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Research Article

Comparative Study on the Characteristics and Performance of Ni-Impregnated and Non-Impregnated Natural Zeolite Catalysts in the Hydrocracking of Palm Oil to Biofuels

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Abstract

A catalyst was synthesized from Bayah's natural zeolite with low crystallinity and uneven pore distribution. To overcome these limitations, the Bayah natural zeolite was subjected to activation and modification processes aimed at increasing its surface area, improving pore structure, and enhancing overall catalytic activity by impregnating with nickel metal which is active catalyst for cracking reaction. Therefore, this study compares the Ni-impregnated Bayah Natural Zeolite (Ni/ZAA) and non-impregnated Bayah Natural Zeolite (Ni/ZAA) with respect to performance of the hydrocracking of palm oil to biofuels (gasoline, kerosene, and diesel). The natural zeolite was pretreated via desilication using NaOH, followed by calcination. Ni was introduced into the zeolite through ultrasonic-assisted impregnation, and the resulting catalysts were characterized using XRD and XRF techniques. Hydrocracking was conducted at 500 °C with a WHSV of 0.1 min^{-1} using both Ni/ZAA and non-impregnated ZAA catalysts. The liquid products were analyzed by GC-MS to determine selectivity and yield, including coke and gas formation. The desilication process enhanced slightly the Si/Al ratio and catalytic properties of the Bayah zeolite. While Ni impregnation was achieved, suboptimal processing conditions affected the quality of the resulting catalysts. Increasing Ni content improved crystallinity and catalytic activity but also promoted coke formation, which reduced reaction efficiency and liquid product yield. The highest biofuel yield was obtained using the non-impregnated ZAA catalyst, while the 10% Ni/ZAA catalyst showed reduced yield due to excessive coking and pore blockage. These findings suggest that while Ni enhances catalytic activity, excessive loading can lead to overactivity and reduced performance in biofuel production.

Keywords: Bayah Natural Zeolite; Nickel; Ni/ZAA; Hydrocracking; Palm Oil; Biofuel

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1. Introduction

The global demand for energy continues to rise annually, driven by population growth [1]. According to the Indonesian Ministry of Energy and Mineral Resources, fossil fuels remain the dominant energy source in Indonesia, accounting for nearly 95% of total energy consumption, half of which is fuel oil (BBM). In 2023, fuel oil consumption reached 4.975 million kiloliters, while domestic petroleum production was only 3.515 million kiloliters [2], highlighting a significant supply-demand gap. Fossil fuels are not a sustainable long-term solution due to their finite nature, contribution to global warming, acid rain, and high CO_2 emissions, estimated at 37

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billion tons globally by the end of 2017 [3]. This underscores the urgent need to develop renewable and environmentally friendly energy alternatives, such as biofuels [4]. Indonesia, as one of the world's largest palm oil producers, offers significant potential for biofuel development. In 2023, palm oil production reached 30.86 million tons, with 28.63 million tons exported [5]. Palm oil, a vegetable-based feedstock, is highly suitable for biofuel production, with a reported conversion efficiency of 82.05% [6].

Biofuels can be produced through various methods, including transesterification, gasification, catalytic cracking, and pyrolysis. Among these, hydrocracking is considered a favorable route due to its high conversion efficiency, high yield of middle distillates, and the production of fuels with a high cetane number. Hydrocracking is a catalytic process that involves the reaction of vegetable oils with hydrogen gas under specific temperature and pressure conditions [6]. Despite its advantages, hydrocracking also presents several challenges. These include the need for high operating temperatures and pressures, specialized equipment, and precise control over reaction parameters such as catalyst type, catalyst preparation method, temperature, pressure, and reaction time.

