



Research Article

Hydrocracking of Crude Palm Oil over Bimetallic Oxide NiO-CdO/biochar Catalyst

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Received: 16th April 2022; Revised: 16th June 2022; Accepted: 17th June 2022
Available online: 18th June 2022; Published regularly: June 2022



Abstract

The bimetallic oxide NiO-CdO/biochar catalyst was prepared by coprecipitation and calcination methods. Characterizations of catalyst were carried out using Fourier Transform Infra Red (FTIR), Surface Area Analyzer (SAA), X-ray Diffraction (XRD), and Scanning Electron Microscope-Energy Dispersive X-ray (SEM-EDX) mapping methods. The catalyst showed a good average crystalized size of 12.30 nm related to the nanoparticles and high dispersion of Ni and Cd metals on the biochar surface. Analysis of liquid fuel products was observed using Gas Chromatography - Mass Spectrometry (GC-MS) which was separated to the main product of gasoline fraction (C₆-C₁₀), and the second product of kerosene fraction (C₁₁-C₁₆), and diesel fraction (C₁₇-C₂₃). The presence of the catalyst in the hydrocracking resulted in more liquid product of 56.55 wt% than the thermal cracking with a liquid product of 20.55 wt%. The best performance activity of catalyst was found at a temperature of 150 °C with high selectivity to hydrocarbon fuel with 12 types of gasoline fractions (39.24 wt%) compared to gasoline fractions obtained at higher hydrocracking temperatures of 250 °C and 350 °C. The results of this study showed that the bimetallic oxide catalyst supported with biochar from palm kernel shell plays an important role in the hydrocracking process to increase the selectivity of the gasoline fraction.

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Keywords: NiO-CdO/biochar; Crude Palm Oil; Hydrocracking; Gasoline Fraction; Palm Kernel Shell

How to Cite: A. Allwar, R. Maulina, T.S. Julianto, A.A. Widyaningtyas (2022). Hydrocracking of Crude Palm Oil over Bimetallic Oxide NiO-CdO/biochar Catalyst. *Bulletin of Chemical Reaction Engineering & Catalysis*, 17(2), 476-485 (doi: 10.9767/bcrec.17.2.14074.476-485)

Permalink/DOI: <https://doi.org/10.9767/bcrec.17.2.14074.476-485>

1. Introduction

Nowadays, the use of energy from fossil fuel has been dominant to fulfil human needs, and the industrialized world started from production to infrastructure and transportation. The efforts to renewable energy resources must be well understood for the sustainable development, efficiency of natural resources, and economic growth. Crude palm oil has the greatest possibility to replace fossil fuel because it consists of

high carbon and hydrogen contents as the main elements to produce hydrocarbon fuels. Several researchers have studied the conversion of crude palm oil into gasoline, kerosene, and diesel fraction by the catalytic hydrocracking process and utilization of bimetallic catalyst [1].

The development of new materials for hydrocracking process becomes a great challenge for the future. Hydrocracking is a catalytic process in which hydrocarbon molecules with long-chain carbon is converted into shorter-chain carbon using appropriate bimetallic catalyst. Recently, the development of catalytic hydrocracking focused on the preparation of a new bimetal-

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lic catalyst supported by a low-cost porous material to improve the catalyst performance. Several studies reported that mono and bimetallic catalysts from transition metals are widely used to increase several active sites and played important roles in catalytic hydrocracking [2]. However, the use of transition metals as catalysts is low effective due to low thermal stability, easy deactivation, and low selectivity in the catalyst performance.

It is necessary to improve the heterogenous catalyst performance by combining metal ions and supporting materials possessing a large surface area. Monometallic catalyst such as Pt/Al₂O₃ has successfully converted crude palm oil into hydrocarbon fuels of gasoline, kerosene, and diesel product by the hydrocracking process. In this case, Al₂O₃ compound is a mesoporous material with high acidity to initiate the cracking process, while platinum as a transition metal plays important role for the catalytic cracking and isomerization in the hydrogenation and dehydrogenation process [3]. The Ni/Zeolite catalyst has been successfully used in the catalytic hydrocracking to convert crude palm oil instead of fossil fuels to produce petroleum-based jet fuels, such as alkanes and cycloalkanes [4–7]. Bimetallic catalyst, such as Ni-Cu/zirconium, Ni-W/zeolite, Ni/Al₂O₃, and Ni/SiO₂-Al₂O₃, show an additional increase in active metallic sites of catalysts due to the dispersion of more metal ions on the surface porous materials. The result shows that immobilization of metal ions on the large surface areas can promote the catalytic activity, selectivity, and reduce the sintering of the catalysts during the reaction hydrocracking. Recently, the preparation of heterogeneous catalyst is focused on the bimetallic oxide with high oxygen functional groups which is supported by porous materials having a low-cost raw material such as biochar. This is a promising heterogeneous catalyst to develop due to its high activity, selectivity, stability, and low-cost production for the hydrogenation and dehydrogenation process [8–12].

