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BIOFUEL PRODUCTION FROM CANDLENUT OIL USING CATALYTIC CRACKING PROCESS WITH ZN/HZSM-5 CATALYST

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ABSTRACT

Biofuel is an alternative energy product that is environmentally friendly. Biofuel production is one of resolving the problems of energy shortage and global warming. This research aims to study the process of biofuel production from candlenut oil. The research was carried out by reacting the candlenut oil in a micro fixed bed reactor with diameter of 1 cm and length of 16.4 cm. Catalytic cracking method with Zn/HZSM-5 catalyst was used in this process. The effect of reactor temperature and nitrogen flow rate on the quality of biofuel was studied. Biofuel products were analyzed using Gas Chromatography. Biofuel composition is obtained by comparing the chromatogram of biofuels to the standart chromatogram. The result proves that biodiesel was the highest fraction of biofuels. The highest percentage of biodiesel was 80.75 % at a temperature of 325 °C and a nitrogen flow rate of 60 ml/min. Biofuel density was in the range of 0.81 to 0.84 g/ml. This biofuel had a cetane number of 74.8. Biofuel had octane number of 124.7, 114.7, and 119.7 using RON, MON, and AKI methods respectively. Biofuel had higher heating value of 19.269 btu/lb. Cetane number of biofuel was 46, 7% greater than that of fuel European Standard EN 590. This product can be recommended as a cetane improver.

Keywords: biofuel, candlenut oil, cetane, improver, Zn/HZSM-5.

INTRODUCTION

Nowadays, the fossil energy resources become scarce, and they cannot be renewed. Moreover, the using of fossil energy resources is not environmentally friendly. This has triggered the awareness to find another sustainable energy resource [1]. Vegetable oils can be used in diesel engines after several chemical processes. Its viscosity and volatility can be reduced by trans-esterification process [2]. Later, biodiesel can be produced from this process in fatty acid methyl ester (FAME) form. Additionally, biofuel can be produced from vegetable oils by cracking process [3-9]. Biofuel has more advantages than that of FAME biodiesel. Biofuel is similar to conventional diesel oil chemical in its composition and it is liquid fuel [10]. Government of Indonesia through Presidential Decree No. 5 of 2006 has commanded the development of biofuel as a substituting energy resource. The use of biofuel is expected to be more than 5% in 2025. Vegetable oils that have been studied for biofuel production are palm oil, castor oil, candlenut oil, bintaro oil and nyamplung oil.

Candlenut is one resource of vegetable oil that has high oil content of 60-65%. Candlenut plants are very easy to grow and easy to maintain. Although the biofuel production process of candlenut oil has not been studied before, but it has been believed that the cracking process can provide better results than the esterification process. The achivement of the devolopment of zeolit catalys for palm oil cracking are not automatically used for other vegetbale oils. For example ultrastable Y zeolite (USY) catalyst can be used for rubber seed oil cracking produced liquid fuel similar to those of gasoline-based fuels [3].

Composite catalyst from USY (SiO_2/Al_2O_3 = 14), HY (5.5), Beta (37), ZSM-5 (90) and ZSM-5 (1770)) (25 wt %), commercial alumina (60 wt %) and alumina-sol (15 wt% as Al_2O_3) with water if it is used for soybean oil, it will produce main fraction of biodiesel [4]. The study of plants, especially palm oil, cracking and the using of zeolites as catalyst have been carried out as a comparison [5]. Actually, the previous researchers have done the research with beeter result, but the catalyst has not been used for candlenut oil cracking yet.

Although the composition of candlenut oil is different from palm oil but they have some similar constituent of fatty acids. Therefore, the use of Zn/HZSM-5 in the catalytic cracking process of candlenut oil is very interesting to be developed. The purpose of this study was to determine the composition of the candlenut oil, to obtain the proper operating conditions to produce biofuel with the largest biodiesel fraction and to obtain the characteristics of the biofuel.

This research is useful to develop new energy from vegetable oil. The main point of this research is to produce special biofuel. The achievement of producing biofuel with cetane number higher than that of conventional fuel give real contribution in the development of new energy product. The use of candlenut oil is attracted because it is produced from a potential plant. The biofuel can be used directly or it is mixed by conventional fuel. The product with high cetane number can be developed as new cetane improver.