Numerous studies have investigated the use of vegetable oils for biofuel production, with zeolites serving as effective catalysts due to their unique physicochemical properties. Zeolites possess a hydrophobic nature and a well-defined porous structure, making them suitable for cracking triglyceride-rich vegetable oils. Marlinda [7] reported that palm oil could be converted into biofuels using an HZSM-5 catalyst, yielding 17.55% biogasoline, 13.48% kerosene, and 5.84% diesel through catalytic cracking. In metal-supported catalyst systems, zeolites offer high catalytic activity, thermal stability, broad porosity, and resistance to agglomeration [8]. Nickel (Ni) is widely utilized as a hydrogenation catalyst due to its ability to form relatively weak bonds with reactants, facilitating faster reaction rates and easier desorption of products, even for long-chain hydrocarbons [9]. The catalytic performance of Ni can be significantly enhanced by dispersing it onto a suitable support material, such as zeolite, which increases the number of active sites and improves contact between reactants and the catalyst surface [10]. This enhanced interaction accelerates the conversion process and promotes efficient product formation. Despite the inherent advantages of zeolite catalysts in controlling activity and selectivity during the cracking process, the yields of desired biofuel fractions, such as gasoline, kerosene, and diesel, are often limited. However, these yields can be substantially improved through zeolite modification with nickel, which enhances both catalytic activity and product distribution [11].

Sodium hydroxide (NaOH) treatment, also known as desilication, is a widely used method to enhance the textural properties of natural zeolites. Although it does not significantly alter the microcrystalline framework, it effectively removes amorphous phases between crystals, thereby increasing surface area and improving pore accessibility [12]. For example, the surface area of natural zeolite can increase from 43.19 m^2/g to 97.61 m^2/g after hierarchical modification, and from 266.3 m^2/g to 526 m^2/g following desilication [13]. Catalyst preparation is commonly performed using the impregnation method, in which active metal components from precursor salts are deposited onto a support material. An ideal support should be inert, thermally stable, porous, and capable of effectively binding metal particles—criteria that zeolites fulfill well. As a support, zeolite provides a stable matrix for dispersing active metal sites, thereby enhancing catalytic efficiency. The impregnation technique is particularly effective in increasing the surface area and adsorption capacity of support materials such as activated carbon. It promotes surface enlargement, pore development, and enhances both mesopore volume and the distribution range of mesopore sizes. Hierarchical zeolite catalysts, in particular, demonstrate excellent reactivity and efficiency in mesopore formation [14]. NaOH treatment further contributes to these improvements by dissolving amorphous regions and opening up the pore structure, making the catalyst more accessible to reactants.

In this study, the catalyst was synthesized from natural zeolite sourced from Bayah, Banten, Indonesia. However, its catalytic performance is limited by low crystallinity and uneven pore distribution. To overcome these limitations, the Bayah natural zeolite was subjected to activation and modification processes aimed at increasing its surface area, improving pore structure, and enhancing overall catalytic activity by impregnating with nickel metal which is active catalyst for cracking reaction. Increasing Ni content on the ZAA catalyst improved crystallinity and catalytic activity, however it promoted coke formation, which reduced reaction efficiency and liquid product yield. Therefore, this study compares the Ni-impregnated Bayah Natural Zeolite (Ni/ZAA) and non-impregnated Bayah Natural Zeolite (Ni/ZAA) with respect to performance of the hydrocracking of palm oil to biofuels.

2. Materials and Methods

2.1 Materials

The natural zeolite utilized in this study was sourced from Bayah, Banten. Nickel(II) nitrate hexahydrate ($Ni(NO_3)_2.6H_2O$), used as the metal precursor for catalyst impregnation, was obtained from Merck. The palm oil feedstock employed was a commercially available Tropical brand cooking oil. Ultra-high purity (UHP) nitrogen (N_2) gas was used as a flushing agent prior to the hydrocracking process, while UHP hydrogen (H_2) gas served as the active cracking agent during the reaction.