Indonesia is one of the largest crude palm oil productions in the world. Crude palm oil is used as raw material for variety of food, cosmetics, and hygiene products. An increase in the crude palm oil production might increase the presence of solid waste. Solid waste such as palm kernel shell is highly potential to produce environmental problem such as water pollution. However, palm kernel shell is a valuable material that can be used as precursor for the preparation of biochar. Palm oil is expected as an alternative oil for hydrocarbon fuel products

due to its high chemical content in the range of C₁₄–C₂₄ as fatty acids, a predominance of C₁₈ [13]. In recent years, palm oil has attracted attention as an alternative oil that can be converted into gasoline through the catalytic hydrocracking process. The resulted hydrocracking process is liquid which can be classified into gasoline (C₅–C₁₀), kerosene (C₁₁–C₁₆), and diesel (C₁₇–C₂₃) fractions. The gasoline fraction consists of hydrocarbon fuels, such as aliphatic (alkanes), olefin, and aromatic compounds, which are high in spark-ignited internal combustion. Kerosene is a mixture of combustible hydrocarbon compounds. It is widely used for industry and household needs. Diesel is a heavy fuel consisting of higher carbon contents that are used in diesel engines [14,15].

Biochar is a porous material that is widely used in the separation and purification process as an adsorbent including as a catalytic support [16,17]. Biochar is prepared from a material with a high carbonaceous compound such as palm oil fruit bunch, palm kernel, and coconut shell by chemical and physical activation [18,19]. Chemical activation is a more popular method because it can create an excellent physical and chemical property such as large surface area, high micropore, and rich surface functional groups [20]. Biochar has acidic properties with high oxygen content that can be considered a supporting material in the heterogeneous catalyst. The incorporation of metal oxide over the surface of biochar can increase the active sites of the catalytic process and will be a great challenge as a new catalyst model for the hydrocracking and isomerization process.

The performance of the bimetallic oxide NiO and CdO can be carried out by the calcinate process in nitrogen atmosphere [21,22]. The incorporations of the bimetallic oxides over the biochar surface has attracted attention as the model of a heterogeneous catalyst. Various transition metals, such as NiO, MoO and CoO, have been synergy with porous materials as catalyst due to their highly selective hydrogens for the catalytic cracking, hydrocracking, and deoxygenation process. This process requires hydrogen gas to improve the ratio of hydrogen and carbon in the cracked molecules and boarder range of end hydrocarbon fuel products, such as gasoline (C₅–C₁₀), kerosene (C₁₁–C₁₆), and diesel (C₁₇–C₂₄) fractions [23].

The purpose of this study is to prepare bimetallic oxide NiO-CdO/biochar and study its efficiency to convert the crude palm oil into hydrocarbon fuels, such as gasoline, with lower carbon atom (C₆–C₁₁). Characterization of the

catalyst is carried out by FTIR, SAA, XRD, and SEM-EDX mapping. Determination of gasoline fraction is conducted by the GC-MS spectrometry.

2. Material and Methods

2.1 Materials

The palm kernel shell and crude palm oil (CPO) are collected from Palm Oil Industry, Kalimantan, Indonesia. Chemicals such as nickel(II) nitrate hexahydrate ($\text{Cu}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$), cadmium(II) acetate dihydrate ($\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$), potassium hydroxide (KOH), and nitric acid (HNO_3) were purchased from Sigma-Aldrich and used without purification.

2.3 Preparation of Biochar

The palm kernel shell was washed with distilled water and dried in the oven at 110 °C for 24 h. The dried sample was grounded into particle sizes (50 mesh). About 100 g of the dried sample was impregnated with 60% potassium hydroxide and strongly stirred overnight at 85 °C. The mixture was washed with deionized water, neutralized to pH 6-7, and dried at 110 °C in the oven for 24 h. Approximately, 25 g of dried impregnated sample was placed into stainless steel reactor and pyrolyzed at temperature of 600 °C for 3 h under a nitrogen flow rate of 100 mL/min. The yield was washed with 2 M nitric acid and finally washed with deionized water. The yield was dried at 110 °C in the oven for 24 h. The result is biochar and kept for further analysis.

2.4 Preparation of NiO-CdO/Biochar

Preparation of bimetallic oxide NiO-CdO was carried out by coprecipitation process.

About 2.91 g of nickel(II) nitrate hexahydrate and 2.67 g of cadmium(II) acetate dihydrate were mixed and added with 100 mL deionized water and 50 mL ethanol with vigorous stirring at room temperature. The mixture was slowly heated to 60 °C for 1 h and wisely dropped with 5 M NaOH to pH 10-11 until the formation of saturated precipitation. The precipitate was subsequently filtered, washed with deionized water/ethanol (1:1), and dried in the oven at 110 °C overnight.

