ZEOLITE-BENTONITE CATALYST SYNERGY IN THERMAL DISTILLATION OF WASTE LUBRICANT OIL FOR FUEL OIL PRODUCTION

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This study examines the synergy of zeolite-bentonite catalysts in thermal distillation of waste lubricant oil for alternative fuel production. Zeolite was modified with NH_4NO_3 and calcined at 500 °C to increase acidity, while bentonite was activated with HCl and calcined to improve surface area and thermal stability. Distillation was performed up to 400 °C using zeolite: bentonite ratios of 1:1, 2:1, and 1:2, and compared with a non-catalytic process. XRD and SEM-EDX characterization revealed changes in crystal structure, surface morphology, and elemental composition that supported higher catalytic activity. The mixed catalyst reduced viscosity and density while increasing calorific value. The 2:1 ratio produced the highest calorific value, 6509.46 cal/g, whereas the 1:1 ratio most effectively lowered initiation temperature and time from 298 °C and 34 minutes to 229 °C and 26 minutes. Overall, this catalyst synergy improves distillation performance and liquid-fuel quality from waste oil conversion.

Keywords: *waste lubricating oil, thermal distillation, zeolite, bentonite, fuel.*

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Introduction

Waste lubricating oil (WLO) is a hydrocarbon waste generated in large quantities from transportation and industrial activities [1]. If not managed properly, this waste can pollute soil and water because it contains heavy hydrocarbon fractions, oxidation products, and various inorganic impurities [2]. On the other hand, the hydrocarbon content in used oil still has a high energy value, so it has the potential to be reused through a thermal conversion process into liquid fuel fractions [3]. This approach is attractive because it not only reduces the hazardous waste load but also opens up opportunities for energy recovery from oil-based residues.

One widely developed method for reusing used oil is pyrolysis, or thermal distillation. However, uncatalyzed thermal processes generally require high temperatures, consume large amounts of energy, have poor product selectivity, and tend to produce heavy residues and coke [4]. The use of solid catalysts is an important strategy for lowering the activation energy of hydrocarbon cracking, accelerating the formation of light fractions, and improving the quality of the resulting liquid products [5]. Several studies have also shown that catalytic processing of heavy oil can increase the yield of light fractions while improving fuel quality compared to conventional thermal processes.

Zeolite is a porous aluminosilicate material known to have high acidity, good thermal stability, and strong catalytic activity in hydrocarbon cracking reactions [6]. Due to these properties, zeolite has been widely used in the refining and upgrading processes of oil fractions to produce lighter fuel products [7]. Meanwhile, bentonite is a layered aluminosilicate clay that has a large surface area, good cation exchange capacity, and

adsorptive properties that support interactions with polar compounds and impurities in oil [8]. Chemical activation of bentonite can increase the surface area and acidity properties, so this material has the potential to play a role not only as an adsorbent, but also as a supporter of catalytic activity in thermal systems [9]. The combination of zeolite and bentonite is interesting to study because both have complementary characteristics [10]. Zeolite contributes through active acid sites and effective microporous structures for cracking, while bentonite can support dispersion, surface accessibility, and interaction with heavy components and impurities [11]. Several studies have reported the use of zeolite or bentonite separately [12], [13] as well as the utilization of zeolite–bentonite composites [14] in adsorption and catalysis applications. However, studies that specifically evaluate the synergy of zeolite–bentonite catalysts in the thermal distillation of waste lubricant oil, especially with variations in the catalyst mixture ratio and its effect on the quality of the liquid product and the initial performance of the distillation, are still limited.

Based on this background, this study aims to analyze the effect of the synergy between modified zeolite and bentonite catalysts on the thermal distillation of waste lubricating oil. The focus of the study is directed at changes in catalyst characteristics after activation and calcination, as well as the effect of variations in the zeolite:bentonite ratio on the physical properties of the liquid product and process performance, especially viscosity, density, calorific value, initiation temperature, and time of first droplet appearance. Thus, this study is expected to contribute to the development of used-oil waste utilization through a more efficient and effective catalytic approach.

Materials and Methods

Research Materials

The main materials used in this study included waste lubricating oil (WLO), natural zeolite and bentonite, and several chemicals used in the catalyst modification process. WLO was obtained from a motor vehicle repair shop located in Metro City, Lampung Province, Indonesia. The lubricant used is Shell Advance 4T AX5 oil, a standard lubricant commonly used in Otto engines; its physicochemical properties are presented in Table 1. This type of oil was chosen because of its viscosity and thermal stability characteristics, which represent two-wheeled vehicle lubricants that are widely used in Indonesia, so it is relevant for the study of used oil regeneration through a thermal process [15].

Natural zeolite and bentonite used as catalysts were obtained from different commercial sources with different chemical compositions presented in Table 2. Natural zeolite was obtained from AquaSolutions (Bandung, West Java), and bentonite from Ophin Alat Lab Alkes (Malang, East Java) via an e-commerce platform. The use of natural zeolite and bentonite is based on their abundant availability, relatively low cost, and their ability to provide acid active sites and porous structures that support hydrocarbon cracking reactions [16].

Ammonium nitrate (NH_4NO_3) is used as an ion exchange agent in the zeolite modification process [17] to produce H-zeolite precursor, while hydrochloric acid (HCl) is used in the bentonite activation process through an interlayer cation exchange mechanism. The ion exchange method using NH_4NO_3 and acid activation with HCl are common approaches used to increase the acidity and surface area of natural mineral-based catalysts [18].

