IJFAC

Indonesian Journal of
Fundamental and Applied Chemistry

Article http://ijfac.unsri.ac.id

Utilization of Polypropylene (PP) Plastic Waste and Empty Palm Fruit Bunch for an Alternative Fuel

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Abstract

The need for plastic corresponds with the annual rise in population. Meanwhile, plastic waste that is improperly managed can negatively influence the environment. Therefore, a more promising alternative recycling process is needed to convert this waste into fuel by cracking. The process of plastics conversion to fuels is possibly assisted by adding empty palm fruit bunches. This study examines how the ratio of Polypropylene (PP) plastic waste to empty palm fruit bunch (EPFB) influence liquid conversion during catalytic cracking. The research was carried out using completely randomized design (CRD) with treatment in the ratio of plastic raw materials to EPFB (1:0, 1:1, 1:2, and 1:3). The mixtures underwent cracking using spent FCC catalyst at 450°C for 20 minutes. The result shows that the cracking produced liquid conversion of 80% for ratio PP to EPFB 1:1 with heating value of 6.681 MJ/kg. The ratio of PP to EPFB, however, did not affect the liquid and gas yields of the catalytic cracking (p>5%).

Keywords: Catalytic cracking, polypropylene plastic, empty fruit bunch, alternative energy

Abstrak (Indonesian)

Meningkatnya jumlah penduduk setiap tahunnya, hal ini sejalan dengan meningkatnya kebutuhan masyarakat akan plastik. Sampah plastik yang tidak dikelola dengan baik, dapat berdampak negatif bagi lingkungan. Perlu adanya alternatif proses daur ulang yang lebih menjanjikan yaitu dengan mengkonversi sampah plastik menjadi minyak dengan proses perengkahan. Proses perengkahan plastik dapat dibantu dengan penambahan tandan kosong kelapa sawit (TKKS) dalam proses perengkahan tersebut. Penelitian ini bertujuan untuk mengetahui pengaruh rasio Polypropylene (PP) dan TKKS terhadap persen konversi cairan hasil perengkahan dan nilai kalor bahan bakar yang dihasilkan. Penelitian ini menggunakan rancangan acak lengkap (RAL) dengan perlakuan rasio bahan baku plastik : TKKS (b/b) yaitu sebesar 1:0, 1:1, 1:2, dan 1:3. Perengkahan katalitik dilakukan menggunakan spent FCC sebagai katalis pada temperatur 450°C selama 40 menit. Rasio PP terhadap TKKS 1:1 menghasilkan % konversi cairan hasil perengkahan sebesar 80% dengan nilai kalor 6.681 MJ/kg. Rasio PP terhadap TKKS pada proses perengkahan katalitik secara statistik tidak berpengaruh terhadap rendemen cairan dan gas hasil perengkahan.

Kata Kunci: Perengkahan, perengkahan katalitik, plastik polypropylene, biomassa, energi alternatif

Article Info

Received 16 January 2022
Received in revised 9 October 2022
Accepted 19 October 2022
Available online 28 October 2022

INTRODUCTION

The need for plastic corresponds with the annual rise in population. The use of plastic and plastic-based goods increases along with technology, industry, and the people [1]. Plastics that are no longer used will become waste and have a detrimental effect on the environment since they cannot be decomposed by soil [2].

Non-organic is the second-largest waste composition, where 14% is plastic waste [3].

According to the Jambi City Environmental Service data, the overall composition of waste in Jambi City in 2016 showed that non-organic and plastic waste accounted for 38.1% and 12.3% of total waste [4].

Polypropylene (PP) is the common type of plastic waste produced in the world and recycling is one way to reduce the amount of plastic waste. The recycling of the plastic waste can be done by converting it to useful products such as alternative energy sources [2].

Several technologies can be employed to convert plastic waste into fuel, including solid fuel, liquid fuel, and gas fuel. Converting plastic waste into energy sources can be carried out by cracking or fracturing the polymers [3].

Cracking is the process of breaking large hydrocarbon molecules into smaller molecules at high-temperature of around 600-700°C (thermal cracking) or at a lower temperature (300-550 °C) with the presence of catalyst (catalytic cracking) [5, 6].