The bimetallic oxide NiO-CdO/biochar catalyst was prepared by the following procedures. Approximately, 5.0 g of NiO-CdO and 5.0 g of biochar (1:1) were added with 100 mL beaker glass and strongly stirred to homogeneous conditions. The mixture was replaced inside the stainless-steel reactor in the graphite furnace and slowly calcined at a temperature of 600 °C with flow nitrogen gas rate of 100 mL/min for 3 h. The yield is bimetallic oxide NiO-CdO/biochar catalyst and kept for further analysis.

2.4 Catalytic Characterization

Specific surface area and pore size distributions were calculated from nitrogen adsorption-desorption isotherm using Quantachrome Nova touch LX4. The morphology and distribution of catalyst particles were studied using a JEOL JED-2300, Scanning electron microscope with energy dispersive X-ray analysis Mapping. The crystalized size of the catalyst was calculated using a Bruker D2 Phaset Gen, the X-ray diffractometer (XRD). The presence of surface functional groups was determined by the Fourier transform infra-red spectroscopy (FTIR), Perkin Elmer Spectrum Version 10.5.1. Efficiency of catalyst was observed to convert crude palm oil into gasoline using catalytic hydrocracking process. Crude palm oil was used as a feedstock for the thermal cracking and catalytic hydrocracking process. The liquid hydrocarbon fuels resulted from the process was analyzed by the gas chromatography-mass spectrometer (GC-MS) to determine the fraction of gasoline, kerosene, and diesel. The coke formation and residue were weighted to obtain the amount of by-product.

2.5 Thermal Cracking and Hydrocracking Process

The experiment was set up as shown in Figure 1. The thermal cracking process was applied non-catalyst in the reactor. About 100 g of crude palm oil as feed was injected into the pyrolysis reactor, and then it was slowly heat-

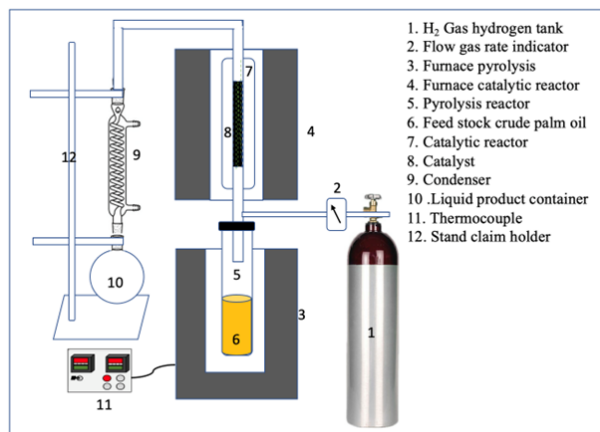


Figure 1. Type of reactor for thermal cracking and hydrocracking process.

ed to 320 °C for 30 min with a flowing hydrogen gas 20 mL/min. Resulted liquid was collected as a thermal cracking product for further analysis. For the catalytic hydrocracking, the process was carried out by the continuous method at different temperatures. About 100 g of palm oil was injected into the pyrolysis reactor, and 0.5 g of catalyst was set up at the catalytic reactor. The pyrolysis reactor was heated to 320 °C as the initial temperature for 30 min as the contact time. The yield of the gas product passed through the second reactor which have NiO-CdO/biochar catalyst. The gas was condensed into liquid at 150 °C to obtain the first liquid product for further analysis. With a similar process, the temperature of the pyrolysis reactor was increased to 400 °C and kept for 30 min as contact time. The gas product was condensed into liquid at temperature of 250 °C and passed through the catalyst in the catalytic reactor to obtain second liquid product. Thereafter, the temperature of the pyrolysis reactor was increased to 500 °C and kept for 30 min as contact time. The gas product was condensed into 350 °C to find the third liquid product. During the catalytic process, the hydrogen gas was injected into the reactor with flow rate 20 ml/min. At the end of the catalytic reaction, it was obtained three types of products: liquid as the main product, while coke and residue are by product of hydrocracking process. The percentage of liquid, coke and residue product was calculated based on the following Equations (1)–(3). The fourth product is gas which could not be collected and disappear during the process. However, amount of gas percentage was predicted from the following Equation (4) [24].

$$L (wt\%) = \frac{w_l}{w_f - w_r} \times 100\% \quad (1)$$

$$C (wt\%) = \frac{w_{cat} - w_{cbt}}{w_f - w_r} \times 100\% \quad (2)$$

$$R (wt\%) = \frac{w_r}{w_f} \times 100\% \quad (3)$$

$$G (wt\%) = 100 - L(wt\%) - R(wt\%) - C(wt\%) \quad (4)$$

where, L is liquid conversion obtained from the catalytic process (wt%), C is coke formation on the catalyst (wt%), R is residue in the reactor (wt%), G is gas conversion (wt%), w_l is weight of liquid obtained after treatment, w_r is residue weight after treatment, w_f is a weight of crude palm oil. w_{cat} is weight of catalyst after treatment, w_{cbt} is weight of catalyst before treatment.