The distilled water used in the catalyst preparation and material rinsing stages was obtained from Aquades Store (South Lampung, Lampung Province). All chemicals used were of technical purity and were used without further purification, as is common practice in natural material-based catalyst research [19].

The main equipment used in this study includes a thermal distillation reactor equipped with an electric heating system (heating mantle), obtained from CV Dichandra Labglass (Bandung, West Java). This reactor is used for

the thermal distillation process of used oil, both without a catalyst and with the addition of a zeolite–bentonite catalyst, in accordance with the thermal process-based used oil regeneration approach that has been widely reported in the literature.

Table 1. Physicochemical Properties of Shell Advance 4T AX5 [20]

Propertles			*Method*	*Shell Advance 4T AX5*
SAE Viscosity grade				15W-40
Kinematic Viscosity	@40℃	mm^2/s	ASTM D445	106.2
Kinematic Viscosity	@100℃	mm^2/s	ASTM D445	14.3
Vlscoslty Index			ISO 2909	150
Denslty	@15℃	Kg/m^3	ASTM D4052	870
Flash Point (COC)		℃	ISO 2592	235
Pour PoInt		℃	ISO 3016	-30

Table 2. Chemical Composition of Zeolite and Bentonite

Chemical Properties	***Mass(%)***		***Atom (%)***	
	Zeolite	Bentonite	Zeolite	Bentonite
C	25,81		35,28	
O	34,33	57,89	35,23	71,26
Na	0,25	4,65	0,18	3,98
Mg	2,16		1,46	
Al	33,85	11,80	20,60	8,62
Si	10,24	18,51	5,99	12,98
K	0,96		0,40	
Ca	1,48	0,36	0,60	0,18
Fe	0,86	3,90	0,25	1,37
Cl		2,89		1,60

Preparation of Zeolite and Bentonite Catalysts

The catalyst preparation is shown in Figure 1, Natural zeolite and bentonite were first dried, ground, and sieved to a 200-mesh size to obtain homogeneous particles. Untreated zeolite was used as a reference catalyst. Zeolite modification was carried out through ion exchange using NH_4NO_3 [21]. A total of 100 g of zeolite was mixed with 10 g of NH_4NO_3 in 700 mL of distilled water, then stirred at 80°C for 2 hours. After completion of the process, the mixture was filtered, washed to a neutral pH, dried at 110°C for 8 hours, and then sieved again to a 200-mesh size.

Bentonite modification was carried out through acid activation using HCl [22]. A total of 100 g of bentonite was mixed with 10 mL of HCl in 700 mL of distilled water and stirred at 80°C for 2 hours. The suspension was then filtered, washed to neutral pH, dried at 110 °C for 24 hours, ground, and sieved to 200 mesh. Some of the modified zeolite and bentonite were further calcined at 500 °C for 3 hours to improve catalytic properties and thermal stability before use in the distillation process.

Catalyst Characterization

Catalyst characterization was conducted to evaluate changes in physical and chemical properties resulting from the modification and

calcination processes, and to elucidate their relationship to catalyst performance in the thermal distillation of used oil. The zeolite samples analyzed included natural zeolite and NH_4NO_3-modified zeolite. The bentonite samples analyzed included bentonite, HCl-activated bentonite.

Characterization was performed using X-Ray Diffraction (XRD) and Scanning Electron Microscopy–Energy Dispersive X-ray (SEM-EDX). XRD analysis using PANalytical X'Pert PRO was used to identify the crystalline phase, degree of crystallinity, and structural stability of the catalyst after activation and calcination [23]. Meanwhile, SEM-EDX using an Inspect S50 FEI was used to observe the surface morphology, particle size, and degree of agglomeration, and to qualitatively and semi-quantitatively identify the elemental composition of the catalyst [24]. The characterization data are used to explain how changes in the catalyst's structure and morphology affect its performance in the thermal distillation of used oil.