EXPERIMENTAL SET-UP

The study was initially started with catalyst preparation. The impregnation of Zn to HZSM-5 was done to obtain Zn/HZSM-5 catalyst. This catalyst was characterized using X-ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Brunauer Emmett Teller (BET) methods. XRF method was used to determine the moles ratio of Si/Al and the Zn content. XRD method was used

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to prove the existence of HZSM-5 in catalyst. BET method was used to determine the specific surface area and the pore size of catalyst.

Another preparation is the extraction of candlenut oil. The extraction process was done by compression with pressure of 17.692 kg/m^2. The composition of candlenut oil was analyzed by Gas Chromatography-Mass Spectrometry (GC-MS).

Later, the cracking process was carried out in a micro fixed bed reactor. The cracking process equipment series consists of evaporator, reactor, condenser and nitrogen gas cylinder, as seen in Figure-1. The process was initiated by charging candlenut oil as a feed to be heated up to temperature of 250°C, while nitrogen was streamed to the reactor. Later, the cracking process was brought into each determined variable. The products out from the reactor were later analyzed by Gas Chromatography (GC) method.

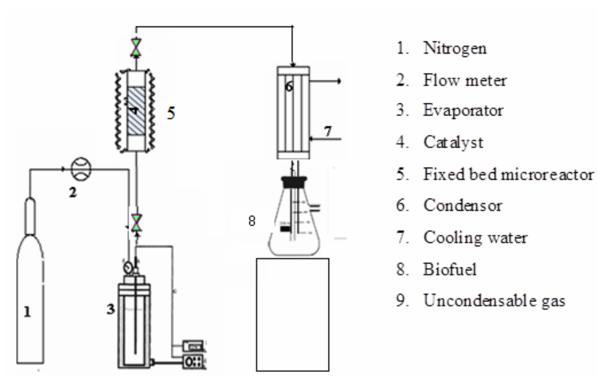

Figure-1. Equipment series of catalytic cracking.

RESULTS AND DISCUSSIONS

Determination of candlenut oil composition

The extraction of candlenut oil by compression produced 425 ml oil per kg of seed. Based on the GC-MS analysis result, candlenut oil contains oleic acid, 2-butyl-5-hexyloctahydro, palmitic acid and carbonic acid. The highest content was oleic acid of 69, 708%, as seen in Table-1.

Table-1. The composition of candlenut oil.

Name of fatty acid	Fatty acid (%)
Carbonic acid	3.685
Palmitic acid	8.357
Oleic acid	69.708
2-butyl-5-hexyloctahydro	18.251

Characterization of catalysts

The catalyst was proved as Zn/HZSM-5 with surface area of 109.345 m^2/g, pore volume of 0.018 cm^3/g, pore diameter of 37.235 Å, Zn content of 4.55% of mass and Si/Al mole ratio of 24.3.

Characteristics of Biofuels

Effect of reaction temperature on biodiesel selectivity

Temperature affected the selectivity of biofuel content, especially biodiesel in the product. Figure-2 shows that at nitrogen flow rate of 60 ml/min, the selectivity of biodiesel is in range of 76.77%-80.75%. The highest selectivity of biodiesel is reached at temperature of 325°C. Meanwhile, at nitrogen flow rate of 100 ml/min, the result shows that biodiesel selectivity increases from 40% to 70% from temperature of 300°C to 325°C, but later it decreases to 30% at 375°C. This is caused by the difference in the activation energy of each fraction in biofuels.

The selectivity of biodiesel from candlenut oil was 46.77% higher than that from palm oil with HZSM-5 catalyst. Moreover, the yield of biofuel from candlenut oil was 48.77% higher than that from palm oil with Zn/HZSM-5 catalyst.

Effect of reaction temperature on biokerosene selectivity

Biodiesel content is desired rather than biokerosene content in the product since biokerosene contains many impurities. The result shows that the lowest biokerosene selectivity is 15.17 % at temperature of 325°C and nitrogen flow rate of 60 ml/min, as shown in Figure-3. The selectivity of biokerosene from candlenut oil was 20% higher than that from palm oil cracking with Zn/HZSM-5 catalyst at temperature of 350°C.