2.2 Catalyst Synthesis

The activation of natural zeolite was carried out following the method described by Naafi et al. [15]. The raw zeolite, sourced from Bayah, Banten, was first milled and sieved using an 18-mesh sieve to obtain a uniform particle size. A total of 70.83 grams of the sieved zeolite was placed into a 250 mL glass beaker. Separately, a 250 mL solution of 0.4 M sodium hydroxide (NaOH) was prepared and added to the beaker containing the zeolite. The mixture was then subjected to ultrasonic stirring at 60°C for 30 minutes to enhance the activation process. After treatment, the zeolite was thoroughly washed with distilled water until a neutral pH (pH of 7) was achieved, as confirmed using a universal pH indicator. The sample was subsequently dried in an oven at 110 °C for 3 hours and calcined in a furnace at 550 °C for 6 hours. The resulting activated zeolite is referred to as ZAA, denoting 'Zeolit Alam Aktif' or Active Natural Zeolite.

The Ni/ZAA catalyst was synthesized using an ultrasound-assisted impregnation method, following these steps: Nickel precursor ($Ni(NO_3)_2 \cdot 6H_2O$) at concentrations of 5% and 10% was dissolved in 200 mL of ethanol. The resulting solution was then used to disperse NiO onto 30 grams of ZAA support under ultrasonic irradiation, without applying external heat. The ultrasound generator operated at a power of 400 W, and the irradiation process lasted for 1 hour. After impregnation, the material was dried at 100 °C for 18 hours, followed by calcination at 550 °C for 3 hours, as described by Sadeghi *et al.* [16]. Finally, the catalyst was shaped into pellets.

2.3 Catalyst Characterization Methods

X-Ray Diffraction (XRD) analysis was employed to identify the crystalline phases present in the catalyst material. The measurements were conducted using a SHIMADZU MAXima_X XRD-7000 diffractometer with Cu-Kα radiation ($\lambda = 1.54056$ Å), operated at 30 mA and 30 kV. Powder samples were scanned over a 2θ range of 5° to 90°, at a scanning rate of 2° per minute, with data collected at intervals of 0.02°. The resulting diffractograms were analyzed and compared with reference patterns from the Joint Committee on Powder Diffraction Standards (JCPDS) to determine the crystalline compounds and phases present in the catalyst. X-Ray Fluorescence (XRF) analysis using Rigaku Supermini200 was used to determine the elemental composition and concentration of metal oxides in the catalyst. Each sample was analyzed based on the detection of characteristic X-rays emitted due to photoelectric interactions. These X-rays were captured by a detector and processed to identify and quantify the elements present. The analysis included both qualitative identification of the elements and quantitative determination of their concentrations.

2.4 Catalyst Performance Test

Catalytic cracking was conducted in a fixed-bed reactor containing 10 grams of catalyst, supported by glass wool (Figure 1). Prior to introducing palm oil into the reactor, the entire system was purged with nitrogen gas at a flow rate of 100 cm³/min for 15 minutes to remove residual oxygen and ensure an inert atmosphere. The reactor temperature was maintained at 500 °C throughout the process. Palm oil, used as the feedstock, was pumped into the reactor using a