The catalytic cracking of PP plastic waste into fuel oil using 1.5% (w/w) zeolite A catalyst at 450°C for 60 minutes produced 76.82% liquid conversion with product components was equivalent to gasoline and a heating value of 10.26 cal/g [7]. The plastic has a high heating value but will rapidly run out when burnt due to the presence of high volatile matter concentration which reaches 98.53% [8].

Mixing biomass in the cracking of plastic waste will restrict the development of residual carbon [9]. A study on the processing a mixture of PP plastic waste and palm kernel shell waste using pyrolysis has been carried out and showed that the highest conversion was obtained at 350°C [10]. Therefore, the addition of biomass with low volatile matter content, such as empty palm fruit bunches (EPFB) may increase the yield of catalytic cracking of PP plastic waste.

Based on this background, this research was conducted to determine the effect of ratios of Polypropylene (PP) plastic waste to empty palm fruit bunches on the liquid yield and the heating value of liquid produced during the process of catalytic cracking.

MATERIALS AND METHODS

Materials and methods

The research used Completely Randomized Design (CRD) with treatment on the ratio of PP plastic waste to EPFB of 1:0, 1:1, 1:2, and 1:3 (t = 4) and three repetition (i = 1, 2, 3). As a result, 12 experimental units were obtained.

The cracking process used Spent FCC catalysts of as much as 0.9 grams and 9 grams of raw materials for the ratio of catalyst: sample (1:10). The plastic waste in the form of drinking water cup of the Wigo brand obtained from the Talang Gulo TPA was cut into 2x2 mm and cleaned. The samples of EPFB were obtained from Sumbertama Nusa Pertiwi Jambi Company. These bunches were chopped into 2x2 mm and cleaned and dried in the oven at 60 °C overnight.

The cracking process was performed in a semi batch reactor as previously reported [11]. The PP plastic waste, empty palm fruit bunches, and spent FCC catalyst were mixed and place in the reactor at appropriate amount according to the design. The cracking was carried out at 450 °C for 20 minutes. The results of the cracking process were collected and weighed. Percent liquid yield was calculated using formula below:

$$\% \text{ liquid yield} = (\text{liquid mass})/(\text{total mass}) \times 100\% \quad [12]$$

The effect of ratio of PP plastic waste to EPFB on the yield was obtained by analyzing the yield data using ANOVA. The heating value test of the liquid was determined only for the product at the highest liquid yield.

Heating value analysis

The liquid product of 0.5 grams was weighed and placed in the crucible and placed inside the steel bomb. The steel bomb was tightly closed and oxygen (O2) was flowed inside the bomb steel until pressure of 30 atm was reached. The bomb steel was placed into a calorimeter that was already filled with water. The combustion process was carried out by flowing electricity into the calorimeter. Then the heating value is displayed on the monitor

Catalyst characterisation

The spent FCC catalyst characterization was carried out using XRD and SEM.

RESULTS AND DISCUSSION

Liquid yield

The catalytic cracking of PP plastic waste and EPFB showed that the cracking produced liquid, coke (charcoal), and non-condensable gas. The liquid cracking product was obtained after the condensation process. The gas produced during cracking was a product with less than 5 Carbon atom.

Liquid cracking product is the main product of the cracking process. It is a blackish brown to yellow brown in color. This color is a combination of hydrocarbon and other organic compounds. It is similar to crude oil, therefore needs further separation to produce fuel oil. Figure 1 shows the liquid cracking

resulted from the catalytic cracking of PP plastic waste and EPFB mixture.

The liquid presents a pungent odor, consisting of two thick blacktop layers which refers to a mixture of tar and waxes (wax). In contrast, a brown bottom layer is liquid hydrocarbons or other organic compounds (**Figure** 1).

The liquid yields of cracking process can be seen in **Figure** 2. Although the liquid yield seemed to be differ at different ratio of PP plastic waste to EPFB, statistically the ANOVA showed Fcount is lower than Ftable at 5%. Therefore, the liquid yield is not affected by the treatment (p>5%).