3. Result and Discussion

3.1 Biochar

Preparation of biochar was carried out by the previous procedure with a little modification [25]. The result of biochar was obtained 38% which was calculated by a following Equation (5).

$$Yield (\%) = \frac{\text{weight of biochar}}{\text{weight of dried sample}} \times 100\% \quad (5)$$

3.2 Catalyst Characterizations

Specific surface area and pore size distributions were obtained from the nitrogen adsorption-desorption isotherms at 77 K and relative pressure in the range of 0.05–0.30. The result shows that the specific surface area is 25.5 m²/g, the average pore volume is 0.02 cm³/g, and the average pore size is 2.8 nm. The bimetallic oxide NiO-CdO/biochar tends to the mesopore structure.

The FTIR spectra of biochar and catalyst NiO-CdO/biochar was shown in Figure 2. The comparison study of the spectra is that the weak peak of biochar at around 3133.76 cm⁻¹ is assigned to the stretching vibration of hydroxyl groups. The presence of peak at 3564.84 cm⁻¹ is due to the incorporation of metal oxide and hydroxyl groups from water molecules on the surface of biochar. The peaks at 1623.92 cm⁻¹ and 1622.34 cm⁻¹ are attributed to the C=O stretching vibration of carboxylate and carbonyl groups. The peaks at 1359.45 cm⁻¹ and 1352.47 cm⁻¹ are the characteristic of C–H in the –CH₂ and –CH₃ deformation. The peaks at 459.41 cm⁻¹ and 430.02 cm⁻¹ are assigned to the presence of metal-oxygen bonding in form of Ni–O or Cd–O on the surface of biochar [26]. This result of FTIR spectra can be assumed that the

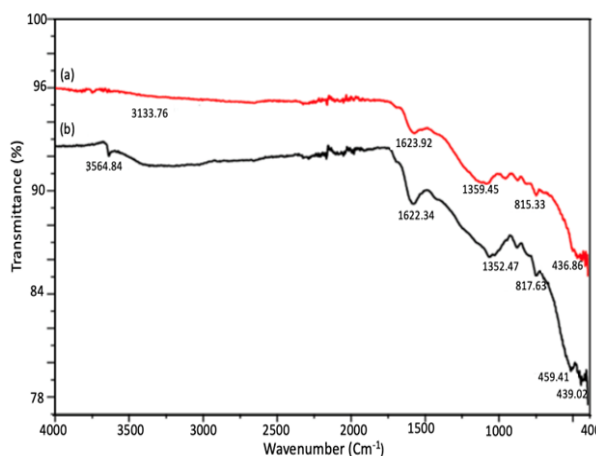


Figure 2. FTIR spectra of (a) biochar and (b) NiO-CdO/biochar.

metal oxides NiO and CdO have been present on the surface of biochar through chemical bounds.

The SEM images of biochar and NiO-CdO/biochar is shown in Figure 3 and 4, respectively. Figure 3 shows the surface morphology of biochar. The surface of biochar is unsmooth with an irregular size and various porosity size. Figure 4 describes the nanoparticles of Ni and Cd metals are agglomerated on the surface of biochar making the surface thickness rough. The EDX mapping describes that the distribution of metal Ni on the surface of biochar was detected with higher metal loadings compared to the metal Cd. It was assumed that the metal Ni has closed the surface of the metal Cd. Other elements are present as an impurity that did not disappear during the washing process. The result shows that the metallic Ni and Cd are successfully immobilized on the surface of biochar which is important activate site in catalytic hydrocracking.

3.3 X-Ray Diffraction Analysis

The XRD analysis was used to determine the crystallized phase of the catalysts at 2θ in the range of $5\text{--}80^\circ$. Figure 5(a) shows a broad peak of biochar at $2\theta = 23.65^\circ$ and 42.88° related to the amorphous structure with the disorderly stacked up by carbon rings. Figure 5(b) shows a variety of peaks at different intensities observed in the XRD pattern corresponding to the improvement of micro-crystallinity with the presence of bimetallic oxide NiO-CdO. The crystalline phases and planes of the NiO-CdO/biochar is shown at $2\theta = 44.25^\circ$ (210), 51.61° (211), 61.72° (22-1), and 76.30° (220), (JCPDS: No. 00-045-1027, No. 00-022-1184, and No. 00-005-0640) [27,28]. The intensity of Cd is relatively low due to its being covered by the nickel ion. The crystallized size of the NiO-CdO/biochar was calculated by Scherer's equation using D (crystallize size) and the FWHM (full width at half maxima) parameters. The

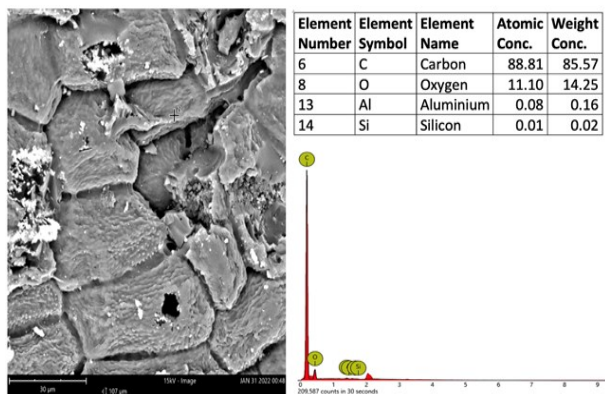


Figure 3. SEM image of biochar.