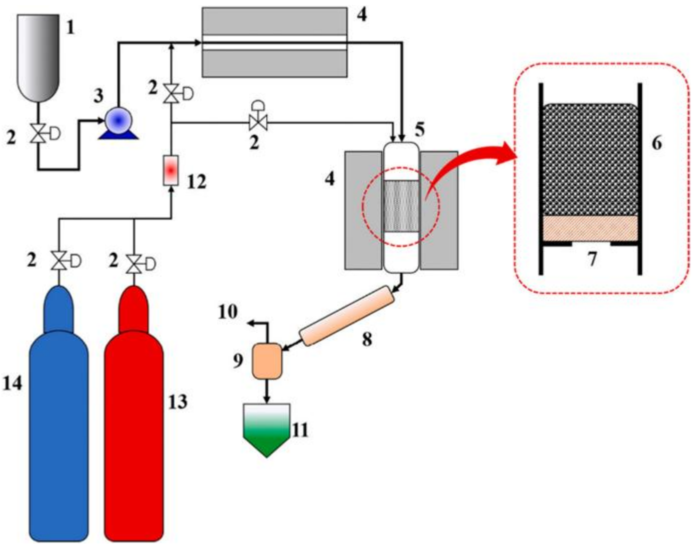

Figure 1. Scheme of the experimental catalytic hydrocracking set up: (1) Palm oil feedstock tank, (2) Gate valve, (3) Peristaltic pump, (4) Electric heating furnace, (5) Reactor tube, (6) Catalysts packing, (7) Glass wool, (8) Condensor, (9) Gas-liquid separator, (10) Gas by product, (11) Liquid fuels product, (12) Gas flowmeter, (13) Hydrogen gas tank and (14) Nitrogen gas tank.

peristaltic pump at a Weight Hourly Space Velocity (WHSV) of 0.1 min^{-1}, calculated using Equation (1), where $Fmass_{\text{feed}}$ is mass flowrate of feed (g/minute) [17]. The gaseous products formed during cracking were directed to a condenser, where they were converted into liquid phase. The resulting cracked liquid product (biofuel) was collected for further analysis. For analytical purposes, biofuel samples were taken during the first 2 hours after steady-state conditions were assumed to be reached, which was estimated to occur 30 minutes after reactor start-up.

$$\text{WHSV (minute}^{-1}) = \frac{Fmass_{\text{feed}}\ \text{(g/minute)}}{Mass\ of\ catalyst\ \text{(g−cat)}} \tag{1}$$

To determine the amount of gasoline, kerosene, and diesel mass fractions formed, the collected liquid biofuels was distilled at temperature ranges of gasoline (25-205 ˚C), kerosene (205-310 ˚C), and diesel (310-370 ˚C). Biofuels fraction selectivity and yield (biofuel, coke, and gas) are calculated using Equations (2)-(6), where liquid product is the mass of collected liquid product obtained from the cracking process at certain interval time basis namely Organic Liquid Product (OLP) [18]. The gaseous products resulting from the hydrocracking reaction of palm oil into gasoline-range hydrocarbons were collected using a gas sampling bag and subsequently analyzed using a GC System (Perkin Elmer) equipped with HayeSep Porapak Q and molecular sieve columns and Thermal Conductivity Detector (TCD) and Flame Ionization Detector (FID) detectors.

$$Selectivity\ (\%) = \frac{m_{\text{gasoline or kerosene or diesel}}}{m_{\text{OLP}}} \times 100\% \tag{2}$$

$$m_{\text{feed}} = m_{\text{OLP}} + m_{\text{coke}} + m_{\text{gas}} \tag{3}$$

$$\text{Yield (\%)} = \frac{m_{\text{gasoline or kerosene or diesel}}}{m_{\text{feed}}} \times 100\% \tag{4}$$

$$\text{Yield of coke (\%)} = \frac{m_{\text{coke}}}{\text{m}_{\text{feed}}} \times 100 \tag{5}$$

$$\text{Yield of gas product (\%)} = \left(100 - \frac{m_{\text{OLP}} + m_{\text{coke}}}{m_{\text{feed}}}\right) \times 100\% \tag{6}$$

3. Results and Discussions

3.1 Catalyst Characterizations

3.1.1 Elemental composition of catalysts

X-Ray Fluorescence (XRF) analysis was conducted to determine the elemental composition of Bayah natural zeolite before and after modification with nickel (Ni), as reported by Kurniawan *et al.* [19] and summarized in Table 1. The results indicated that the primary components of Bayah natural zeolite are silica (Si) and alumina (Al), with a Si/Al ratio of 5.39. Following Ni impregnation at target loadings of 5% and 10%, the actual Ni content in the resulting catalysts was found to be 4.01 wt% and 8.07 wt%, respectively.

