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A study of catalytic cracking in the production of super Cetane Biodiesel from Jatropha Curcas Oil

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ABSTRACT

This study was aimed to study the method employed in the production of super cetane biodiesel from curcas bean (*Jatropha curcas*) oil. Its methodology included the production of curcas bean biodiesel by transesterification process, biodiesel cracking by H-zeolite catalyst. Characterization of the produced biodiesel from catalytic cracking included saponification number, iodine number, and cetane number.

Study findings indicated that the carbon chain breaking of biodiesel unsaturated fatty acid ester can be achieved by catalytic cracking reaction. This was evidenced by the increased saponification number and decreased iodine number of the curcas bean biodiesel after cracked. Analysis of biodiesel product after undergoing catalytic cracking process indicated an optimum temperature of 90^oC and optimum reaction time of 180 minutes. The produced biodiesel at these conditions had a saponification number of 206.332 mg KOH/g sample, iodine number of 60.11 mg iodine/g sample, and cetane number of 68.83. These findings showed that cetane number of curcas bean biodiesel could be increased by about 26.81% from 54.28 before cracking to 68.83 after cracking

Keywords : *curcas bean (Jatropha curcas), hydrocracking catalyst, biodiesel, fatty acid*

1. Introduction

The development of curcas bean plant (*Jatropha curcas* Linn) as a raw material for biodiesel has a great potential, because in addition to producing oil with high productivity, this plant has also a low economic value due to its classification as en inedible plant and is capable of producing abundant fruits all the year. Curcas bean plant has a relatively high oil content, approximately 40-45% of weight containing 77.3% of unsaturated fatty acid, and 22.7% of saturated fatty acid (Alam Syah, 2006). The high unsaturated fatty acid content in curcas bean results in low biodiesel cetane number, approximately 54.28 (Sampeliilng T, et.al, 2011). According to Purba J (2007), the cetane number biodiesel produced from transesterification process is 54.32. Knothe et al (2002) suggested that the increased double bounds can result in low cetane number. The high cetane numbers are observed in saturated fatty acid esters, such as palmitate and stearic acid. Generally, the cetane number of single mono-unsaturated fatty acid like oleic has been reported fall into medium range. Therefore, there is a need to increase the cetane number of the curcas bean biodiesel. According to saponification and iodine numbers, the cetane number of curcas bean biodiesel can be calculated with the following equation:

$$\text{Cetane number} = 46.27 + (5458.3/x) - 0.225y$$

Where x = saponification number, and y = iodine number

2. Methodology

2.1 Instruments and Materials

Instruments: A set of three-neck flask, measuring cup, beaker glass, electric stove, condensor, stative, buret, Seperangkat reaktor leher tiga, gelas ukur, beaker glass, kompor listrik, kondensor, statif, glass buret, analytical balance.

Materials: Curcas bean (*Jatropha* curcas) oil, methanol, NaOH, alcohol, pp indicator, distilled water, chloride acid (HCl), chloroform ($CHCl_3$), KI, sodium thiosulphate ($Na_2S_2O_3$), starch indicator, and H-zeolite catalyst.

2.2 Procedures

In this study, the curcas bean oil was trans-esterified at temperature of 60^{o}C for 120 minutes to produce biodiesel. The produced biodiesel was then cracked with the help of H-Zeolite catalyst at temperature of 70^{o}C, 80^{o}C, 90^{o}C, 100^{o}C, 110^{o}C, and 120^{o}C for 60 minuets, 90 minutes, and 120 minutes. The biodiesel product was then tested quantitatively including the determination of saponification number, iodine number, and cetane number.

3. Findings and Discussion

3.1 Saponification number of curcas bean biodiesel produced from catalytic cracking

According to Sudarmaji (1998), the saponification number is used to grossly determine the molecular weight of oil. Oil comprised of short carbon (C) chain fatty acid has a relatively low molecular weight which will have high saponification number. The high saponification number needs abundant KOH because many of the fatty acid having short chains.

