Operating Parameters for Green Diesel Production from Triglycerides

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Highlights

- Palm stearin was reacted with hexadecane solvent to produce green diesel using Ni/ZrO_2
- Conversion 97.92%, selectivity of green diesel 89.63%, and yield of 87.75% was obtained.
- Optimum conditions were 350 ºC, H_2 pressure of 34 bar and 1:1 reactant to solvent ratio
- Synthesized Ni/ZrO_2 catalyst exhibited comparable efficiency to the Pd/C commercial catalyst

1. Introduction

Ni/ZrO_2 is one of the catalysts to produce the highest percent conversion by many researchers using fatty acid as a reactant and obtained high yield of green diesel ranges [1]. In our previous research study, the performance of Ni-based catalyst by using palmitic acid in low pressure condition for deoxygenation reaction showed the highest conversion of palmitic acid at 98.33% conversion and selectivity of n-pentadecane of 75.46% using Ni/ZrO_2 [2]. Deoxygenation is the main reaction of green diesel production by using triglycerides as a feedstock with catalyst and solvent, which is classified into three reactions pathways: decarbonylation, decarboxylation, hydrodeoxygenation. The effect of solvent exhibited a restraining influence on the decarboxylation and aromatization reactions [3]. Dodecane is mostly used to be solvent in the deoxygenation reaction. However, it is expensive [4]. A part of green diesel i.e., hexadecane and heptadecane can be used instead of dodecane solvent [5]. However, hexadecane and heptadecane have not been undertaken.

In this work, hexadecane was used as a solvent. The effect of pressure, temperature, and ratio of reactant to solvent were focused for green diesel production by using nickel over zirconia as a catalyst and palm stearin as a feedstock. The optimum conditions were determined by response factors such as conversion, selectivity, and yield with response surface methodology (RSM) based on Box-behnken design (BBD). BBD was used to generate experiments and suitable to predict a data [6, 7]. The research developed catalyst to obtain the highest green diesel production.

2. Methods

The catalyst was synthesized by incipient wetness impregnation. Zirconium oxychloride octahydrate was a precursor. The sample was calcined at 550°C in the air for 6 h. Ni solution was slowly dropped into support and stirred. It was calcined again at 500°C for 3 h. The catalysts were characterized by Fourier-transform infrared spectroscopy, X-ray powder diffraction, Scanning electron microscopy and energy-dispersive x-ray spectroscopy, Transmission electron microscopy, Brunauer, Emmett, Teller, and Temperature programmed desorption. The deoxygenation reaction was carried out in a semi-batch type with 100 ml high pressure stirred autoclave (Parr 4598). Hexadecane was a solvent in the reaction with reaction time of 6 h and 2.7%. loading catalyst. The liquid and gas products were analyzed by Gas chromatography mass spectrometry and Gas chromatography.

3. Results and discussion

Ni/ZrO_2 catalyst exhibits an average particle size of 11.15 nm as seen in Figure 1. Ni/ZrO_2 represented the mesoporous structure (pore diameters 2-50 nm) and showed adsorption isotherm type IV corresponding to the IUPAC classification, which had hysteresis loop.

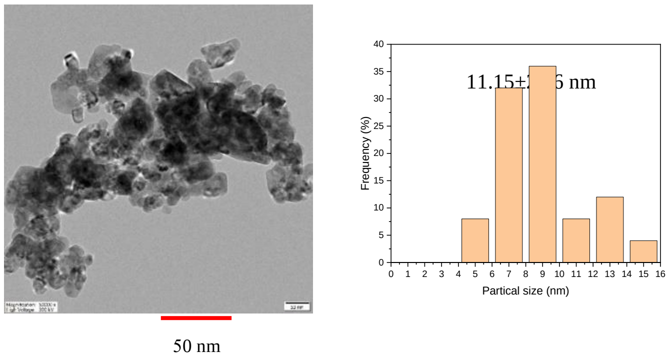

Figure 1. TEM images and particle size distribution of Ni/ZrO_2.

Figure 2(left) relates with ratio of reactant to solvent and temperature, it reveals a significant increase in green diesel yield as both variables are elevated. Furthermore, a comprehensive analysis of the interaction between other variables in Figure 2(middle) and Figure 2(right) indicates a non-significant effect on green diesel yield. However, it is noteworthy that an optimal H_2 pressure of 34 bar. According to the findings, the optimum condition was temperature 350°C, 34 bar H_2 pressure and 1:0.99 or around 1:1 ratio of reactant to solvent and the ratio of reactant to solvent and temperature were identified as the most influential variables on the quadratic model response.

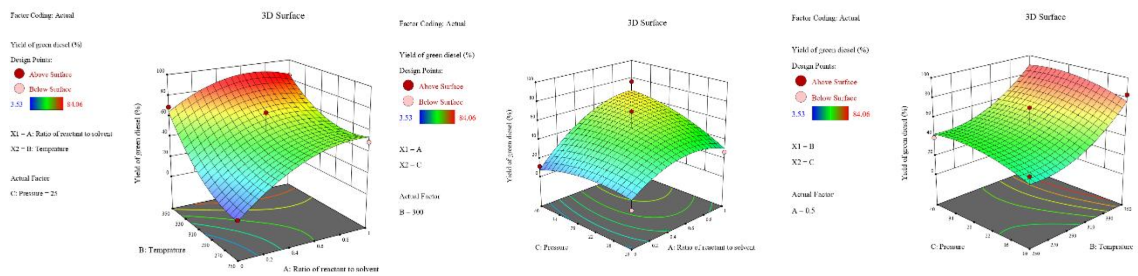

Figure 2 Surface and contour plot of yield interaction between (left) reactant to solvent ratio vs. temperature, (middle) reactant to solvent ratio vs. H_2 pressure and (right) temperature vs. H_2 pressure.

4. Conclusions

The optimal condition for the deoxygenation were a reactant to solvent ratio of 1:1, temperature of 350 °C, and a H_2 pressure of 34 bars. The synthesized Ni/ZrO_2 catalyst demonstrated comparable efficiency to the Pd/C catalyst which is high performance catalytic by its properties.

References

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Keywords
Green diesel; Ni/ZrO_2; Hexadecane; Palm stearin