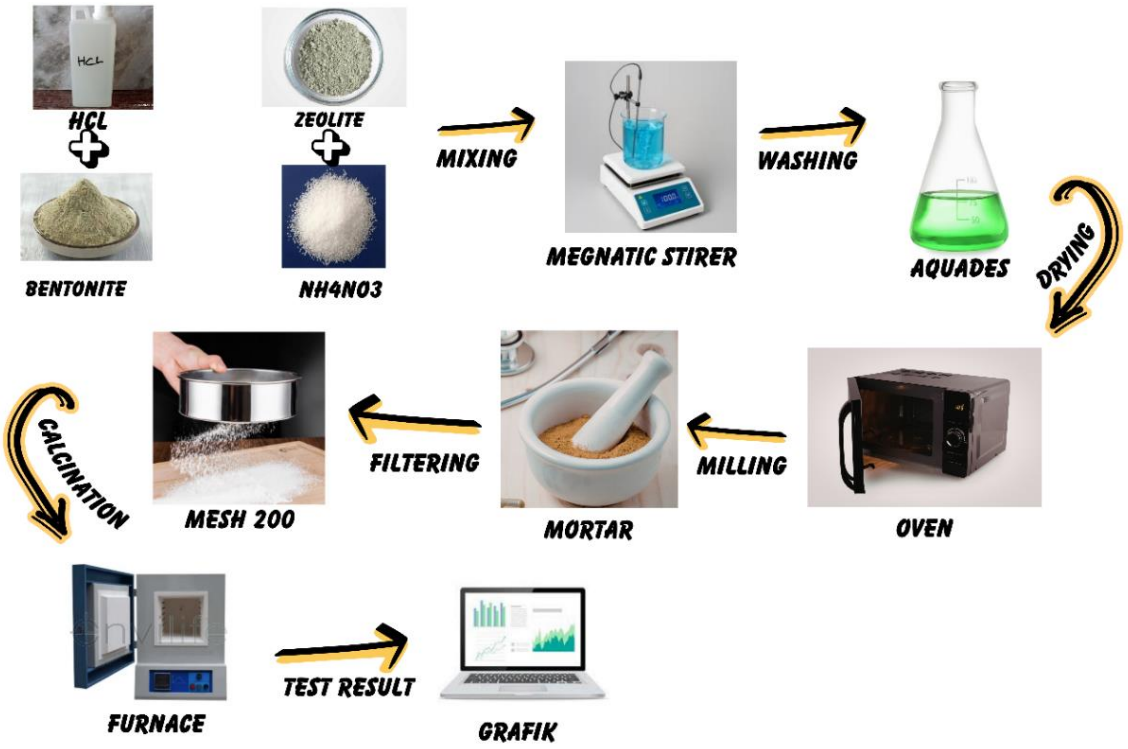


Fig 1. Zeolite and bentonite Modification Preparation Process

Thermal Destillation Process of Used Oil

Thermal distillation testing using the mechanism presented in Figure 2 was conducted on used lubricating oil (WLO) to evaluate the effect of catalysts on distillate characteristics. The experiments were conducted in four variations, namely without catalyst and with a mixture of NH_4NO_3 modified zeolite catalyst and HCl modified bentonite that had been calcined at 500 °C, with zeolite:bentonite ratios of 1:1, 2:1, and 1:2. In each catalytic experiment, 300 mL of WLO and 30 g of catalyst were used, so the oil to catalyst ratio was 10:1.

The distillation process was carried out using a reactor flask heated with a 250 W heating mantle, equipped with a water-cooled condenser, a distillate collection flask, and a thermocouple connected to a calibrated Arduino Uno to record the distillation temperature every 1 second. The reactor was heated gradually to

400 °C for approximately 5 hours. The resulting heated vapor was then condensed and collected as the distillate.

The distillate product was then tested for viscosity, density, and calorific value. Viscosity was measured using a viscometer to determine the product's thickness; density was determined using a pycnometer to measure the distillate's density; and calorific value was measured using a bomb calorimeter to determine the sample's combustion energy. The test data were used to assess the quality of the resulting liquid fraction and the effect of catalyst use on its potential as an alternative fuel.

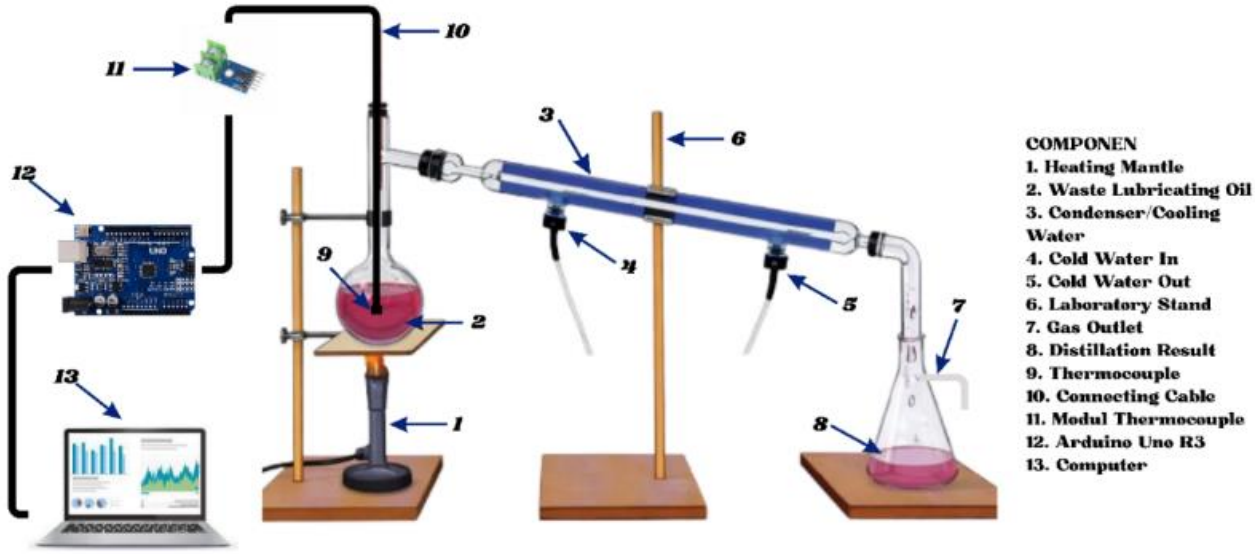


Fig. 2. Thermal Distillation Scheme Description

Results and Discussion Crystallinity and Absorbance Analysis

The XRD results in Figure 3, show that chemical activation has different effects on the crystal structures of zeolite and bentonite. Zeolite modified with NH_4NO_3 still maintains clear diffraction peaks in the 2θ range of 20–35°, indicating that its crystal framework is relatively stable despite changes in crystallinity [25]. This stability indicates that the ion exchange process does not damage the primary structure of the zeolite, thus maintaining its potential for use as a catalyst in thermal distillation processes [26].

Conversely, bentonite activated with HCl exhibits a decrease in structural regularity, characterized by peak broadening and an increase in the diffraction background. These changes indicate a partial transformation of the montmorillonite phase toward a semi-crystalline to amorphous structure [27]. This condition indicates that bentonite is more responsive to acid activation than zeolite. This increased amorphous character may contribute to the formation of a larger surface area and active sites, thus supporting its role in adsorption and catalysis processes [28].