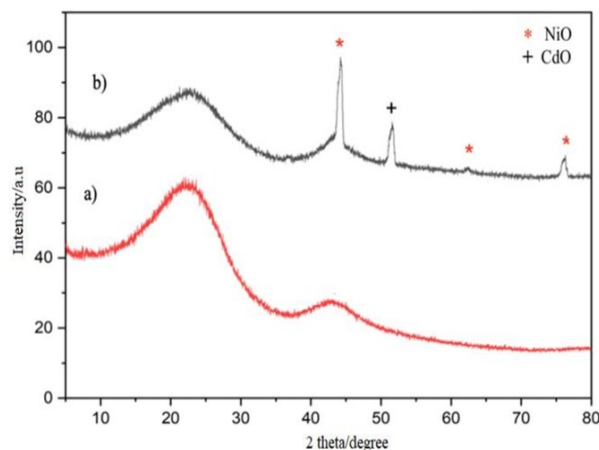


Figure 5. The XRD pattern of (a) biochar and (b) NiO-CdO/biochar.

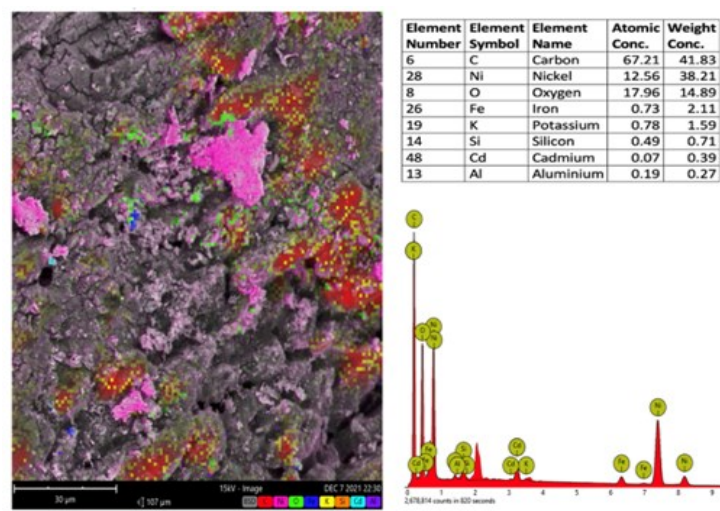
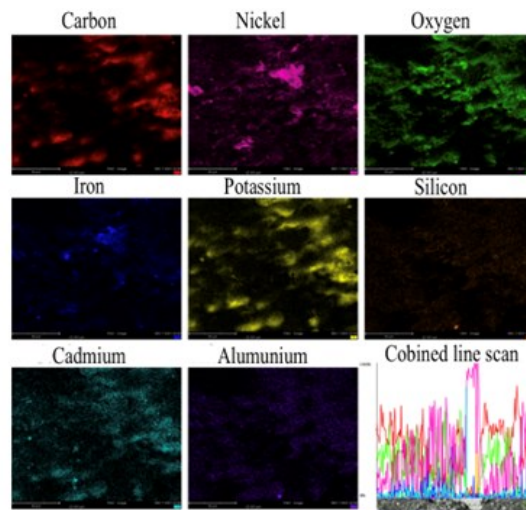


Figure 4. The SEM-image and SEM/mapping of NiO-CdO/biochar.



Scherrer's equation is derived from Bragg's equation, $\lambda = 2d \sin\theta$ with the thickness of $Dd = D$, as the following Equation (5).

$$D = \frac{K\lambda}{\beta \cos \theta} \quad (5)$$

where, λ is X-ray wavelength, $K = 2 \times (\ln 2/\pi)^{1/2}$ is constantly closed to 0.9. The θ is the Bragg reflection angle. Table 1 shows the individual crystal size according to Scherrer's equation, and the average crystallized size (D) is 12.30 nm related to nanoparticles.