Desilication of the zeolite using an alkaline solution (NaOH) slightly reduced the Si/Al ratio. This ratio is a key parameter influencing the structural and catalytic properties of zeolites. The modification process aims to enhance both the physical and chemical characteristics of the zeolite, thereby improving its performance in catalytic applications [20]. According to the classification by Horňáčková *et al.* [21], zeolites are categorized based on their Si/Al ratio as follows: low silica zeolites (Si/Al ≈ 1), medium silica zeolites (Si/Al = 2–10), and high silica zeolites (Si/Al > 10). Based on this classification, both the natural Bayah zeolite and the Ni-modified ZAA catalysts fall into the medium silica category. The observed increase in the Si/Al ratio after Ni impregnation is attributed to the desilication and activation processes that occur during modification. Despite this increase, the Si/Al ratio remains within the medium silica range. As shown in Table 1, Ni impregnation (5% and 10% Ni/ZAA) alters the metal composition of the catalyst. However, not all introduced metals

Table 1. Elemental composition (%) of catalysts (real composition, not normalized).

Metal Content (%w)	Catalyst Samples			
	Bayah Natural Zeolite (untreated)	ZAA	5% Ni/ZAA	10% Ni/ZAA
Si/Al ratio	5.39	4.90	5.06	5.17
Si	21.5	19.3	20.2	16.8
Al	3.99	3.94	3.99	3.25
K	2.15	1.53	1.67	1.58
Ca	1.52	1.16	1.29	1.22
Fe	0.76	0.41	0.44	0.48
Mg	0.25	0.29	0.31	0.24
Ni	-	-	4.01	8.07

may be fully converted into their oxide forms, possibly due to incomplete impregnation or calcination processes [22].

The concentrations of elemental Na and K decrease only slightly during desilication, which may influence catalyst performance in hydrocracking, although their effects are generally indirect and nuanced. Hydrocracking employs bifunctional catalysts comprising metal sites for hydrogenation/dehydrogenation and acid sites for cracking and isomerization. As alkali metals, Na and K tend to neutralize Brønsted acid sites on supports, such as zeolites or alumina, thereby reducing overall acidity [23,24]. This reduction in acidity can suppress cracking while favoring hydrogenation and isomerization, potentially increasing selectivity toward heavier hydrocarbons. Furthermore, by moderating strong acid sites, Na and K can help lower coke formation, improving catalyst stability during extended operation [25]. However, excessive Na or K is often considered detrimental, as it can deactivate acid sites to the extent that cracking activity and overall conversion are significantly reduced. In certain hydrotreating or deoxygenation steps preceding hydrocracking, alkali metals may assist in removing oxygenated species or stabilizing intermediates, though this role is less common in pure hydrocracking. Palm oil, composed primarily of triglycerides, requires both deoxygenation and cracking to yield hydrocarbons. If Na or K is present in high concentrations, the resulting low acidity leads to poor cracking and increased formation of heavy hydrocarbon products. Therefore, maintaining controlled levels of Na and K to achieve moderate acidity can enable selectivity tuning, for example, toward diesel-range hydrocarbons.

3.1.2 Crystal structure and crystal phases identification of catalysts

X-Ray Diffraction (XRD) is a widely used technique in heterogeneous catalysis for analyzing phase composition, crystal structure, and crystallite size of catalyst materials. The diffractogram of the unmodified Bayah natural zeolite is presented in Figure 1(a), while the patterns for the Ni-modified zeolites, 5% Ni/ZAA and 10% Ni/ZAA, are shown in Figure 1(b). The diffractograms in Figure 1(b) reveal the crystalline phases of the modified catalysts, indicating an increase in crystallinity compared to the unmodified Bayah zeolite shown in Figure 1(a). The presence of NiO peaks with increased intensity following Ni impregnation suggests enhanced crystallinity, which is often associated with improved catalytic performance [26]. Higher crystallinity reflects a more stable crystal structure, which contributes to the catalyst's ability to maintain its structural integrity during reactions. This structural robustness is directly linked to increased catalytic activity.