Analysis of FTIR Spectra

As presented in Figure 4, the FTIR spectra of bentonite and zeolite confirmed the presence of aluminosilicate frameworks, indicating their potential application as catalysts in the thermal distillation of waste lubricating oil. Bentonite exhibited absorption bands at around 3625 cm^{-1} and 1628 cm^{-1}, which were assigned to O–H stretching and H–O–H bending vibrations, respectively, indicating the presence of structural hydroxyl groups and adsorbed water [29]. The strong band at 1116 cm^{-1}, together with those at 909, 790, and 683 cm^{-1}, was associated with Si–O–Si/Si–O–Al

vibrations and structural hydroxyl groups typical of clay minerals. In contrast, zeolite showed a prominent band at 994 cm^{-1}, corresponding to the asymmetric stretching vibration of the T–O–T framework (T = Si or Al), confirming the characteristic zeolitic structure. Overall, the presence of hydroxyl groups, adsorbed water, and aluminosilicate frameworks in both materials suggests the availability of active sites that may promote hydrocarbon chain cracking during the thermal distillation of waste lubricating oil, with zeolite demonstrating greater catalytic potential due to its more reactive structural characteristics.

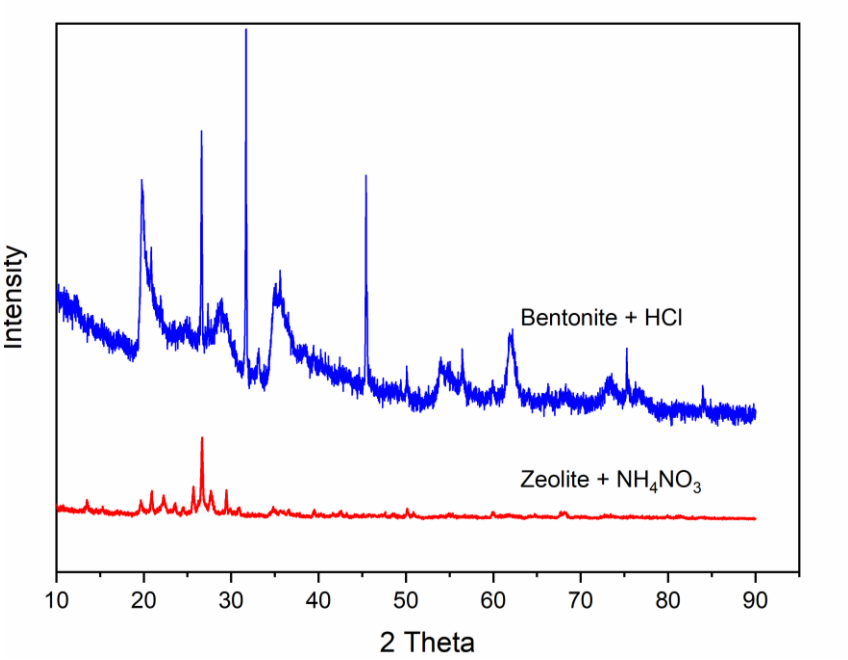


Fig. 3 . XRD Data Results of Zeolite and Bentonite

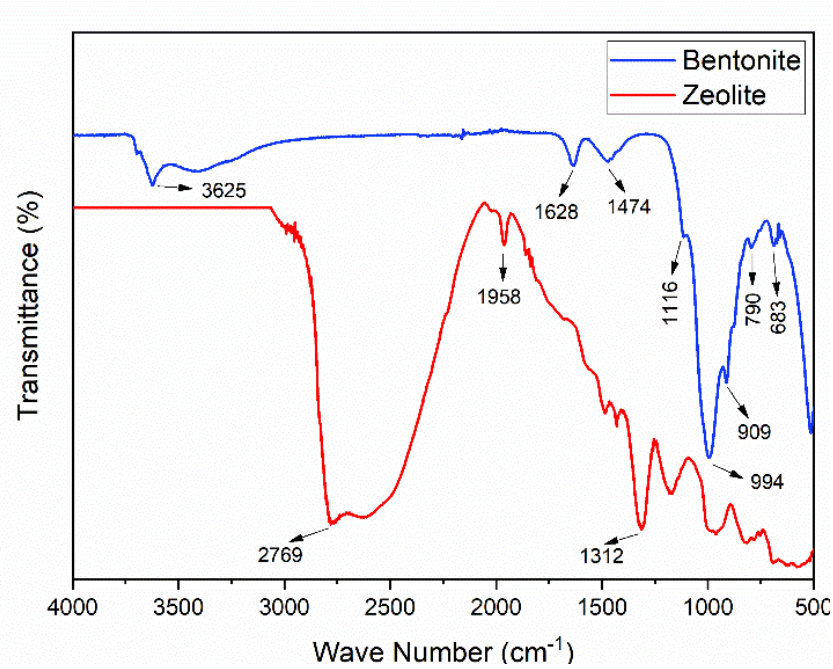


Fig. 4 . FTIR Data Results of Zeolite and Bentonite

Surface Analysis and Composition

The results of the SEM-EDX test are presented in Figure 5. The results of the SEM analysis of zeolite show irregular particle morphology, rough surfaces, and a tendency to agglomerate at the micrometer scale. The particle surface also shows gaps and cavities that reflect the characteristics of porous materials, as is commonly found in zeolites, and supports their role as adsorbents and catalysts [30]. This morphology influences the adsorption and capillary capacity of zeolite, which ultimately determines its performance in separation processes and chemical reactions

