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Enhanced Green Diesel Production from Hydrotreating of Used Cooking Oil via In-Situ Hydrogen Generated from Ethanol

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ABSTRACT

Used cooking oil has great potential as a raw material in the production of renewable fuels, particularly green diesel. This study aims to increase the yield of green diesel from used cooking oil through an in-situ ethanol hydrotreating process using a NiMo/γ-Al_2O_3 catalyst. This process utilizes ethanol as an internal hydrogen donor (in-situ) to replace the need for external hydrogen in the hydrodeoxygenation process. The variables studied include ethanol concentration (5%, 10%, and 15%) and reactor temperature (340°C, 370°C, 400°C, 430°C, and 460°C). Product characteristics were analyzed through density tests, kinematic viscosity, flash point, cetane number, and GC-MS. The results showed that the optimal conditions were achieved at an ethanol concentration of 15% and a temperature of 460°C, yielding 60.025% green diesel, a density of 763.197 kg/m³, a viscosity of 2.682 mm²/s, and a flash point of 61°C. However, the cetane number obtained was still below the minimum SNI standard of 70. This process demonstrates significant potential for converting oil waste into environmentally friendly fuel, while also supporting the reduction of dependence on fossil fuels.

Keywords: *Green Diesel, Hydrotreating, Ethanol In-Situ, Yield, Cooking Oil*

1. INTRODUCTION

Humans had used biomass as an energy source in their daily lives. However, over time, the use of biomass began to decline due to the emergence of natural gas, coal, and oil as the main sources of energy. This transition led to an energy crisis, given the continuous increase in the use of fossil fuels and the threat to the availability of these energy sources. Therefore, it was important to develop new and renewable energy sources to reduce the negative impact of fossil fuel use. Biomass energy, which included bioethanol, biogas, and biodiesel, became increasingly in demand internationally due to its ability to reduce CO_2 levels in the atmosphere [1].

Biomass was developed as an alternative to reduce dependence on fossil fuels and mitigate global warming. Biofuels, produced from organic materials such as plants, animals, and agricultural waste, were considered more environmentally friendly because they produced lower carbon emissions compared to fossil fuels. Biohydrocarbons, one of the key components of biofuels, could be obtained through the hydrotreating process. Coconut oil, with its high content of lauric acid (32.73%), myristic acid (28.55%), palmitic acid (17.16%), and oleic acid (14.09%), held great potential for biofuel production due to its high ester content and excellent combustion properties. Additionally, used cooking oil was regarded as a promising alternative feedstock due to its abundant availability and role in reducing waste [2]. The conversion of used cooking oil and other biomass through the hydrotreating process held significant potential in reducing the use of fossil fuels and green house gas emissions.

The transformation of triglycerides into hydrocarbons from waste oil required the elimination of oxygen through hydroprocessing technologies such as hydrocracking or hydrotreating, which removed oxygen through decarboxylation, decarbonylation, or hydrodeoxygenation mechanisms, producing green diesel or renewable diesel. Catalysts such as NiMo/γ-Al_2O_3 were used to accelerate the reaction and enhance product selectivity in hydrotreating, which was widely applied in research and industry [3]. Research by Straka et al. (2023) showed that used tire pyrolysis oil (STPO) could be hydrogenated using the same catalyst at temperatures of 210–360 °C and pressures of 6–10 MPa, resulting in significant changes in the chemical composition of STPO, including olefin hydrogenation, aromatic reduction, desulfurization, and denitrogenation.

In biomass processing, short-chain alcohols such as methanol, ethanol, and isopropanol were used in solvolysis or alcoholysis processes. Alcohols had advantages over water solvents, such as a lower critical point, which created milder reaction conditions and was more effective in dissolving intermediates with high molecular weights. The low boiling point of alcohol also facilitated separation and recycling through distillation. In addition to being a solvent, alcohol functioned as a hydrogen donor that supplied in-situ hydrogen to stabilize intermediates and prevent repolymerization, thereby improving the efficiency of biomass processing, including the processing of used cooking oil into more environmentally friendly fuels Nugraha et al. (2021). Research conducted by Mujiharti et al. (2019) used waste cooking oil with a free fatty acid content of 1.1% and a methanol ratio of 1:3, plus 4% Al_2O_3 catalyst from Fluid Catalytic Cracking Unit residue. The research results showed optimal conditions at 110 °C for 60 minutes, yielding a biodiesel conversion rate of 76.59%.