Based on the XRD analysis, Bayah natural zeolite consists of two primary crystalline phases: mordenite and clinoptilolite, each with distinct structural and chemical characteristics. The crystallographic chemical formulas for these phases are as follows: Mordenite: ($O_{115.55}Ca_{1.76}Mg_{0.03}Sr_{0.00}Si_{40.53}Al_{7.40}Fe_{0.03}$) and Clinoptilolite: ($Na_{3.12}Ca_{1.32}K_{0.72}Al_{8.16}Si_{27.84}O_{87.92}$). From the XRD patterns confirm that the unmodified Bayah zeolite and the ZAA catalyst (zeolite after alkaline activation) contain both mordenite and clinoptilolite phases. Meanwhile, the Ni-modified catalysts (Ni/ZAA) exhibit additional peaks corresponding to nickel oxide (NiO), indicating

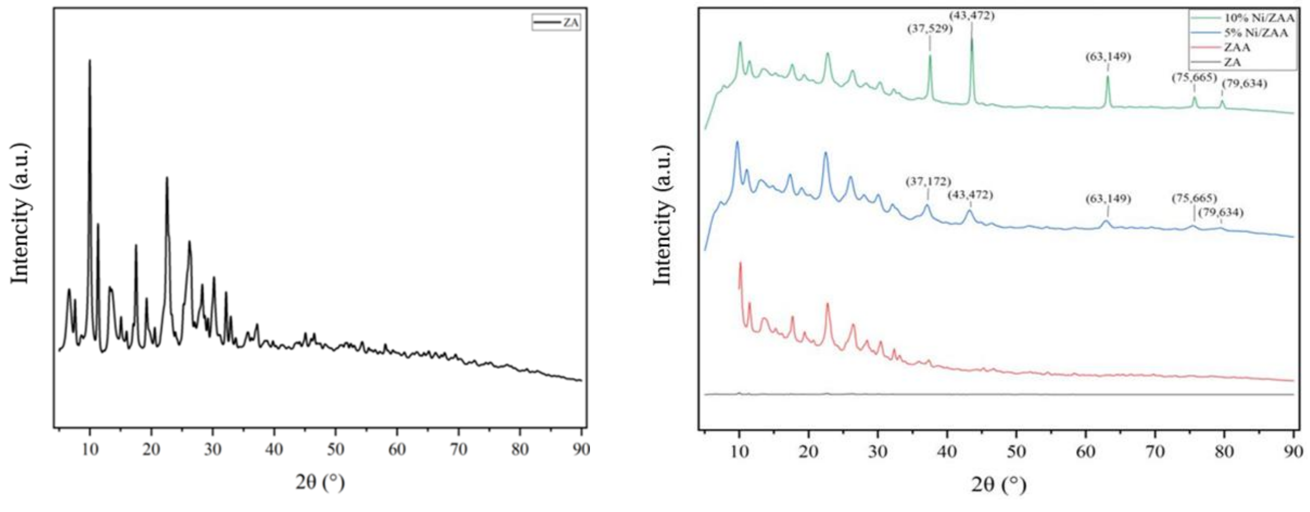

Figure 2. (a) Diffractogram XRD pattern of unmodified Bayah natural zeolite, (b) Diffractogram XRD pattern of modified Bayah natural zeolite catalysts.

successful incorporation of Ni into the zeolite structure. The phase composition of the unmodified Bayah zeolite consists of 36.5% mordenite and 63.4% clinoptilolite. After alkaline treatment (ZAA), the composition shifts to 42% mordenite and 58% clinoptilolite, suggesting structural modification. Upon Ni impregnation, the 10% Ni/ZAA catalyst shows a phase composition of 24.7% mordenite, 53.9% clinoptilolite, and 16% nickel oxide. These results demonstrate that Ni impregnation not only introduces NiO into the catalyst structure but also influences the relative proportions of the existing zeolite phases. The presence of NiO is indicative of enhanced catalytic potential, while changes in phase composition may reflect structural adjustments due to the impregnation and calcination processes.

