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Conversion of Palm Oil (CPO) into Fuel Biogasoline through Thermal Cracking Using a Catalyst Based Na-Bentonite and Limestone of Soil Limestone NTT

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ABSTRACT

Cracking catalytic palm oil (CPO) into hydrocarbon fuel by saponification pretreatment has been carried out with bentonite and limestone-based catalysts. The catalysts used were Na-bentonite and Limestone NTT which were first analyzed using XRF, XRD, and SEM. Saponification pretreatment was carried out on CPO to facilitate the cracking process using a catalyst. The saponification product in the form of a mixture of soap and glycerol was then analyzed by DSC to determine the degradation temperature. Catalytic cracking is carried out in two stages, namely, the first stage hydrocracking at a temperature of 250-350°C using a stainless steel reactor is the source of catalyst Fe / Cr. The resulting distillate was then cracked again using a Na-bentonite catalyst and a TKNTT catalyst. The resulting fuel is a hydrocarbon fuel which is confirmed from the FT-IR results which indicate the presence of long-chain hydrocarbon compounds. This data is also supported by the results of the GC-MS analysis which shows that the fuel fraction produced is mostly biogasoline. Where cracking using a Na-bentonite catalyst produces a biogasoline fraction of 61.36% and a biodiesel fraction of 38.63%, THAT produces a biogasoline fraction of 88.88% and a biodiesel fraction of 11.11%. The characteristics of the hydrocarbon fuels that have been analyzed show that the calorific value of combustion is 6101 cal/g which is determined using a bomb calorimeter, and the cetane index is 62 which is analyzed using CCI. Both types of hydrocarbon fuels have met the physical requirements that must be possessed by biogasoline fuel based on SNI standards.

1. Introduction

Fossil fuels have been used as the main energy source for many years but their use is unsustainable and causes environmental problems associated with burning fossil fuels. Fossil fuels are natural resources that cannot be renewed so that their availability is increasingly limited, while the demand for energy needs for various industrial activities and meeting the needs of human life is increasing day by day (Radionova *et al*., 2016). In addition, the use of fossil fuels is not environmentally friendly and harmful to health because the burning of fossil fuels produces hazardous compounds such as NOx, SOx, Pb, CO, and other particulate compounds (Donatus 2015). Due to the high demand for fossil fuels, alternative fuels are needed that can replace fossil fuels. *Biofuels* have been studied to have great potential as a substitute for fossil fuels. *Biofuels* consist of *biofuels* gas and *biofuels* liquid and are usually produced from renewable natural resources. *Biofuel* Gas Consists of methane and hydrogen and *biofuel* liquid consists of *biogasoline* and *biodiesel* (Ahmad *et al*., 2016). In addition, *biofuel* is an environmentally friendly fuel because it does not contain nitrogen and sulfur compounds (Junifa, S. 2020).

Crude Palm Oil (CPO) is one of the potential alternative energy sources to replace fossil fuels, this is because palm oil has a long carbon chain similar to the hydrocarbon chains in fossils. Therefore, Crude Palm Oil can be processed to produce alternative fuels (biofuels) such as biodiesel and biogasoline which are possible to replace fossil fuels (Nurjanah et al., 2013). In 2011, Oil

World still placed Indonesia as the main producer of CPO with a production volume of 23.9 million tons of CPO/year. This shows that Indonesia has enormous potential to produce biogasoline or other fuel oils derived from palm oil (Jatmiko, Qodri., 2021).

The process of making *biofuel* from palm oil has been carried out by various methods such as esterification, transesterification, and cracking. Cracking is the process of breaking a high molecular weight hydrocarbon compound into a lower molecular weight compound by breaking the carbon chain bonds (C–C). The cracking reaction *is* divided into 2, namely: thermal cracking and catalytic cracking. Thermal cracking or pyrolysis is a reaction to break the bonds of hydrocarbon compounds due to the influence of thermal (high temperature). The mechanism of the thermal cracking reaction is through the formation of free radicals in forming the final product. The catalytic cracking reaction is the reaction of cracking*(cracking)* using a catalyst material (heterogeneous catalysts) as the material is capable of accelerating the reaction rate to achieve equilibrium and produce a final product through the reaction of the carbonium ion formation mechanism. (S, Donatus. 2015).

Catalytic cracking has advantages over the methods used to process triglycerides. Among them, the products of catalytic cracking are gas, organic liquid products, water, and soda. Organic liquid products include (Aldehydes, ketones, carboxylic acids, and hydrocarbons such as paraffin, olefins, and naphthenic) whose boiling points correspond to *gasoline*, *kerosene*, and *diesel*. Both reaction temperatures are lower than those of pyrolysis, and large molecules are broken down into simpler molecules through dehydration, dehydrogenation, deoxygenation, and decarboxylation (Jovas *et al*., 2015).