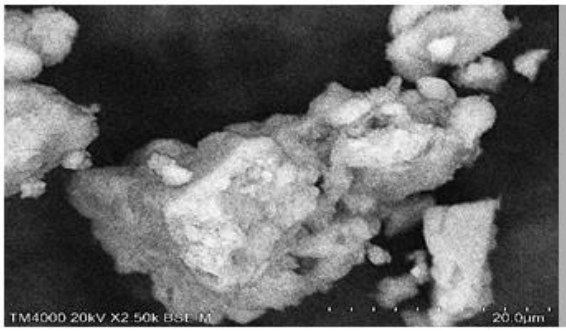
Meanwhile, the results of SEM analysis on bentonite show irregular, overlapping sheet-shaped particle morphology (lamellar), which is a typical characteristic of montmorillonite minerals [31]. Bentonite particles also appear to undergo agglomeration, which is likely influenced by electrostatic forces, Van der Waals forces, and the presence of moisture [32]. The rough surface and the presence of interlayer space indicate the potential of bentonite in providing pore channels that support the adsorption capacity [33]. Compared with zeolite, bentonite has a more flexible layered morphology, potentially leading to different adsorptive responses in environmental and catalytic applications. [34].

EDX testing was conducted to identify the elemental composition of zeolite and bentonite. EDX results showed that both materials were dominated by oxygen (O), silicon (Si), and aluminum (Al), reflecting the typical aluminosilicate framework of zeolite and bentonite. The dominance of these elements indicates the presence of Si–O–Al bonds, which play an important role in forming structural stability, adsorption capacity, and catalytic activity of the material [35]. In addition to the major elements, minor elements such as Na, K, Ca, Mg, and Fe were also detected. These elements generally act as balancing cations or as natural impurities that can affect surface properties, ion-exchange capacity, and material reactivity after chemical treatment. The presence of these minor elements also indicates that the chemical composition of zeolites and bentonites is not only determined by their aluminosilicate framework, but also by the presence of supporting cations that can contribute to the adsorption and catalytic performance [36]. In the modified zeolite samples, the dominance of O, Si, and Al elements indicates that the chemical treatment does not damage the main aluminosilicate framework, but rather affects the cation composition and surface properties. These changes have the potential to improve the physicochemical properties of the material, especially those related to adsorption capacity and catalytic activity [37]

Characteristics of Distillation Results

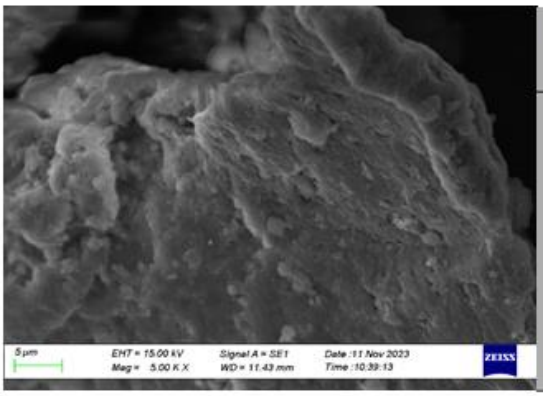
The characteristics of fuel from the distillation of waste lubricating oil were analyzed to evaluate the effect of catalyst use on the quality of the resulting liquid fraction. Assessment was conducted through visual observation and physical property testing, including viscosity, density, and calorific value. These three parameters are commonly used as indicators of the success of the catalyzed distillation process in converting heavy hydrocarbon compounds into lighter, more valuable fractions as fuel [38].

Visual observation of the distillation products showed differences in color, clarity, and homogeneity in samples a, b, c, and d. Samples a and d showed a brighter reddish-brown color and higher clarity, indicating that the separation of light fractions was more effective and that the contaminant content was lower [39]. In contrast, sample b appears darker and cloudier, indicating the presence of heavy fractions, water, or residue due to incomplete separation. Sample c exhibits an intermediate condition with a more homogeneous dark brown color and better clarity than sample b, indicating relatively better process conditions. In general, these differences in visual characteristics indicate that operational conditions and catalyst use influence the purity and quality of the resulting distillate [40].



Element	Mass [%]	Mass Norm [%]	Atom [%]
C	15.56	17.18	25.35
O	44.52	49.17	54.45
Mg	0.57	0.46	0.46
Al	8.43	6.12	6.12
Si	16.13	11.24	11.24
K	2.61	1.31	1.31
Ca	0.90	0.44	0.44
Fe	1.81	0.63	0.63
Rh	0.00	0.00	0.00
	90.53	**100.00**	**100.00**

(a)



Element	Weight %	Weight % Sigma	Atomic %
O	56.69	0.44	70.28
AL	10.64	0.20	7.82
Si	23.90	0.30	16.88
Ca	1.35	0.12	0.67
Fe	3.93	0.31	1.39
Na	2.24	0.15	1.94
Mg	1.25	0.11	1.02

(b)

Fig. 5. SEM-EDX Test Results (a) Zeolite, (b) Bentonite

The viscosity test results showed that adding a zeolite–bentonite catalyst reduced the distillate viscosity compared with the sample without a catalyst. The sample without a catalyst had the highest viscosity of 0.380 cP, then decreased to 0.343 cP at a zeolite:bentonite ratio of 1:1, 0.332 cP at a ratio of 2:1, and 0.330 cP at a ratio of 1:2. This decrease indicates that the use of a catalyst helps break down heavy hydrocarbon molecules into lighter fractions, thereby increasing the flowability of the distillate [41]. These results are in line with the XRD characterization which shows that zeolite retains its crystal framework after activation, while bentonite undergoes structural changes that tend to be more amorphous. This condition is supported by SEM results, which show that zeolite has a porous structure, while bentonite has a layered lamellar form, so that the combination of the two can strengthen the catalytic and adsorptive interactions during the distillation process [42].