2. MATERIAL AND METHODS

2.1 Tools and Materials

The equipment used in the process of hydrotreating waste oil into green diesel products included a hydrotreating reactor unit and a cooler box. Additionally, the analysis of green diesel products included a pycnometer for density analysis, a Hoppler viscometer for viscosity analysis, a flash point tester for determining the flash point of green diesel, a Cleveland Open Cup Tester (COC Tester) for cetane number analysis, and Gas Chromatography–Mass Spectrometry for analyzing the molar percentage contained in the green diesel product.

And This study used waste cooking oil as the main raw material, which contained triglycerides and free fatty acids. Ni-Mo/γ-Al_2O_3 was used as a catalyst, playing an important role in the hydrodeoxygenation (HDO) reaction and the decomposition of ethanol into hydrogen. Ninety-six percent ethanol was used as a hydrogen donor through the steam reforming mechanism and also functioned as a reaction solvent. This system was enhanced by the addition of a 1 M NaOH solution to create a basic environment, there by improving the efficiency of ethanol reforming. For green diesel treatment, bleaching earth and activated carbon were used to minimize aromatic compounds and odors in the green diesel product.

2.2 Methods

The research on producing green diesel from waste cooking oil through the hydrotreating method consisted of several stages, including raw material preparation through filtration, conducting the experimental process, and analyzing the resulting products. All procedures were carried out at the Chemical Engineering Unit Operations Laboratory and the Energy Engineering Laboratory of Politeknik Negeri Sriwijaya. In the hydrotreating process, reaction temperatures of 340°C, 370°C, 400°C, 430°C, and 460°C were applied, along with ethanol concentrations of 5%, 10%, and 15% relative to the mass of the waste cooking oil. The products obtained were then analyzed based on green diesel quality parameters, including density, viscosity, flash point, heating value, cetane number, and compound composition using GC-MS.

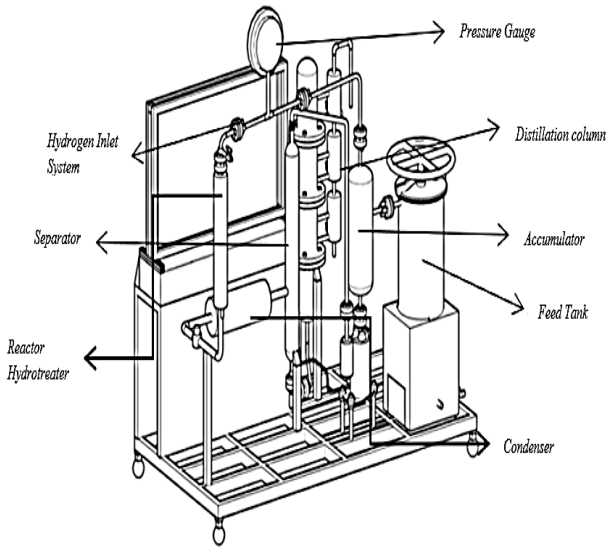


Figure 1. Prototype of the hydrotreating unit

Figure 1 presented the prototype of the hydrotreating apparatus employed in this research. The equipment was designed to process waste cooking oil into green diesel through an in-situ ethanol hydrotreating process. The system included a feed tank, hydrogen inlet system, hydrotreating reactor, separator, distillation column, condenser, and accumulator, with a pressure gauge for monitoring the operating conditions. This integrated setup enabled the experimental investigation of temperature and ethanol concentration variations on the quality and yield of green diesel.