The purpose of this study was to determine the characteristics of the fuel produced using Na-bentonite and TKNTT catalysts. Over the centuries, fossil fuels have been used in many aspects of life, but these fuels are non-renewable and will eventually run out. The scarcity of fuel now makes people have to look for alternative energy sources that are easily renewable *(renewable fuels),* one of which is *biofuel*. In recent years, many developments have been carried out on raw materials for making *biofuels* from plants, especially oil palm, this is because this fuel is non-toxic and does not contain nitrogen and sulfur compounds. *Palm stearin* is a derivative product of palm oil which is solid at room temperature and can be used as a raw material for the production of biofuel(Chuckling and Ratnawali, 2014).

Alternative fuels *(biofuels)* can be produced from various varieties of renewable natural resources. Among them, triglycerides have a very important role and are compounds that are commonly found in vegetable and animal oils (Doronin *et al.,*2012). Several techniques have been studied to convert vegetable oils and animal fats into *biofuels*. One of the most promising techniques for producing alternative fuels from vegetable and animal oils is pyrolysis. Pyrolysis is also known as thermal cracking and catalytic cracking. (Xu *et al.,*2013).

2. Literature Review

Anando *et al.,* 2016) have investigated the production of *biogasoline* from palm oil through a catalytic cracking reaction with a gamma-alumina catalyst and obtained the peak results of the compounds analyzed by GC-MS similar to the peaks of commercial gasoline and obtained straight-chain hydrocarbon compounds at C_6-C_{11}. Mancio *et* al.,(2016) have done a catalytic thermal cracking of the *crude palm oil* at a pilot scale using a catalyst Na_2CO_3. This study produced a conversion *of* 60% and produced biofuel with an acid value of most rendah. Senyawa-hydrocarbons The resulting product has characteristics similar to *petroleum diesel*.

The latest research was also carried out by Friskila, S (2020) namely the use of palm oil into hydrocarbon fuels with Saponification Pretreatment through the cracking of CPO with Fe/Cr catalyst. In this study, a chromatogram with the largest area was produced for the compound 1-Dodecane ($C_{12}H_{24}$) which was equivalent to the fraction *biodiesel*.

Jonathan, H (2021) also conducted a similar study, in which *Crude Palm Oil was cracked* using Na-Bentonite and Fe_2O_3 as catalysts. From this research, the result is that there is a dominant compound which is a straight-chain hydrocarbon compound, namely 1-pentadecane ($C_{15}H_{30}$).

The effect of pore size on catalytic cracking has been studied. (Sadramelli, M, S. 2016) has investigated the effect of catalyst pore size on n-octane catalytic cracking activity using ZSM-5, HZMS-5, and Hβ catalysts with small, medium, and large pore sizes. The selectivity of olefins increases with a decrease in the pore size of the catalyst. Another study also examined the effect of aluminum (Al) in the catalyst and concluded that a lower amount of aluminum (Al) in the catalyst resulted in higher olefin production, this was due to the slightly lower amount of aluminum (Al) in the acid site in the catalyst. the catalyst which results in higher selectivity for olefins. In this study, researchers will crack CPO by comparing the use of two catalysts, namely Na-bentonite and Al_2O_3 from limestone soil of NTT. Researchers want to compare the amount of conversion of CPO into biogasoline and biodiesel fractions produced on each catalyst.

3. Research methods

Preliminary analysis was carried out on the CPO samples to determine the value of free fatty acids. Then put 100 g of CPO sample into a glass beaker and then heated at a temperature of 90°C then added 30 g of NaOH and then heated while stirring with a magnetic stirrer until the soap was formed. The soap was allowed to stand for 24 hours and then put into a stainless steel reactor and then heated on a gas stove at a temperature of 250°C-360°C for 2 hours while connected to a distillation device. The resulting distillate is accommodated. Each 100 mL of the resulting distillate was added with 5 g of Na Bentonite and 5 g of NTT lime soil. Cracked by heating on a gas stove at a temperature of 250-350°C for 2 hours while connected to a distillation apparatus. The resulting distillate is accommodated. The resulting distillate was analyzed using GC-MS, FT-IR, and *Calculated Cetane Index* (CCI).

4. Results and Discussion

Free Fatty Acid Analysis of CPO

The results of the analysis of CPO fatty acids were determined using the following calculations:

$$\text{ALB content} = \frac{V\ NaOH\ x\ N\ NaOH\ x\ 25.6}{Weight\ of\ CPO\ Samples}$$

Determination of free fatty acids of CPO samples was carried out 3 times analysis then the value of free fatty acids was determined from the average value.