The density test results show that adding a catalyst decreases density, although the change is relatively small. The sample without a catalyst has a density of 0.780 g/cm³. At the same time, at a zeolite: bentonite ratio of 1:1, the value becomes 0.776 g/cm³, at a ratio of 2:1, it is 0.778 g/cm³, and at a ratio of 1:2, it reaches its lowest value of 0.771 g/cm³. This decrease in density indicates a tendency for the formation of lighter fractions during the catalyzed distillation process [43]. The small changes indicate that the catalyst does not drastically change the total density, but rather plays a role in improving the distribution of hydrocarbon fractions. This is consistent with the SEM-EDX results which show the dominance of O, Si, and Al elements in zeolite and bentonite as the main aluminosilicate framework, which supports the

structural stability and catalytic role of the material [44].

The results of the calorific value test indicate that the use of a zeolite–bentonite catalyst improves the energy quality of the distillate compared to the sample without a catalyst. The sample without a catalyst has the lowest calorific value of 6084.80 cal/g, while at a zeolite:bentonite ratio of 1:1, the value increases to 6490.65 cal/g. The highest calorific value is obtained at a ratio of 2:1, namely 6509.46 cal/g, which indicates that the dominance of zeolite plays a major role in increasing the formation of higher energy hydrocarbon fractions. At a ratio of 1:2, the calorific value decreases slightly to 6498.19 cal/g, but remains higher than the sample without a catalyst. This increase in calorific value is in line with the XRD results, which show that zeolite is better able to maintain its crystal structure after activation, thus remaining effective in providing active sites for the cracking process. On the other hand, bentonite that undergoes structural changes due to activation contributes through increased surface area and adsorptive properties, as supported by SEM and EDX results [45].

Overall, the combination of zeolite-bentonite catalysts has been proven to improve the characteristics of the distillate from the processing of waste lubricating oil, indicated by a decrease in viscosity and density as well as an increase in calorific value. Based on these three parameters, the zeolite: bentonite ratio of 2:1 yields the best results for producing distillate with better fuel quality. This finding is also consistent with the results of XRD and SEM-EDX characterization, which show that zeolite and bentonite have complementary roles: zeolite provides a porous structure and active sites, and bentonite serves as a layered material that enhances surface area and supports adsorptive interactions during the thermal distillation process distillation, with a 1:1 ratio being the most optimal condition [47]

Thermal Distillation Process Performance

Observations on the time and temperature of the appearance of the first drop are presented in Figure 8, showing that the use of zeolite-bentonite catalysts can accelerate the start of the thermal distillation process of used oil compared to the use of ordinary catalysts. In conditions without a catalyst, the first droplet appeared at the 34th minute at a temperature of 298 °C.

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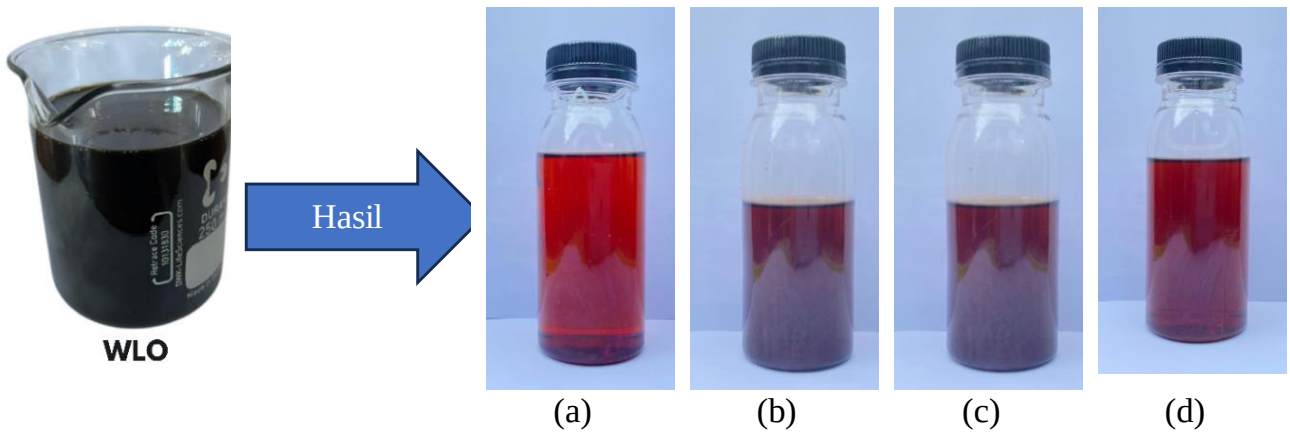


Fig. 6. WLO Distillation Fuel, (a) Without Catalyst, (b) Zeolite 1:1 Bentonite, (c) Zeolite 2:1 Bentonite, (d) Zeolite 1:2 Bentonite