3.4 Thermal Cracking and Hydrothermal Products

The presence of the catalyst and hydrogen gas in the hydrocracking process plays an important role in catalytic activity. The cracking is initiated by the presence of the catalyst of NiO-CdO/biochar through the dehydrogenation process. The hydrogen molecule is adsorbed by the metal surface, transported to the biochar as an acidic site, broken up the carbon-carbon chain, and finally hydrogenation process of the cracked shorted chain molecules. A type of product can be separated into liquid, coke, and residue related to the mass of carbon content. The liquid product is a primary product in the thermal and hydrocracking process in which the product is collected during the catalytic process. The coke product is the coke formation

that is attached to the surface of the catalyst. The residue product is the residue of the combustion of feedstock obtained in the reactor. However, gas product is the product that is assumed to disappear during the catalytic process and is responsible for the reducing of the total weight of the product. Figure 6 shows the percentage of the liquid, coke, and residue that were obtained by the thermal cracking and hydrocracking. In the thermal cracking, the total conversions of crude palm oil at a temperature of 320 °C consist of the liquid (20.55 wt%), residue obtained in the reactor (27.44 wt%), and gas (52.01 wt%). There was not the formation of coke attached on the catalyst because the thermal cracking did not used catalyst in the process. This result indicates that thermal cracking produced a low liquid yield as the main product for the thermal cracking. In catalytic hydrocracking, the total conversions of crude palm oil consist of the liquid (56.55 wt%), coke (2.11 wt%), residue (2.12 wt%), and gas (39.32 wt%). The all gas product is assumed as the lightest hydrocarbon fuel product that cannot be collected because it was disappeared together with the rest of hydrogen gas during the process. The comparison study shows that the catalyst played an important role in the catalytic hydrocracking by reaching a higher liquid product (56.55 wt%) than the resulting of thermal cracking (20.55 wt%). The percentage weight of gas was obtained by the comparison study with all the yields. The catalytic hydrocracking process shows that the bimetallic oxides and porous biochar have played an important role to break down heavier-chain hydrocarbon to lighter-chain carbon compounds. It proves the catalyst has high selectivity to produce the liquid products.

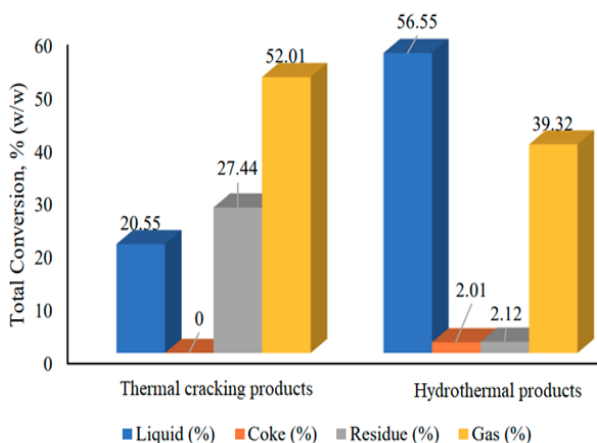


Figure 6. Type of thermal cracking and hydrothermal product.

3.5 Analysis of Liquid Product

The liquid is the main product resulting from the thermal cracking and catalytic hydrocracking process. The liquid product is analyzed by GC-MS and differentiated according to the number of carbons and retention time. Figure 7 shows the peaks of GC analysis distribut-

Table 1. Crystallized particle size of NiO-CdO/biochar.

2θ (°)	FWHM (°)	Crystallized size (nm)	Average crystallized size (nm)
23.35	9.46	0.91	
44.25	0.77	11.65	
51.61	0.72	12.77	12.30
61.72	0.48	20.11	
76.30	0.66	16.04	

ed on the retention time in the range of 2–26 min and separated into gasoline (C_5 – C_{10}), kerosene (C_{11} – C_{16}), and diesel (C_{17} – C_{23}). Figure 7(a) shows the distributions of the liquid product obtained by the thermal cracking at a temperature of 320 °C. Based on the GC analysis, there is only one peak (peak no. 1) at a retention time 9.5 min which is predicted as the main product of gasoline, and other peaks are located at retention time higher than 10 min as the second product of kerosene and diesel. Figure 7 (b) shows the GC analysis resulting from the catalytic hydrocracking at a temperature of 150 °C. The result gives more peaks (peak no. 1 to 12) a retention time in the range of 2-4 min as an indication of the main gasoline fraction. However, the peaks found at a higher retention time (peak no. 12 to 50) are called the kerosene and diesel products. The selectivity of the catalyst has reached the optimum condition to convert crude palm oil into the gasoline product at a temperature of 150 °C with the highest number of gasoline peaks. Figure 7 (c) and (d) show the number of peaks obtained from GC analysis at a temperature of 250 °C and 350 °C, respective-

ly. For both temperatures, there are 9 peaks related to the gasoline products with peak number 1 to 12 at the retention time in the range of 2 to 8 min. However, the peak number with higher than 12 exhibit the kerosene and diesel products. Therefore, in this study, an increase in temperature hydrocracking shows a decrease in the number of gasoline peaks and an increasing the number of peaks as an indication of kerosene and diesel.