Table 1. Analysis of free fatty acid (ALB) levels of CPO

Experimental	Sample Weight	Volume NaOH (mL)	Normality NaOH	ALB value
1	5,214	8.6	0.1	4.24
2	5.514	9.04	0.1	4.20
3	5,120	8, 44	0.1	4.22
Average				4.22

ALB levels in the CPO samples used in this study were 4.22%. ALB levels indicate the level of product damage due to the breakdown of triglycerides into glycerol and free fatty acids. A high acid number indicates that the free fatty acids present in vegetable oil are also high so that the quality of the oil is even lower (Winarno, 2004). According to widya (2015), There are various grades of CPO (Crude Palm Oil) that can be used as an alternative to raw materials, *biofuel* namely standard CPO (FFA < 5%), off-grade CPO (FFA 5 20%), waste CPO (FFA 20 70 Determination of free fatty acids can be carried out using the alkaline titration method (NaOH). In principle, this method analyzes free fatty acids based on the amount of NaOH used in the titration to form a pink sample color. This is in accordance with the statement of Maligan (2014) which stated that the principle of acid-base titration is the analysis of the amount of free fatty acids in a sample which is equivalent to the amount of base (NaOH) added in the titration which is marked by a change in the color of the sample to pink.

Pretreatment of CPO with Saponification

The first step of this research is to perform cracking of CPO samples with saponification pretreatment. At this stage, a distillate will be produced. According to Friskilla's research (2020), the distillate used The resulting biodiesel fraction. Furthermore, the resulting distillate will be cracked using Na-Bentonite and TKNTT catalysts. At this stage, Palm Oil / Crude Palm Oil is reacted with NaOH base to form soap (salt of fatty acid triglycerides). Palm Oil Saponification Reaction produces soap (triglyceride fatty acid salt) based on the following reaction:

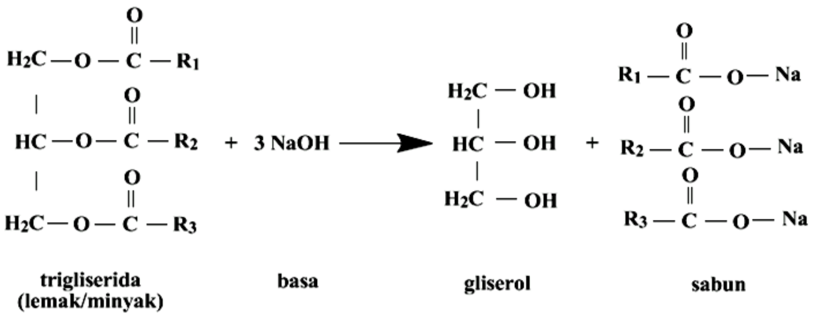

Figure 1. Reaction Saponification

The saponification reaction of CPO uses NaOH base which functions to stabilize the reactive groups found in triglycerides. Stabilization or neutralization of these reactive groups is important because it can prevent polymerization and polycondensation reactions triggered by the state of the reactive groups. The reactive groups in question are ester, hydroxyl, and unsaturated carbon bonds (double bonds).