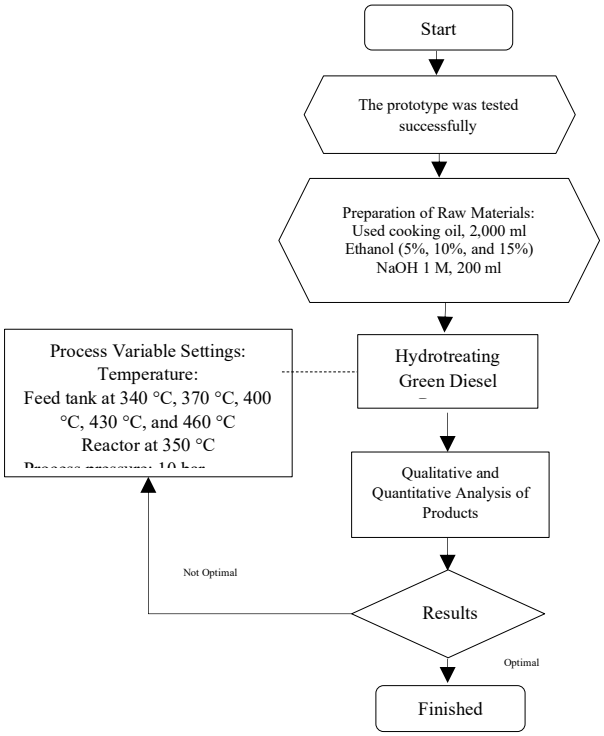


Figure 2 The Hydrotreating Process of Waste Cooking Oil into Green Diesel

Figure 2 presented the flow diagram of the hydrotreating research conducted in this study. The diagram illustrated the overall process, beginning with the preparation of raw materials, including waste cooking oil and supporting chemicals, followed by the adjustment of process variables such as temperature and reactor conditions. The subsequent stage was the hydrotreating reaction to convert waste cooking oil into green diesel. Afterward, qualitative and quantitative analyses of the resulting products were performed to evaluate their characteristics. Finally, the results were assessed to determine whether the operating conditions achieved optimal performance, thereby concluding the experimental process.

3. RESULTS AND DISCUSSIONS

This study analyzed the quality and quantity of green diesel fuel based on variations in the amount of ethanol hydrogen donors and the effect of optimal temperature in fuel production through the in-situ hydrotreating process.

To provide a clearer overview of the experimental results, the main characteristics of green diesel produced under different ethanol concentrations and operating temperatures were summarized in Table 1 and Table 2. This tabulation complemented the graphical data (Figures 2–6) by presenting the yield, density, viscosity, flash point, heating value, and cetane number in a concise and structured format.

Table 1 Characteristics of Green Diesel Samples

Temperature (°C)	Ethanol Concentration (%)	Yield (%)	Density (kg/m³)	Viscosity (mm²/s)	Flash Point (°C)
340		39,725	814,13	3,71	70
370		40,77	806,69	3,58	60
400	5	22,25	832,71	3,69	60
430		29,02	780,67	3,38	63
460		37,5	773,23	3,33	65
340		25,765	776,95	2,88	83
370		31,01	791,82	2,99	67
400	10	35	817,47	3,05	64
430		42,53	776,95	2,80	65
460		45,01	782,90	2,52	63
340		32,215	788,10	3,01	78
370		39,01	784,39	2,77	65
400	15	51,08	796,65	3,22	62
430		55,005	784,39	2,77	62
460		60,025	763,20	2,68	61

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Table 2 Calorific Value and Cetane Number of Green Diesel

Ethanol Concentration (%)	Heating Value (MJ/kg)	Cetane Number
5	42,55	
10	43,98	65,5
15	44,96	

3.1 Effect of Hydrogen Ethanol Donor Concentration on Green Diesel Yield

Yield percentage was a measure that expressed the amount of product produced compared to the amount of raw materials used, usually expressed as a percentage (%). In the context of green diesel, yield indicated how much green diesel was successfully produced from vegetable oil or waste oil raw materials fed into the hydrotreating process. The effect of variations in the amount of ethanol hydrogen donor and the effect of temperature on yield could be seen in Figure 3