3.2 Catalyst Performance Testing

3.2.1 Effect of Ni metal doping on modified Bayah natural zeolite catalyst towards hydrocracking performance

The Ni-doped ZAA catalysts were evaluated for their performance in the hydrocracking of palm oil to produce biofuels, specifically targeting the gasoline, kerosene, and diesel fractions. The resulting Organic Liquid Product (OLP) from the catalytic hydrocracking process was separated via distillation, based on boiling point ranges of hydrocarbons: Gasoline: 25–205 °C, Kerosene: 205–310 °C, and Diesel: 310–370 °C. As illustrated in Figure 3, the product yields from hydrocracking using ZAA, 5% Ni/ZAA, and 10% Ni/ZAA catalysts are presented, while Figure 4 shows the selectivity of each catalyst toward specific biofuel fractions.

The OLP yield for all catalysts ranged from 85.05% to 88.75%, indicating efficient conversion of palm oil into organic liquid product. Notably, the 5% Ni/ZAA catalyst exhibited the highest selectivity toward diesel-range hydrocarbons, outperforming both the unmodified ZAA and the 10% Ni/ZAA catalyst. This confirms that Ni sites catalyze hydrogenolysis of C–O bonds, while zeolite acid sites facilitate C–C cleavage [27]. This suggests that nickel doping at an optimal concentration enhances diesel selectivity, likely due to improved catalytic activity and structural properties. Interestingly, even the activated Bayah natural zeolite without Ni doping (ZAA) demonstrated significant diesel selectivity, achieving 27.28%, highlighting its inherent catalytic potential. These findings imply that both catalyst structure and metal loading play critical roles in determining product distribution during hydrocracking.

The promising hydrocracking performance of the Ni/ZAA catalysts highlights the critical roles of both catalyst crystallinity and nickel loading in influencing product distribution. These factors enhance the interaction between reactant molecules and active sites, thereby improving overall reaction efficiency. Nickel (Ni) is widely recognized as an effective hydrocracking catalyst due to its superior properties compared to other transition metals such as Cu, Co, and Fe. Its favorable atomic volume, structure, and atomic radius contribute to its catalytic performance [19]. Moreover, Ni exhibits electronic characteristics that enable catalytic activities similar to those of noble metals, particularly in the selective cleavage of C–C and C–H bonds in hydrocarbon molecules. Nickel has acidic sites that enhance the hydrocracking reaction. Zeolite is a buffer with porous material and has acid sites on its surface so that it can support the performance of nickel as the active phase of the catalyst in cracking palm oil into biofuel [28]. Incorporating

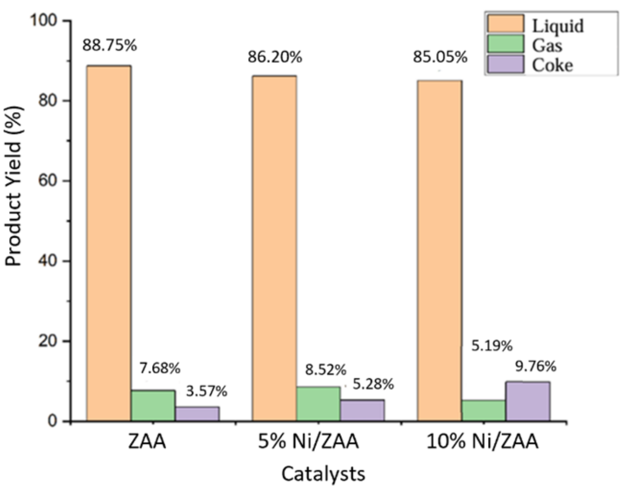

Figure 3. Yield of the catalytic hydrocracking product (organic liquid product, gas, and coke).