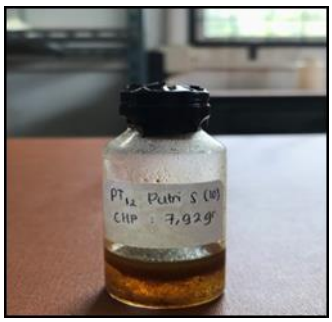


Figure 1. Liquid cracking product

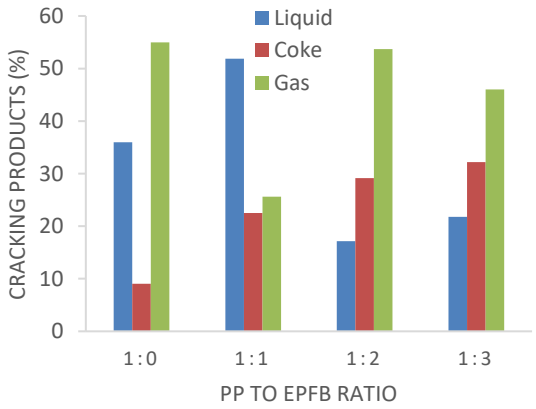


Figure 2. The yields of cracking products at several ratio of PP plastic waste to EPFB

The addition of EPFB increased the liquid yield from catalytic cracking of PP plastic waste and EPFB mixture (**Figure** 2). At ratio higher than 1:1, however, the increase in EPFB in the mixture reduced the liquid yield. This result similar to study previously reported by Wibowo [13] for pyrolysis of biomass and PP plastic waste mixture at 400oC. A higher liquid yield in the present study could be obtained if the cracking process was carried out at lower temperature [13, 14]. The higher temperature applied during cracking, may degrade the molecules into even shorter molecules in form of gas.

Quality of the liquid product

The best results from the cracking product are examined for heating value based on the outcomes of the cracking process in the form of CHP. Heating value is the amount of heat energy released by the fuel during the oxidation of the chemical elements present in the fuel [15]. The heating value test uses a bomb calorimeter on the sample with the highest result (Ratio PP plastic waste to EPFB = 1:1). The heating value of the liquid was 6,681MJ/kg which is relatively low. However, this demonstrates that the heating value of the cracking product obtained does not exceed Indonesian fuel oil quality norms. This demonstrates that the heating value of the cracking product obtained does not exceed Indonesian fuel oil quality norms [16].

Coke and gas yield

The coke (charcoal) is a solid cracking product consisting of hydrocarbons of 30 or more Carbon atom left in the reactor.

Figure 3. Coke cracking product

The amount of coke produced during cracking process can be seen in **Figure** 2. The amount of coke increased as ratio of PP plastic waste to EPFB increase. This is confirmed statistically as the ANOVA showed Fcount is higher than Ftable at 1%. Therefore, the coke is significantly affected by the treatment (p<1%).

Similar to liquid yield, the gas yield is also not affected by the ratio of PP plastic waste to EPFB (p>5%). The pattern of gas yields during cracking the mixture is like liquid yields, that the lowest gas yields occurred at ratio 1:1. The increase in either PP plastic waste or EPFB will increase the gas yields.

Catalyst characteristics

In the cracking test of PP plastic waste and palm oil empty fruit bunches as an energy source, a test using a catalyst (catalytic cracking) is carried out, where the type used in this test is spent FCC. Processing waste into an energy source can succeed when a catalyst is used. Catalyst is defined as a chemical compound that can direct and increase the kinetics of a reaction. However, the compound (catalyst) does not undergo a chemical change at the end since the position of the

chemical equilibrium is not changed in the reaction [17].

The lattice parameters, crystal size, and crystalline phase identification of a spent FCC catalyst reactivated are then determined using X-Ray Diffraction (XRD). Then the acidity and pore or surface area test of the FCC Sp Spent Catalyst is carried out. X-ray diffraction or XRD is an analytical method to characterize a solid material's crystal structure and size [18]. For example, the results of XRD analysis for spent FCC catalyst after activation can be seen in **Figure** 4.