Table 1. Relationship between reaction time and temperature with saponification number (mg KOH/g sample)

Temperature (^{o}C) / Time (menit)	70	80	90	100	110	120
60	176.72	177.48	179.52	162.69	161.12	100.98
120	177.84	178.45	194.79	160,45	160.67	153.15
180	178.1	187	**206.33**	152.59	159.88	161.01

Saponification number of biodiesel produced from transesterification was 109.17 mg KOH/g sample. Data on Table 1 indicates that there is an increase in saponification number up to 206.332 mg KOH/g sample at cracking temperature of 90^{o}C and reaction time of 180 minutes. The increased saponification number indicated increasing short-chain fatty acid number comprising the curcas bean biodiesel. From these data it can assumed that a cracking reaction that break the carbon chains of unsaturated fatty acids (oleic and linoleic) has occurred in the curcas bean biodiesel. The breaking of carbon chains in unsaturated fatty acid esters will form new fatty acids of 12 to 16 carbons. This was confirmed by GCM analysis which found a significant increase in methyl palmitate.

3.2 Iodine number of curcas bean biodiesel after catalytic cracking

Iodine number in biodiesel reflects the unsaturation level of compounds comprising the biodiesel. Analysis of iodine number for curcas bean biodiesel produced after trans-esterification reaction indicated an iodine number of 92.83 mg iodine/g sample. This value meets the SNI 04-7182-2006 standard requiring the maximum iodine number of 115 mg iodine/g sample for biodiesel. The iodine number found in the present study was lower than this standard, so it can be assumed that the biodiesel still contain high unsaturated fatty acid ester.

Tale 2. Relationship between reaction and temperature with the iodine number (mg iodine/g sample)

Temperature (^{o}C) / Time (minutes)	70	80	90	100	110	120
60	92,27	79,35	60,92	66,58	68,19	60,92
120	90,88	77,49	60,92	81,94	71,70	61,72
180	88,21	71,18	60,11	61,45	68,19	68,19

Curcas bean biodiesel produced after undergoing a catalytic cracking reaction can be seen from Table 2. These data indicated a decrease in iodine number up to 60.11 mg iodine/g sample. The decrease in iodine number of biodiesel after cracking reaction suggested that the produced biodiesel was more saturated, meaning a reaction that break the carbon chains on double bounds has occurred. This was confirmed by the GCMS analysis, in which a decrease in unsaturated fatty acid esters of 56.96-68.69% was observed after being cracked.

3.3 Cetane number of curcas bean biodiesel after catalytic cracking

Fuel ignition quality of a biodiesel is measured by an index called cetane number. Cetane number shows the ability of a fuel to self-ignited. The high cetane number indicates that a fuel can ignite at relatively low temperature, and the low cetane number means that a fuel can ignite at relatively high temperature (Shreve, 1956).

The observed cetane number for biodiesel from transesterification was 54.28, but after catalytic cracking process this number increased up to 68.83. Compared to standard biodiesel quality in Indonesia (SNI) which requires a minimum cetane number of 51, the obtained product in the present study meets this standard.

Table 3. Relationship between reaction time, temperature, and cetane number

Temperature (^oC)/ Time (minutes)	70	80	90	100	110	120
60	56.39	59.17	64.36	64.84	64.8	66.61
120	56.51	59.42	65.88	61.85	64.11	68.02
180	57.07	59.44	**68.83**	68.22	65.06	64.82

The low cetane number before cracking was due to fact that the curcas biodiesel was still comprised of unsaturated fatty acid such as oleic and linoleic. After the cracking process, the cetane number could be increased up to 14 (30%), as shown in Table 3. According to Knothe et. al (2003), increased double bound number can result in lower cetane number and, generally, the high cetane number for saturated fatty acid. Therefore, the decreased unsaturated fatty acid comprising the curcas bean biodiesel (baseline level 90%) resulted in increased cetane number (Syah, 2006).

Knothe (2003) further suggested that cetane number for linear chain esters with fatty acids like palmitate was about 85.9, stearic 101, oleic 59.3, and linoleic 38.2. Therefore, according to this present study, the increase in cetane number for curcas bean diesel after catalytic cracking process was due to its higher level of saturated fatty acids than the unsaturated fatty acids.

4. Conclusions

Conclusions that can be drawn from this study:

1. According to analysis of biodiesel product after catalytic cracking process, the optimum temperature was 90^{o}C and optimum time reaction was 180 minutes.
2. Biodiesel produced from these conditions had a saponification number of 206.332 mg KOH/g sample, iodine number of 60.11 mg iodine/g sample, and cetane number of 68,83.

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