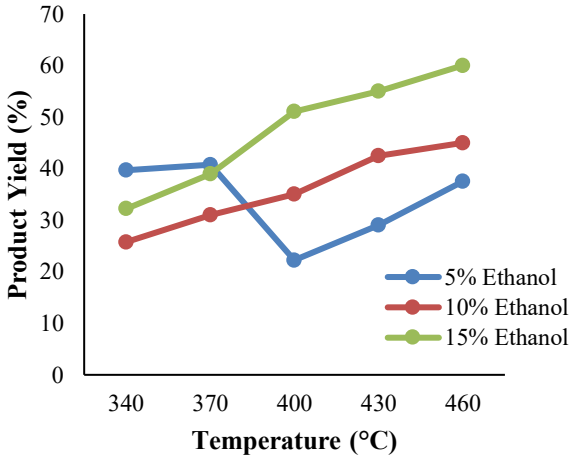


Figure 3. Effect of Ethanol Concentration On Green Diesel Yield

Based on Figure 3, the variations in hydrogen donor concentration have different values. The difference is that the 5% hydrogen donor concentration shows an increase and decrease at each different temperature. However, the 10% and 15% hydrogen donor concentrations show a stable increase in yield. This is consistent with the research by Wongsurakul et al., (2025), which states that an increase in ethanol concentration is associated with an increase in alkane concentration in the liquid product. This increase can raise the final reaction pressure, which has the potential to improve mass transfer during the reaction process. An increase in ethanol content can increase the partial hydrogen pressure during the reaction. High ethanol concentrations also cause the formation of small alkanes. This is because higher ethanol concentrations increase the hydrogen content in the gas product, which can lead to more cracking reactions occurring. Additionally, the varied operating temperatures were applied to the feed tank containing a mixture of ethanol, NaOH, and waste oil as preheating before entering the main reactor.

This initial heating plays a crucial role in converting ethanol into vapor, which then serves as a hydrogen donor during the hydrotreating process. The phase change of ethanol into gas allows for better contact between the hydrogen donor and the compounds in the waste oil, enabling the hydrodeoxygenation and cracking reactions to occur more effectively. Thus, temperature variations in the feed tank not only affect the availability of hydrogen from ethanol but also contribute to reaction efficiency and the final yield of green diesel. This initial heating also helps optimize catalyst activity since the reactants are already in a more reactive state before entering the main reaction zone. In this regard, research by Douvartzides et al. (2019) shows that hydrotreating waste cooking oil at two temperatures, 350°C and 400°C, yields 28% at the lower temperature, while at the higher temperature, there is a significant increase to 84%.

Additionally, the same study showed that the optimal reaction temperature of 420°C yielded the highest green diesel yield of 83.51%. This indicates that temperature significantly influences yield, aligning with previous research findings that the highest yield was achieved at 460°C with a 15% ethanol concentration, yielding 60.025%, while the lowest yield was observed at a 10% ethanol concentration at 400°C, yielding 25.762%.

3.2 Analysis of Green Diesel Product Density

Density was a measure of mass per unit volume of an object or substance. Density indicated how dense the material contained in a given volume was. The higher the density, the more mass there was in the same volume. It was an important physical

property used to identify and distinguish substances because each substance had a different density value. The effect of variations in the number of ethanol hydrogen donors and the effect of temperature on density could be seen in Figure 4

Based on Figure 4, the data from the research and calculations of the density of green diesel products through the in-situ ethanol hydrotreating process ranged from 773.23 to 832.714 kg/m³. The graph illustrated the relationship between ethanol concentration (%) and density (kg/m³) of the green diesel product at five operating temperatures varied in the feed tank as initial heating before entering the main reactor, namely at temperatures of 340 °C, 370 °C, 400 °C, 430 °C, and 460 °C. From the graph, it could be seen that an increase in ethanol concentration tended to reduce the density of the product.