A comparative study shows that the effect of the catalyst and temperature played an important role to convert crude palm oil into hydrocarbon fuels. A high-hydrocracking temperature can accelerate to break of carbon-carbon and carbon-hydrogen bonds and is followed by the formation of carbon deposition of coke on the surface of catalyst. The coke may block the active site resulting in the inability of the catalyst to break the carbon-carbon bond into a shorter-chain carbon. However, the effect of the catalyst might increase the selectivity of the catalyst. The active sites may break the carbon-carbon bonds through the formation of free radicals. The presence of hydrogen in the cata-

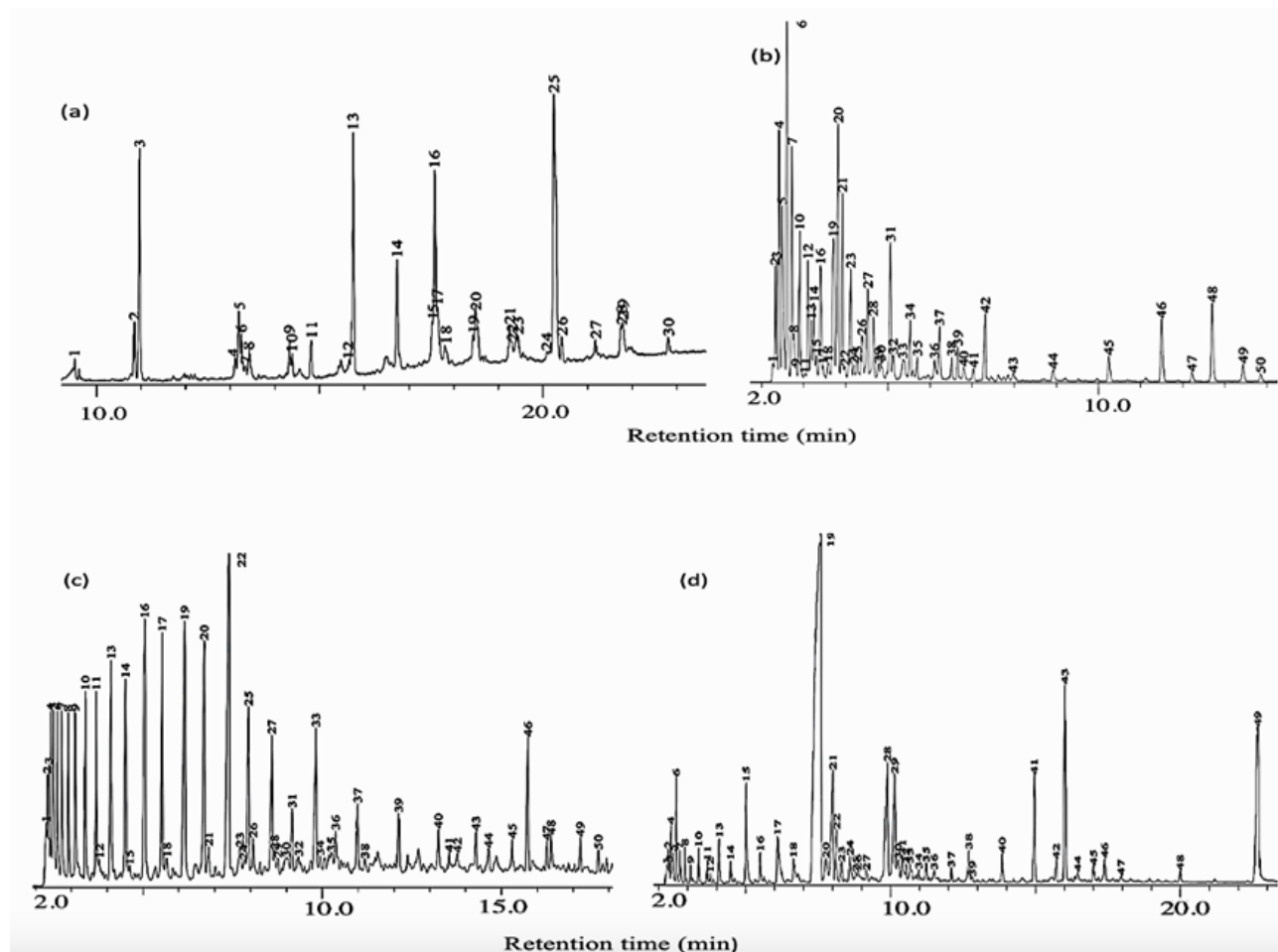


Figure 7. GC-MS spectra of gasoline fraction (a) thermal cracking products, (b) hydrocracking products at 150 °C, (c) 250 °C, and (d) 350 °C.

lytic process may support the incorporation of free radicals to form shorter carbon-carbon bonding [29]. Figure 8 shows the total conversion of the liquid product into gasoline (C₅–C₁₀), kerosene (C₁₁–C₁₆), and diesel (C₁₇–C₂₄) based on the total percentage area from the GC analysis.

3.5 Selectivity of Gasoline Fraction

The Mass spectrometer was carried out to evaluate the activity catalyst on the selectivity of gasoline fractions with carbon content in the range of C₅–C₁₀ as described in Table 2. The fraction of gasoline was observed by the highest similarity index (SI) in the mass spectrum analysis. The result shows that the gasoline fraction of the thermal cracking is 0.45 wt% with one type of product as 1-undecane (n-C₁₁H₂₂) and most other fractions are kerosene and diesel fractions as the second products.