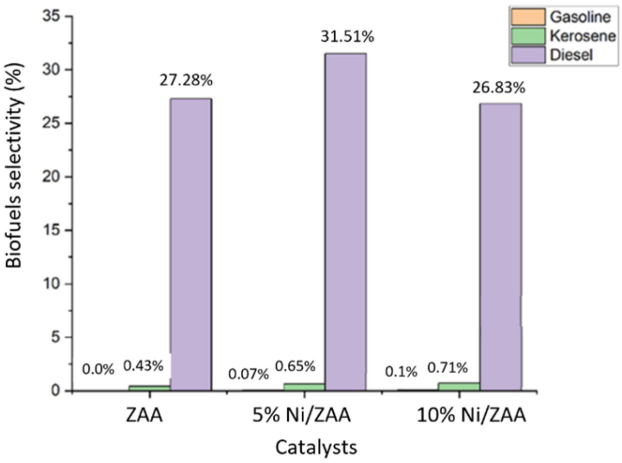

Figure 4. Selectivity of the organic liquid product (OLP), i.e. gasoline, kerosene, and diesel fractions, from the catalytic hydrocracking palm oil to biofuels.

Ni into the zeolite structure enhances the conversion of palm oil into biofuels through the hydrocracking process. Nickel oxide (NiO) serves as active sites on the catalyst surface, accelerating chemical reactions and increasing the efficiency of feedstock conversion [26]. However, excessive NiO loading can lead to carbon deposition (coking), primarily due to interactions between CH_4 and CO_2 on the catalyst surface. This phenomenon causes catalyst deactivation and reduces reaction efficiency, particularly in processes such as dry reforming of methane. Consistent with the findings of Aziz *et al.* [21], optimal NiO concentrations yield better catalytic performance than excessive loading. Overloading Ni can make the catalyst overly active toward carbon formation, leading to pore blockage and diminished accessibility of active sites. Therefore, careful control of Ni content is essential to balance catalytic activity and stability.

The detection of gases such as H_2, CO, CO_2, and H_2O in the hydrocracking gas products indicates the occurrence of key reaction mechanisms, including hydrocracking and deoxygenation processes, namely decarbonylation, decarboxylation, and hydrodeoxygenation. These reactions are essential for removing oxygen-containing functional groups from the feedstock and converting it into hydrocarbon fuels. In addition, the formation of light hydrocarbons, such as ethylene, acetylene, ethane, propylene, propane, and methane, further confirms that cracking reactions took place during the catalytic hydrocracking process. The presence of these compounds reflects the breakdown of larger triglyceride and fatty acid molecules into smaller hydrocarbon fragments, contributing to the production of fuel-range molecules.

4. Conclusions

The strong performance of the Ni/ZAA catalysts underscores the importance of both crystallinity and nickel loading in influencing product distribution. This study demonstrates that NiO impregnation on Bayah natural zeolite significantly enhances the catalyst characteristics and performance in the hydrocracking of palm oil into biofuels, especially hydrocarbons product selectivity. Among the tested catalysts, 5% Ni/ZAA exhibited the highest selectivity toward diesel-range hydrocarbons, outperforming both the unmodified ZAA and the 10% Ni/ZAA catalyst. This suggests that optimal nickel doping enhances diesel selectivity, likely due to improved catalytic activity and favorable structural properties. Furthermore, the detection of gases, such as H_2, CO, CO_2, and H_2O in the hydrocracking gas products, indicates the occurrence of key reaction mechanisms, including hydrocracking and deoxygenation processes, specifically decarbonylation, decarboxylation, and hydrodeoxygenation. These reactions are essential for the removal of oxygen-containing groups and the conversion of triglycerides and fatty acids into fuel-range hydrocarbons.

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CRedit Author Statement

Author Contributions: I. Istadi: Writing – review & editing, Writing –original draft, Supervision, Resources, Methodology, Conceptualization, Investigation. Teguh Riyanto: Writing –review & editing, Resources, Project administration, Methodology, Formal analysis. Alda Salsabilla: Writing –original draft, Methodology, Formal analysis, Conceptualization, Validation Data curation; Novaya Aulia Qotrunnada: Writing –original draft, Methodology, Formal analysis, Conceptualization, Validation Data curation. All authors have read and agreed to the published version of the manuscript.

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