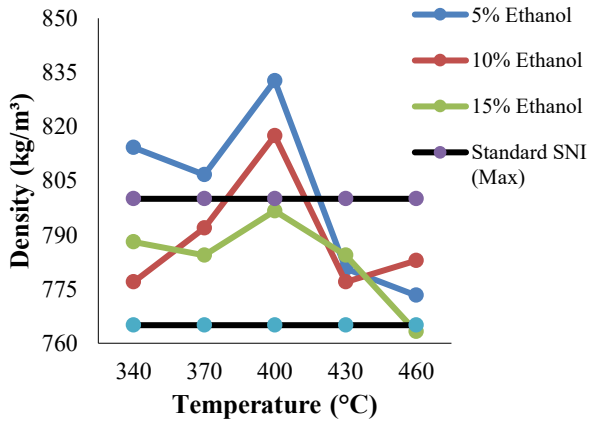


Figure 4 Effect of Ethanol Concentration on Green Diesel Density

At an ethanol hydrogen donor concentration of 5%, the standard set was exceeded, while at hydrogen donor concentrations of 10% and 15%, the product was partially within the specified standard. The product density at 400 °C was generally higher than at other temperatures at the same ethanol concentration, indicating that higher reaction temperatures produced green diesel with lower density. Most samples remained within the SNI range, except at ethanol concentrations of 5% and 10% at specific feed tank operating temperatures that exceeded the standard limits. This indicated that feed tank operating temperature conditions and ethanol concentration needed to be optimized to maintain green diesel quality in accordance with standards. These results were also in line with research by Putra et al. (2023), which showed that at a temperature of 400 °C, a density of 852.3 kg/m³ was obtained, and at a temperature of 460 °C, the value obtained was lower than at 400 °C, so that the density decreased at higher temperatures. This supported the finding that the density of green diesel from this process generally ranged around 800 kg/m³. This was because, as temperature increased, molecules became more active. As a result, intermolecular forces weakened, leading to a decrease in density as temperature rose. The lower the density, the better the quality of the fuel, as it would burn more easily in the engine [5].

3.3 Viscosity Analysis of Green Diesel Products

Viscosity was a measure of internal friction resistance when a fluid flowed. Fluids consisted of several layers, and friction forces arose between layers when one layer moved relative to another. These friction forces constituted the viscosity of the fluid (Studi & Sipil, n.d.). The effect of hydrogen ethanol donor concentration on the viscosity of green diesel could be seen in Figure 5

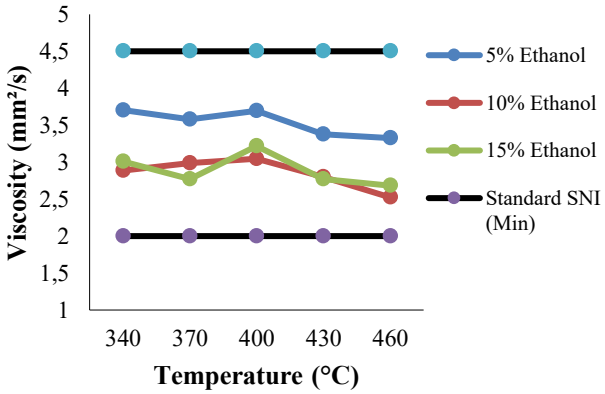


Figure 5. Effect of Ethanol Concentration on the Viscosity of Green Diesel

Figure 5 showed the effect between ethanol concentration (%) and viscosity (mm²/s) of green diesel produced through the in-situ ethanol hydrotreating process at five varying operating temperatures in the feed tank as initial heating before entering the main reactor, namely 340 °C, 370 °C, 400 °C, 430 °C, and 460 °C. The graph showed that as ethanol concentration increased, product viscosity tended to decrease. This aligned with research conducted by Lapuerta et al. (2017), which found that green diesel viscosity changed as ethanol concentration in the mixture increased during the in-situ ethanol hydrotreating process. As the ethanol concentration increased, the viscosity of green diesel tended to decrease non-linearly.

In the study, ethanol concentrations of 0%–10% showed a decrease in viscosity but remained within standards, while concentrations of 10%–36% exhibited a significant, non-linear decrease in viscosity but still met the standard criteria. The viscosity of the product at a feed tank operating temperature of 460 °C was generally lower than that

of the product at other feed tank operating temperatures for the same ethanol concentration, indicating that a higher feed tank operating temperature produced green diesel with lower viscosity. The viscosity values obtained from this study ranged from 2.682 to 3.705 mm²/s. The dashed horizontal line on the graph indicated the minimum and maximum viscosity limits permitted by the SNI standard for diesel fuel. Most of the experimental samples fell within this standard range, indicating that the produced green diesel met the quality requirements in terms of viscosity.