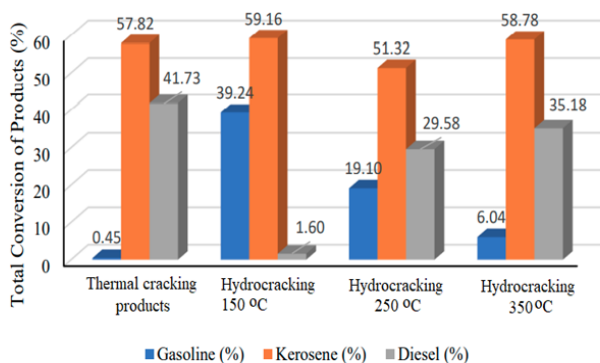


Figure 8. The percentage of hydrocarbon conversion of liquid product into gasoline, kerosene, and diesel fractions.

Table 2. Distribution of carbon number in the liquid products on the thermal cracking and hydrocracking process based on the MS chromatogram.

Peak no	Liquid product	Conversion of crude palm oil to gasoline fractions (%)			
		Thermal cracking 150 °C (wt%)	Hydrocracking 150 °C (wt%)	Hydrocracking 250 °C (wt%)	Hydrocracking 350 °C (wt%)
1	n-Hexane	-	0.46	1.22	0.56
2	n-Heptane	-	1.82	1.41	0.50
3	1-Heptene	-	2.11	1.53	0.33
4	n-Octane	-	4.81	2.23	0.84
5	1-Octene	-	4.71	2.76	0.69
6	n-Nonane	-	10.30	2.51	1.61
7	1-Nonene	-	5.12	2.62	0.63
8	Cyclooctene	-	1.02	-	-
9	2-Nonene	-	1.29	-	-
10	n-Decane	-	3.78	2.44	0.61
11	Cyclooctene	-	1.01	-	-
12	1-Decene	-	2.81	2.38	0.27
13	1-Undecene	0.45	-	-	-
Total		0.45	39.24	19.10	6.04

However, the hydrocracking at temperatures of 150 °C is a good performance of catalytic activity having 12 types of gasoline fractions (C₅–C₁₀) starting from n-hexane to 1-decene with the percentage gasoline of 39.24 wt%. An increase in the hydrocracking temperature process to 250 °C and 350 °C has decreased the gasoline products to 19.10 wt%, and 6.04 wt%, respectively. An increasing the temperatures of hydrocracking can accelerate a break bond of carbon-carbon from a heavier molecule of palm oil and incorporation to build up a kerosene and diesel product instead of gasoline. The result shows that NiO-CdO/biochar has proved an important catalyst in the hydrocracking process and showed the best selectivity of catalyst at temperature of 150 °C by producing 12 types of gasoline fractions (39.24 wt%). The schematic process of thermal cracking and catalytic hydrocracking process is shown Figure 9.

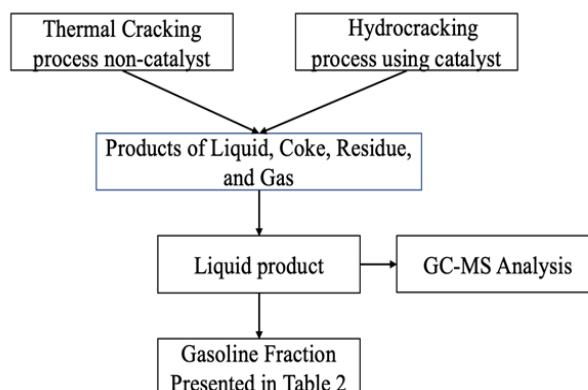


Figure 9. The flow charge of thermal cracking and hydrocracking.

4. Conclusions

In summary, biochar was prepared from palm kernel shell by chemical activation using potassium hydroxide and bimetallic oxide was prepared by coprecipitation method. The catalyst of NiO-CdO/biochar was characterized by SAA, FTIR, EDX, and SEM-EDX Mapping. Characterized results show that the catalyst has a good performance with metal particles dispersed on the biochar surface. Analysis of liquid product was observed using GC-MS to determine the gasoline fraction. The efficiency of the catalyst was observed for the conversion of crude palm oil into a gasoline fraction. A comparison of the result shows that the hydrocracking process using NiO-CdO/biochar catalyst produced more liquid product (56.55%) than thermal cracking product (20.55%). The best performance of activity catalyst was found at a temperature of 150 °C consisting of 12 types of gasoline fractions (30.24 wt%). The result of this study shows that the NiO-CdO/biochar has a potential catalyst for the conversion of crude palm oil into gasoline fractions.

Acknowledgement

The authors would like to thank to The Ministry of Education, Culture, Research, and Technology (Kemdikbudristek) for research funding through The Higher Education Leading Basic Research Scheme (PDUPT) 2021: No. 003/DirDPPM/70/DPPM/PDUPT-Kemendikbudristek/VII/2021.

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