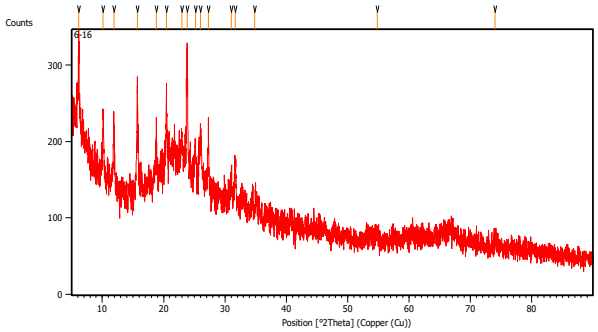
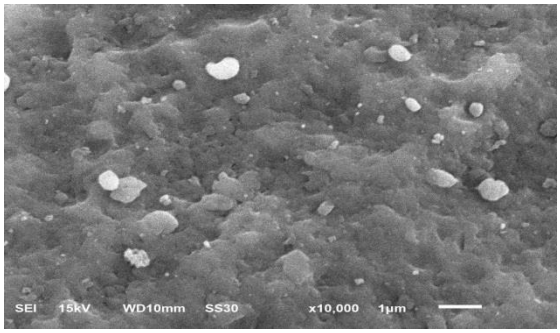


Figure 4. FCC Spent Catalyst XRD diffraction pattern after reactivation

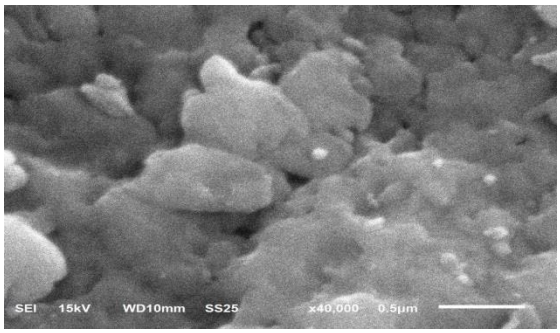
Figure 4 showed that the crystal structure of the spent FCC catalyst gives rise to specific peaks, the Spent FCC structure is at position 2θ ranging from 6-30, all peaks on the Spent FCC catalyst have high intensity at an angle of 2θ = 6.2°; 10,12°; 20.4; 23.8; 27.2 and 31. Therefore, strong and sharp peaks indicate that the spent FCC catalyst has a crystalline phase characterized by sharp diffractogram peaks in the 2θ area between 18° and 25°. Which stated that sharp peaks with high intensity indicate the solid is crystalline while broad peaks indicate the solid is amorphous [19].

SEM analysis was used to analyze the shape of the catalyst, which includes spent FCC catalyst particles with a porous crystalline phase, as shown by the micrograph. The surface morphology of the spent FCC catalyst solid consists of a porous crystalline phase shown from the SEM identification results. XRD test can be confirmed on SEM, and the analysis for spent FCC catalysts with magnifications of 10,000x and 40,000x can be seen in **Figure** 5.

Based on the SEM analysis in Figure 5, the crystals formed are not crystalline and less uniform. The figure also shows that some crystals are amorphous, and some are in aggregates or unified and separated. The spent FCC structure is shaped like lumps. When a catalyst has a large surface area and pore volume, waste entering the cavity (pores) cracks more intensely, and the surface area affects catalytic activity. Therefore, it can be concluded that the greater the catalyst's surface area, the more active phase that is disseminated to boost the product's activity [20].



(a)



(b)

Figure 5. SEM image (a) Spent FCC catalyst at 10,000x magnification; (b) Spent FCC catalyst at 40,000x magnification

CONCLUSION

The ratio of PP plastic waste to EPFB in the catalytic cracking significantly affect coke produced ($p<1\%$) but did not significantly affect the liquid and gas yields ($p>5\%$). Both liquid and gas yields may be affected to different direction. The ratio of 1:1 produced the highest liquid yields and the lowest gas yields. The liquid has heating value 6,681 MJ/kg which has not meet the established quality standard.

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