In the study conducted by Putra et al. (2023), no product had a viscosity value that met the green diesel product standard, which was 6.4563 cSt at 400 °C. The addition of ethanol and the increase in temperature during the in-situ ethanol hydrotreating process significantly reduced the viscosity of green diesel. However, the ethanol concentration had to be maintained to ensure that the viscosity remained within the standards for diesel fuel.

3.4 Analysis Heating Value of Green Diesel Products

The calorific value was a crucial parameter in fuel characterization, as it reflected the amount of energy that could be released and transferred into the combustion system through chemical reactions. This available energy served as a key indicator for evaluating the thermal efficiency of the fuel. A higher calorific value corresponded to a greater amount of energy released during combustion, which directly enhanced engine performance and overall combustion efficiency [6].

Ethanol, acting as a hydrogen donor, played a significant role in the hydrodeoxygenation and hydrogenation reactions involved in green diesel production. As shown in **Figure 5**, an increase in ethanol concentration from 5% to 15% was accompanied by a notable rise in the calorific value of the green diesel product. Specifically, the calorific value measured 42.55 MJ/kg at 5% ethanol, increased to 43.98 MJ/kg at 10%, and reached 44.96 MJ/kg at 15%. This trend indicated that the presence of ethanol as a hydrogen donor enhanced the efficiency of the reaction, resulting in an improved energy quality of the final product.

The increase in calorific value could be attributed to the effective deoxygenation reactions, which removed oxygen-containing functional groups from fatty acid derivatives, converting them into saturated hydrocarbons [7]. Higher ethanol concentrations provided more available hydrogen to bind with oxygen atoms, thereby increasing the proportion of saturated hydrocarbons in the product, which inherently possessed higher calorific values.

According to the European Standard EN15940:2016/A1:201, the minimum calorific value requirement for green diesel was 43.7 MJ/kg, while the maximum was 44.5 MJ/kg. The calorific value of the green diesel samples in this study remained safely within these limits [8]. The observed trend showed that higher ethanol concentrations brought the product closer to the maximum allowable calorific value, indicating a substantial improvement in fuel quality. These findings demonstrated that ethanol was effective in enhancing the energy characteristics of green diesel through its role in the reduction of oxygen-containing compounds.

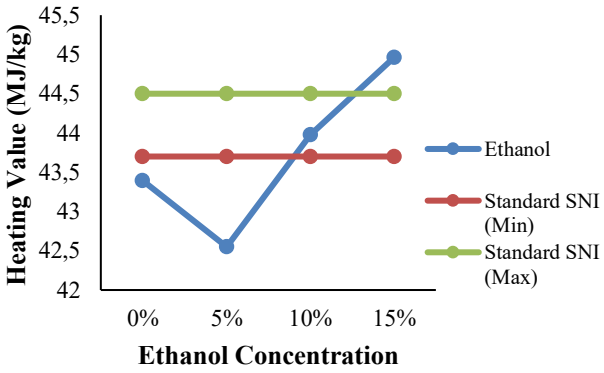


Figure 6 Effect of Hydrogen Donor Concentration on the Heating Value of Green Diesel

3.5 Flash Point Analysis of Green Diesel Products

The flash point was the minimum temperature at which a fuel began to evaporate sufficiently to produce a vapor–air mixture that could ignite upon exposure to a flame or spark. In general, there was a direct relationship between flash point and vapor pressure: the higher the vapor pressure of a substance, the lower the temperature required to reach its flash point. Therefore, the flash point was often used as a key indicator of flammability and volatility. In addition to being a technical parameter, the flash point also played a significant role in assessing fire and explosion risks, particularly during fuel production, storage, and distribution. Knowledge of the flash point was also essential for classifying hazardous materials that required special handling [9].

In this study, the flash point values of green diesel samples produced through the hydrotreating

of waste cooking oil using 3% NiMo/γ-Al_2O_3 catalyst were determined under varying temperatures and ethanol concentrations as the hydrogen donor. The flash point data are presented in Figure 7.

