Table 2 displays the findings from proximal examinations of various polymers. Changes in the content of the feedstock have an effect on the yields of the pyrolysis products. When the amount of volatile substances in the plastic composition is high, more liquid is produced; nevertheless, when the amount of ash is high, more char is produced. All plastics are believed to have small amounts of ash but a lot of volatile matter [23]. According to the operating parameters, these qualities indicate that plastics may have a great potential to produce a high yield of liquid oil during the pyrolysis process.

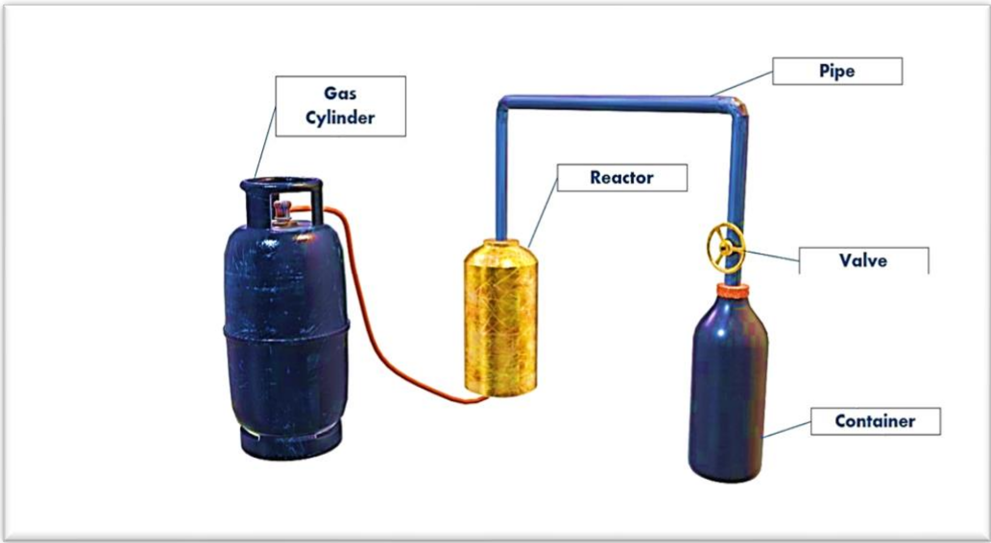

Figure (1) Pyrolysis Process

Table (2) Plastic Analysis

Polypropylene Analysis wt%	Moisture	Fixed carbon	Volatile	Ash
	<0.3	<1.7	96–99	1–5

3.1.1 Elemental composition of raw material

An elemental analyzer, the Thermo-Electron Flash EA1112, was used to examine the elemental compositions (C, H, N, and O) of PP that were prescented and listed in Table (3). The elemental analysis revealed that carbon and hydrogen made up the majority of the PP components.

Table (3) Elemental Composition of Raw Material

Raw material	C %	H %	N %	S %	O %
PP	87 %	13 %	-	-	-

3.2 The effect of the amount of zeolite on yield of oil

Figure (2) depicts the relation between the composition of the zeolite and the raw material with the liquid yield at a fixed temperature of 300°C and an interval period of 80 minutes. The experiments revealed that the liquid production decreased as the amount of zeolite increased. At 42.5 gm of zeolite, the lowest liquid yield was found to be equal to 25%; at 34 gm, the liquid yield was found to be equal to 32%; at 25.5 gm, the liquid yield was found to be equal to 45%; and at 17 gm, the maximum liquid yield was found to be equal to 57%. It was found that the rate of oil generation lowers when a smaller catalyst (zeolite) equivalent to 15g is used in comparison to the amount of raw materials.

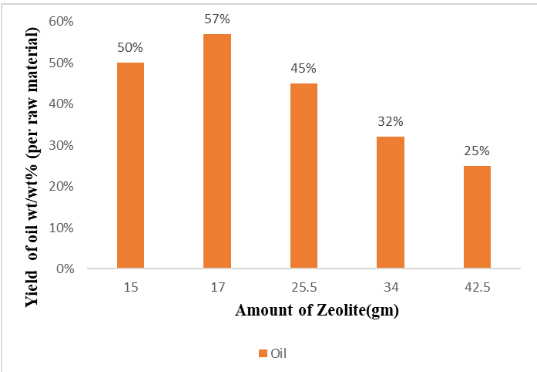

Figure (2) Effect of zeolite on yield of oil (at fixed temperature 300 oc and time 80 min)

3.3 The effect of temperature on yield of oil

At a constant zeolite-to-raw-material weight ratio of 1:100 At each temperature, a reaction is run for 80 minutes. The relationship between temperature and liquid yield is shown in Figure 3. When the temperature rises from 250°C to 275°C, the degradation starts at 100°C and intensifies dramatically. The liquid yield increases as the temperature rises, up to 275 °C. Oil production begins at 100 oC and increases with temperature, up to 275 oC. Nevertheless, it was observed that 275 oC , which is the lowest temperature of this process,was the ideal temperature for getting the best liquid yield (57%). When the temperature was raised to 300 oC, the liquid production dropped by 52%.