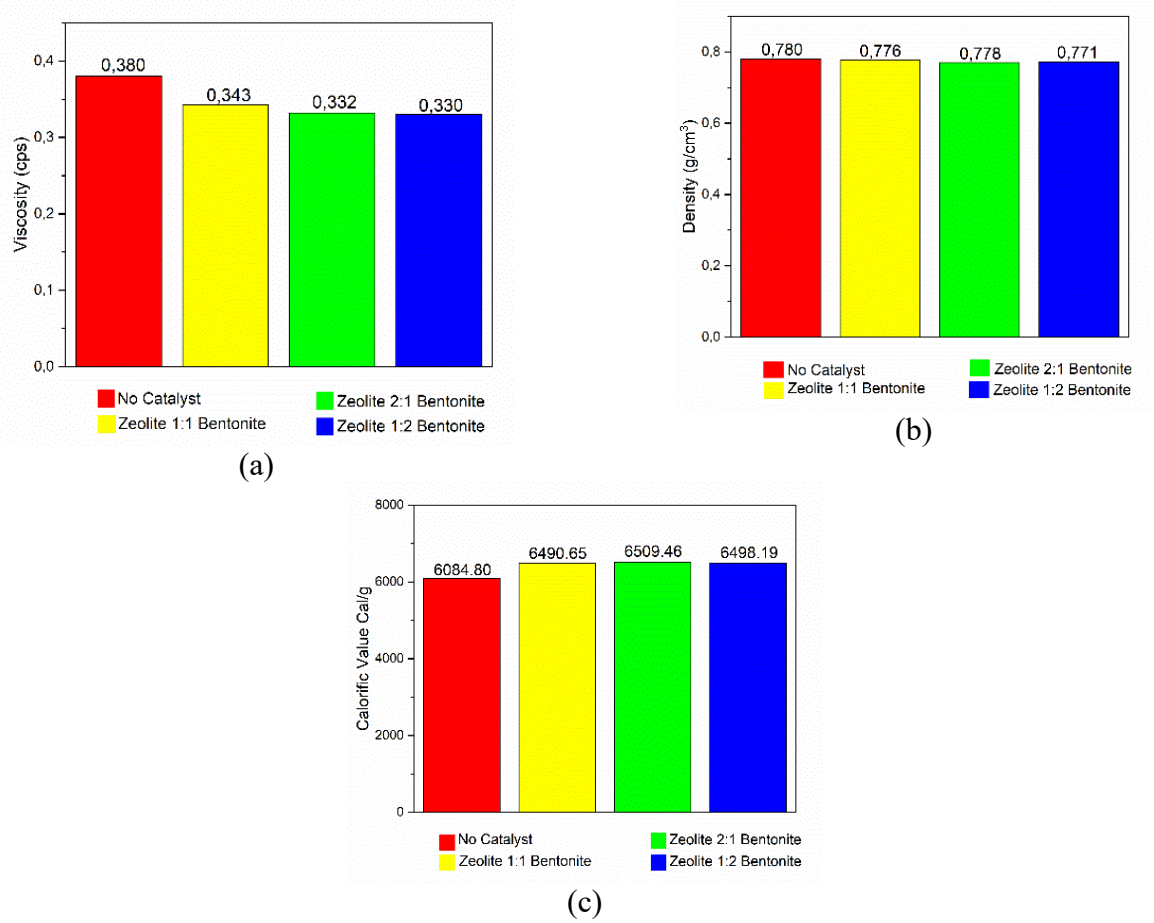


Fig. 7. Characteristics of Distilled Fuel: (a) Viscosity, (b) Density, (c) Calorific Value

In contrast, at a zeolite: bentonite ratio of 1:1, the first droplet appeared earlier, namely at the 26th minute at a temperature of 229 °C. At a ratio of 2:1, the first droplet appeared at the 27th minute at a temperature of 237 °C, while at a ratio of 1:2 it occurred at the 29th minute at a temperature of 259 °C. These results indicate that a ratio of 1:1 provides the best performance in reducing the initial distillation time and temperature [46]. These findings are consistent with the XRD and SEM characterization results, which show that zeolite maintains its crystalline structure and has a porous morphology, while bentonite has a lamellar structure that supports adsorptive interactions. Overall, the zeolite–bentonite catalyst effectively increases the efficiency of the initial stage of used oil thermal.

Liquid fuel production

The distillate output shown in Figure 9 indicates that the non-catalytic process produced the highest liquid volume (81 mL), while the addition of zeolite–bentonite catalysts reduced the output to 60 mL, 66 mL, and 72 mL for catalyst ratios of 1:1, 2:1, and 1:2, respectively. This trend suggests that the mixed catalysts did not primarily enhance total liquid yield, but rather influenced the cracking pathway and product distribution during thermal distillation. The lower liquid output under catalytic conditions may indicate that part of the feed was converted into lighter non-condensable fractions or retained as heavier residues on the catalyst surface. Nevertheless, this reduction in distillate volume was accompanied by improved fuel-related properties, as evidenced by the lower viscosity

and density and the higher calorific value of the catalytic products compared with the non-catalytic process [48]. Among the catalyst ratios, the 2:1 zeolite:bentonite mixture showed the most favorable performance, since it produced the highest calorific value while maintaining a moderate liquid output, indicating a better balance between distillate quantity and fuel quality