The results showed that increasing the process temperature from 340°C to 460°C significantly reduced the flash point of green diesel across all ethanol concentrations (5%, 10%, and 15%). The highest flash point was recorded at 340°C, particularly at 10% ethanol concentration, reaching 83°C. However, as the temperature increased, the flash point dropped sharply, approaching or even matching the minimum threshold of 55°C at higher temperatures. This decline reflected a reduction in thermal stability due to reactions occurring at elevated temperatures.

The consistent decrease in flash point across all ethanol concentrations indicated that reaction temperature played a crucial role in the stability of the final product. Although ethanol functioned as a hydrogen donor during hydrotreating, its presence at high temperatures could trigger side reactions such as dehydration, decarboxylation, or mild cracking, producing short-chain hydrocarbons and other volatile compounds. These compounds possessed low flash points, thus lowering the overall flash point of the resulting green diesel mixture.

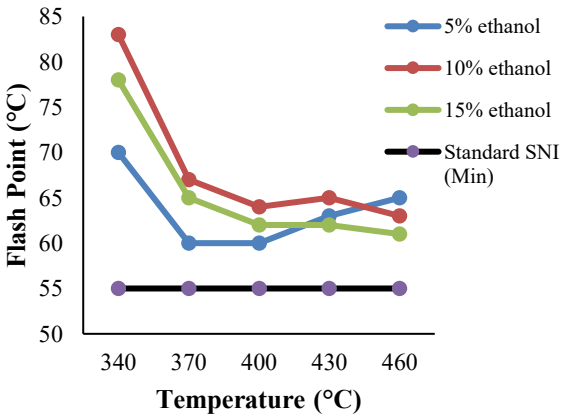


Figure 7. Effect of Temperature and Ethanol Concentration on the Flash Point of Green Diesel

In addition to temperature, ethanol concentration also contributed to variations in flash point. A 10% ethanol concentration appeared to provide a positive effect at lower temperatures, but this effect diminished at higher temperatures, where all ethanol concentrations exhibited similarly reduced flash points converging near the minimum value. This phenomenon highlighted that the combined influence of temperature and reactant composition was critical in determining the fuel's safety characteristics, particularly the flash point, which is a key indicator for assessing fire risk and storage stability.

The flash point of the green diesel sample at 340°C with 10% ethanol concentration was the highest recorded, indicating that the resulting fuel was safer against fire hazards and more stable during storage.

3.6 Cetane Number Analysis of Green Diesel Product

The cetane number (CN) was the main indicator of diesel fuel combustion quality. The higher the value, the faster the fuel ignited after injection, resulting in smoother and more efficient combustion. International standards, such as EN 590 and ASTM D975, set the minimum CN for conventional diesel at 51 [10].

The test was conducted on the best-performing sample. The test results for the green diesel sample, as shown in Appendix I, indicated a CN of 65.5, which significantly exceeded the minimum standard. This value showed that the green diesel had superior combustion quality.

Such a high CN was generally attributed to the high content of saturated alkanes, particularly long chains (C_{15}–C_{20}), which were structurally prone to ignite quickly and burn steadily. This had been confirmed by Sriprathum et al. [11], who showed that increasing saturation and carbon chain length was directly proportional to the rise in cetane number.

Overall, the cetane number of 65.5 indicated that the green diesel produced from hydrotreating waste cooking oil not only met but also exceeded combustion standards, making it a highly potential alternative fuel for modern diesel engines.

4. CONCLUSIONS

Based on the results of the research conducted, the optimal operating temperature condition in the evaporator feed tank for producing green diesel yield in the hydrotreating process of waste cooking oil was at a temperature of 460 °C, which resulted in a green diesel yield of 60.025%. The optimal ethanol concentration percentage as a hydrogen donor for green diesel yield in the hydrotreating process of used cooking oil was at an ethanol concentration of 15%, yielding a value of 60.025%, while the lowest yield percentage was obtained at an ethanol concentration of 10%, yielding a value of