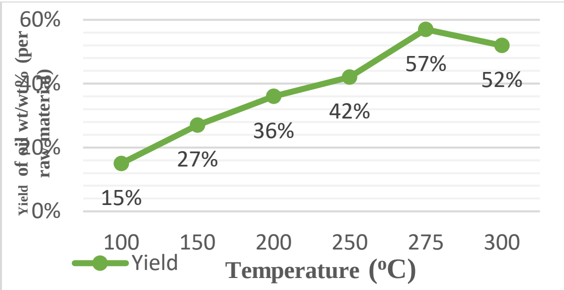

Figure (3) Effect of temperature on Yield of oil (At fixed percentage 1:100 wt.% zeolite to raw material and time 80 min)

3.4 The effect of time on yield of oil

The liquid yield increases with increasing duration at a constant temperature of 275 °C and a fixed percentage of zeolite of 1:100 weight percent. The time and liquid yield connection is shown in Figure (4). Starting at 20 minutes, or 17%, the oil formation continues at 40 minutes, or 32%, and at 60 minutes, or 44.8%, until it reaches 80 minutes. 57% is the greatest rate of liquid yield at this time. The proportion of the yield remained the same after allowing the process to run for an additional 20 minutes.

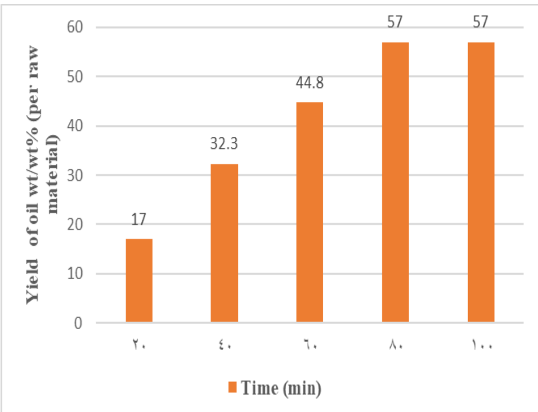

Figure (4) Effect of time on Yield of oil (At fixed percentage 1:100 wt.% of zeolite to raw material and temperature 275 oc)

- **3.5 Characterization of waste plastic oil**

All the measured data was carried out at Suez oil processing company was compared with standard diesel and standard biodiesel shown in Table (4) [24] [25]. It was found that the density of pure biodiesel produced is 0.786 kg/L which is close to standard diesel from 0.82 to 0.86 kg/L and standard biodiesel 0.800 kg/L. The viscosity of pure biodiesel produced is 1.836 cSt which is proximate to the standard diesel from 2.0 to 4.5 cSt and standard biodiesel from 1.9 to 6. The flash point of pure biodiesel produced is> 50 °C which is also near to the standard diesel is 60 to 80 °C and standard biodiesel 130°C min. The pour point of pure biodiesel produced equal -36 °C, standard diesel from -35 to -15°C and standard biodiesel from -15 to -16°C. The cetane index of pure biodiesel produced is 58.6 which better than standard diesel is 46 and standard biodiesel 47. The distillation of pure biodiesel produced at 10% vol. recovered equal 133°C, at 50% vol. recovered equal 232°C, at 90% vol. recovered equal 353°C, standard diesel is 370 max and standard biodiesel is 360 max. The pure biodiesel produced results are close to the standard diesel. Comparing the results with the scientific investigation [26], the viscosity is 1.167 cSt, the flash point is 18 °C, and the pour point is -12 °C. This indicates that our findings are superior to those of earlier studies[27] [28] [29].

Table (4) Comparison between pure biodiesel produced, standard diesel and standard biodiesel

Tests	Test Methods	Pure biodiesel produced	Standard diesel	Standard biodiesel	Units
Density @15°C	ASTM D4052	0.7860	0.820 to 0.860	Max 0.880	kg/L
Viscosity Kinematic @ 40°C	ASTM D7042	1.836	2.0 to 4.5	1.9 to 6	cSt
Flash Point (PM c.c)	ASTM D93	<50	60 to 80	Min 130	°C
Pour Point	ASTM D97	-36	-35 to -15	-15 to -16	°C
Cetane Index	ASTM D4737	58.6	Min 46	Min 47	—
Distillation	ASTM D86	—	—	—	°C
I.B. P		77	—	100 to 115	°C
10% Vol. recovered		133	Max 370	Max 360	°C
50% Vol. recovered		232			°C
90% Vol. recovered		353			°C

4.

CONCLUSION

The pyrolysis procedure was employed in this study to turn the plastic trash into biodiesel using a zeolite catalyst. The reactor design was constructed with special specifications. Additionally, according to trials with various temperatures and ratios of catalyst to raw materials, the higher the catalyst amount, the lower the yield of the bio-oil. The experiment's ideal conditions resulted in the greatest yield of 57%wt/wt with a conversion rate of 98% at 1:100%wt of catalyst to the raw material at the lowest temperature of 275°C, a process that takes 80 minutes. By contrasting the liquid product with conventional diesel fuel in accordance with the Decree of the Directorate General of Oil and Gas from 2008, it was determined that the liquid product could be used as diesel fuel.

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