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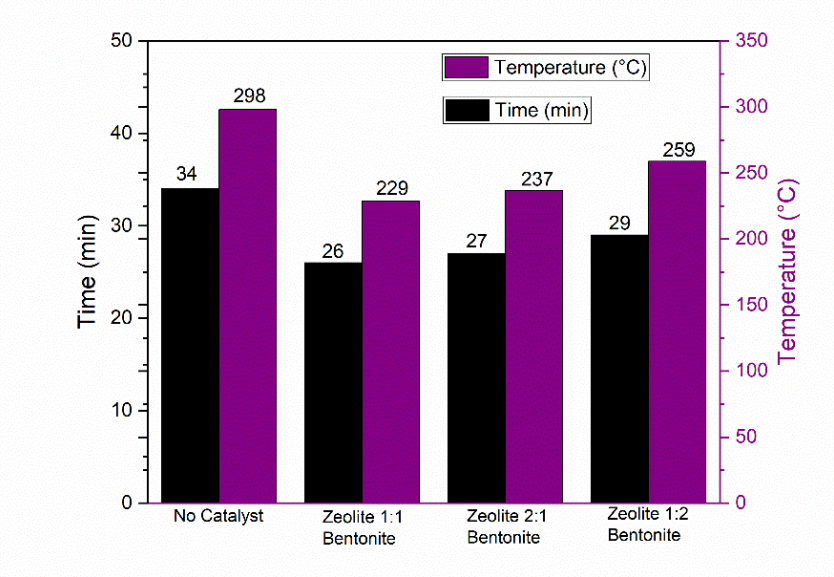


Fig. 8. Initiation Temperature and First Drop Time in the Distillation Process

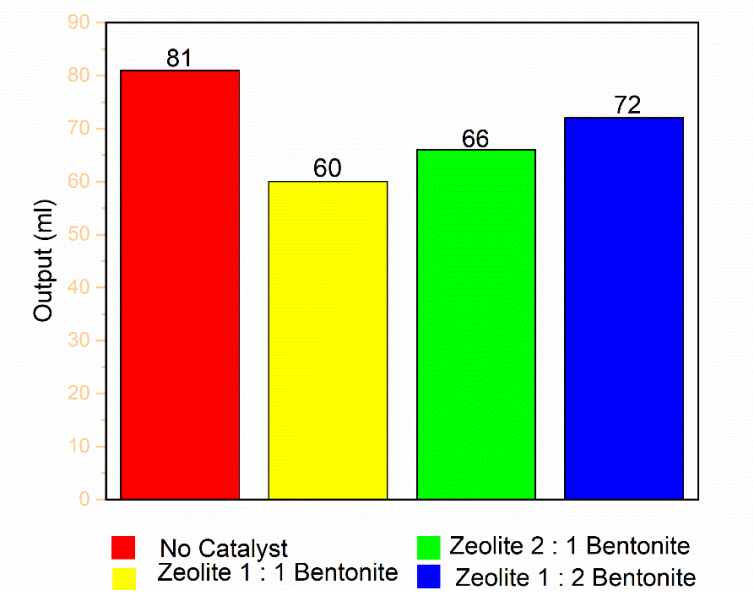


Fig. 9. Liquid fuel production

Conclusion

This study proves that zeolite–bentonite catalysts effectively improve the performance of thermal distillation of waste lubricating oil. Activation of zeolite with NH_4NO_3 and bentonite with HCl produces catalyst characteristics that support the hydrocarbon cracking process, as shown by the results of XRD and SEM-EDX characterization. The use of mixed catalysts can reduce the viscosity and density of the distillate and increase its calorific value compared with using a

single catalyst. A zeolite:bentonite ratio of 2:1 provides the highest calorific value, while a ratio of 1:1 is the most effective in reducing the temperature and initial distillation time. Thus, zeolite–bentonite catalysts have the potential to improve distillate quality and the efficiency of used-oil waste processing through thermal distillation.

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YANACAQ MAZI İSTEHSALI ÜÇÜN TULLANTI SÜRTKÜ YAĞININ TERMİK DİSTİLLƏSİYASINDA SEOLİT-BENTONİT KATALİST SİNERGİYASI

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Bu tədqiqat alternativ yanacaq istehsalı üçün istifadə olunan sürtkü yağının termal distillə edilməsində seolit-bentonit katalizatorlarının sinergiyasını araşdırır. Seolit NH_4NO_3 ilə modifikasiya edilmiş və turşuluğu artırmaq üçün 500°C-də kalsine edilmiş, bentonit isə HCl ilə aktivləşdirilmiş və səth sahəsini və termal stabilliyi yaxşılaşdırmaq üçün kalsine edilmişdir. Distillə 400°C-də 1:1, 2:1 və 1:2 seolit: bentonit nisbətlərindən istifadə etməklə aparılmış və katalizləşdirilməmiş proseslə müqayisə edilmişdir. Rentgen difraksiyası (XRD) və enerji-dispersiya rentgen analizi (SEM-EDX) ilə skanlama elektron mikroskopiyası kristal strukturunda, səth morfologiyasında və element tərkibində dəyişikliklər aşkar etmişdir ki, bu da katalitik aktivliyin artmasına səbəb olmuşdur. Qarışıq katalizator qızdırma dəyərini artırarkən özlülüyü və sıxlığı azaltmışdır. 2:1 nisbəti ən yüksək kalorili dəyəri - 6509.46 kal/q təmin etdi, 1:1 nisbəti isə reaksiya temperaturunu və başlama müddətini 298°C və 34 dəqiqədən 229°C və 26 dəqiqəyə ən təsirli şəkildə azaltdı. Ümumilikdə, bu katalizator sinerjisi tullantı yağı emalından əldə edilən maye yanacaqların distillə səmərəliliyini və keyfiyyətini artırır.

Açar sözlər: tullantı sürtkü yağı, termal distillə, seolit, bentonit, yanacaq.