25.765%. The results of the analysis of the characteristics of green diesel products met the standards and quality specifications for biodiesel fuel in the Regulation of the Director General of New, Renewable Energy, and Energy Conservation at the Ministry of Energy and Mineral Resources No. 95.K/EK.05/DJE/2022. Based on the results of the study conducted, the optimal density was obtained at an ethanol concentration of 5% with a value of 780.669 kg/m³ at a temperature of 430 °C, 10% with a value of 791.822 kg/m³ at a temperature of 370 °C, and 15% with a value of 788.104 kg/m³ at a temperature of 340 °C. The optimal kinematic viscosity was found at an ethanol concentration of 5% with a value of 3.705 cSt at a temperature of 340 °C, at an ethanol concentration of 10% with a value of 3.047 cSt at a temperature of 400 °C, and at an ethanol concentration of 15% with a value of 3.218 cSt at a temperature of 400 °C. The flash point at an ethanol concentration of 5% was 70 °C at a temperature of 340 °C, at an ethanol concentration of 10% was 83 °C at a temperature of 340 °C, and at an ethanol concentration of 15% was 78 °C at a temperature of 340 °C. The cetane number was 65.5, and the GC-MS (Gas Chromatography–Mass Spectrometry) result was 23.55

REFERENCES

[1] F. H. Yudhistira and A. A. Wibowo, "Green Diesel: Bahan Bakar Cair Terbarukan Pengganti Biodiesel," *DISTILAT J. Teknol. Separasi*, vol. 8, no. 4, pp. 979–987, 2023.

[2] Aditia, "Konversi Minyak Nabati Menggunakan Katalis Ni/Tio2 Dalam Etanol Superkritik," 2024.

[3] R. adi Nugraha, A. Zikri, and A. Suci Ningsih, "Konversi Minyak Jelantah Menjadi Green Diesel Dengan Proses Hydrotreating Menggunakan Katalis Nimo/ ?-Al2o3," *J. Pendidik. dan Teknol. Indones.*, vol. 1, no. 12, pp. 475–480, 2021.

[4] S. L. Douvartzides, N. D. Charisiou, K. N. Papageridis, and M. A. Goula, "Green diesel: Biomass feedstocks, production technologies, catalytic research, fuel properties and performance in compression ignition internal combustion engines," *Energies*, vol. 12, no. 5, 2019.

[5] J. Ananda, A. Zikri, T. Kimia, P. N. Sriwijaya, and J. S. Negara, "Pengaruh Temperatur Proses Hydrotreating," vol. 5, pp. 11–17, 2024.

[6] W. N. M. Wan Ghazali, R. Mamat, H. H. Masjuki, and G. Najafi, "Effects of biodiesel from different feedstocks on engine performance and emissions: A review," *Renew. Sustain. Energy Rev.*, vol. 51, pp. 585–602, 2015.

[7] G. Di Vito Nolfi, K. Gallucci, and L. Rossi, "Green diesel production by catalytic hydrodeoxygenation of vegetables oils," *Int. J. Environ. Res. Public Health*, vol. 18, no. 24, 2021.

[8] Z. Zurohaina, I. Rusnadi, J. M. Amin, A. Zikri, R. Sabatini, and L. Lindawati, "Penggunaan Katalis Nimo/?-Al2o3 Pada Proses Hydrotreating Minyak Jelantah Menjadi Green Diesel," *J. Pendidik. dan Teknol. Indones.*, vol. 1, no. 12, pp. 465–474, 2021.

[9] J. Fu, "Flash points measurements and prediction of biofuels and biofuel blends with aromatic fluids," *Fuel*, vol. 241, no. December 2018, pp. 892–900, 2019.

[10] N. Asikin-Mijan *et al.*, "Towards sustainable green diesel fuel production: Advancements and opportunities in acid-base catalyzed H2-free deoxygenation process," *Catal. Commun.*, vol. 182, no. June, p. 106741, 2023.

[11] S. Sriprathum, A. Maneedaeng, N. Klinkaew, and E. Sukjit, "Comprehensive analysis of properties of green diesel enhanced by fatty acid methyl esters," *RSC Adv.*, vol. 13, no. 45, pp. 31460–31469, 2023.