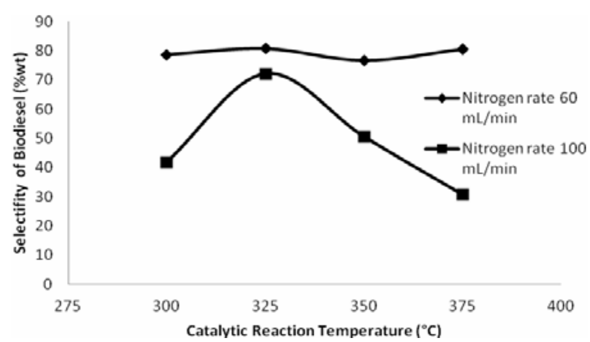

Figure-2. Effect of reaction temperature on the biodiesel selectivity for various nitrogen rates.

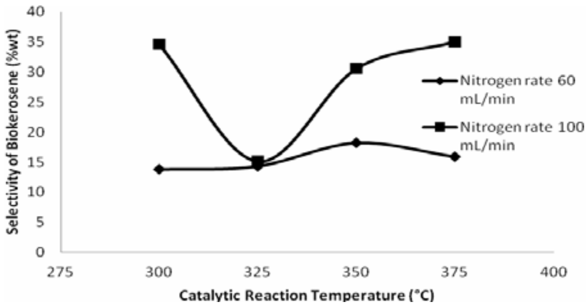

Figure-3. Effect of reaction temperature on the biokerosene selectivity for various nitrogen rates.

Effect of reaction temperature on biogasoline selectivity

Since the desired product is biodiesel content, therefore the lowest biogasoline content is expected. Figure-4 shows that at nitrogen flow rate of 100 ml/min, the lowest biogasoline selectivity of 12.62% is reached at temperature of 325°C. Meanwhile at nitrogen flow rate of 60 ml/min, the lowest biogasoline selectivity of 3.51% is reached at temperature of 375°C.

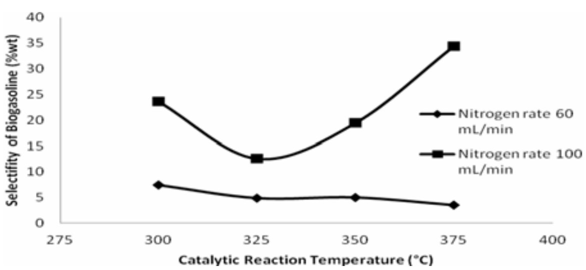

Figure-4. Effect of reaction temperature on the biogasoline for various nitrogen rates octane number, Cetane Number and Heating Value.

Biofuel consists of biodiesel, biokerosene and biogasoline. The highest content was biodiesel with percentage of 80.75%. The other contents were biogasoline with percentage of 4.88% and remaining biokerosene. The octane number of biofuels was analyzed by RON, MON and AKI methods. The octane number was 124.7, 114.7, and 119.7 using RON, MON, and AKI methods, respectively. The cetane number of biofuel was 74.8. This biofuel cetane number was 46.7 % greater than that of the fuel European Standard EN 590. The higher Heating Value (HV) of biofuel was 19, 269 btu/lb. Based on these results, it is clear that biofuel can be recommended to replace conventional biodiesel fuel since it has high cetane number.

CONCLUSIONS

Candlenut oil has different composition to palm oil. The composition of candlenut oil is oleid acid, 2-butyl-5-hexyloctahydro, Palmitic acid dan Carbonic acid with percenatge of 69,708%, 18.251, 8.357% dan 3.685% respectively. The production of biofuel from candlenut oil using catalytic cracking process with Zn/HZSM-5 catalyst can be used as a substitute for fossil fuel energy sources. Biofuel from candlenut oil has higher biodiesel selectivity than that from palm oil. The biodiesel highest selectivity was 80.75% at temperature of 325°C and nitrogen flow rate of 60 ml/min. The cetane number of biofuel was 74.8, which was high enough. Therefore, Zn/HZSM-5 is highly reccomended for biofuel production from candlenut oil.

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