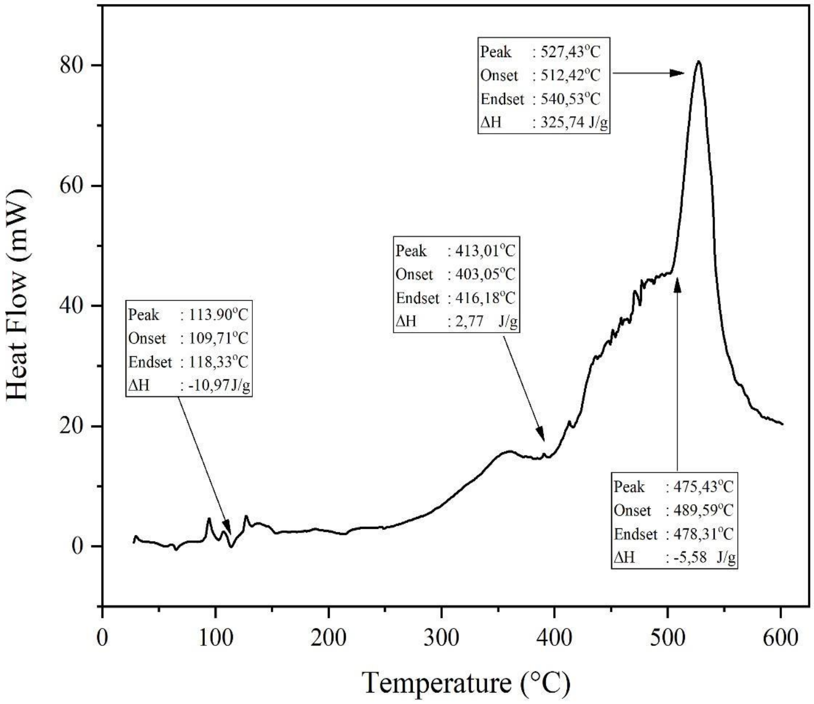

Figure 2. Thermogram of DSC from CPO saponification

Thermal analysis with DSC on the results of CPO saponification in the form of soap is shown in Figure 2. This shows that there is a peak indicating the glass transition*(T_g)*at 94.45°C, crystallization peak at 413°C, peak melting*(T_m)*at 475.43°C, and a decomposition peak at 527.43°C Based on the data obtained, it shows that the temperature required for the process of cracking soap into fuel without using a catalyst is 527.43°C. This data is in accordance with previous research (Supeno *et al.*, 2021). The addition of a catalyst in the cracking process is needed to reduce the activation energy so that the temperature required for the cracking process can be lowered. CPO catalytic cracking process of saponification pretreatment results conducted in the temperature range 250-350°C. Determination of the cracking temperature was envisaged from the boiling point of biodiesel is similar to diesel fuel in the range of 270-350°C.

Catalytic Cracking CPO saponification results

This research does catalytic cracking in stages, where the results of catalytic cracking using a Fe/Cr catalyst against the saponified CPO will be carried out again by catalytic cracking using Na-bentonite and TKNTT catalysts. During the cracking process, the CPO saponification products in the form of soap and glycerol will be converted into hydrocarbon compounds in the presence of a Fe/Cr catalyst from reactor *stainless steel*. Based on the results of research conducted by Supeno *et al.,* (2021), catalytic cracking at this stage produces a biodiesel fuel fraction. In this study, the cracking process was carried out again using Na-bentonite and TKNTT catalysts, where biodiesel fuel would be converted into biogasoline fuel which was analyzed using GC-MS.

The catalytic cracking process occurs at a temperature of 250-350°C and is able to produce energy that causes excitation of electrons from the catalyst (Fe / Cr, Na-bentonite, TKNTT). These electrons will fill the empty orbitals of the carbon atoms that make up the long hydrocarbon chain until the orbitals are full and become saturated. At this time there will be a cracking process. Pretreatment distillate catalytic cracking process CPO produce a yield of 77% calculated as follows:

Yield = $\frac{VolumeCPO\ before\ cracking}{Volume\ CPOafter\ cracking}$ x 100%
mass CPOsample = 100 g
density of oil = 0.9 g / mL

▪ = $\frac{mass\ (g\ )}{Volume\ (ml)}$
V_{CPO} = 0.9 x 100 = 90 mL
Yield = $\frac{70\ ml}{90\ ml}$ x 100%
Yield = 0.77 x 100% = 77.77%

Distillate obtained is then cracked back on heating 180-240°C using different catalysts namely Na-Bentonite and TKNTT so that the distillate is obtained as follows:

Table 2. Fuel from the catalytic cracking of CPO

Cracking catalyst	The volume before cracking (mL)	Volume after cracking (mL)	Yield (%)
Na bentonite	70	65	72.2%
TKNTT	70	67	72.2%

Yield Na-bentonite = $\frac{65}{90} x\ 100\%$
Yield Na-bentonite = 72.2%
Yield TKNTT = $\frac{67}{90}\ x\ 100\%$
Yield TKNTT = 74.4%

Analysis *X-Ray Fluorescence* (XRF)

The chemical elements in bentonite and limestone soils of NTT analyzed using XRF are shown in Table 4.2. The results of X-ray diffraction using *X-Ray Fluorescence* (*Panalytical minipal IV*) *base metal* in Appendix 1 show that bentonite was identified as dominant elements in the form of Si, Al, Fe, P, Ca, and Ti, while the TKNTT samples identified elements as Ca and Si only. . It can be seen that bentonite for Si elements has an intensity of 7.529 cps/mA while other elements have an intensity of fewer than 7.529 cps/▪A, so it can be assumed that the largest constituent of bentonite is Si. This is in accordance with the results of previous studies (Abukhadra et al., 2019). The element Ca is the largest constituent of TKNTT with an intensity of 37.359 cps/▪A.

Table 3. XRF test results for chemical elements in bentonite and KTNTT

Bentonite	Mass%	TKNTT	Mass%
Si	12.5	Ca	5.87
Al	4.3	Si	0.835
Fe	4.07	Te	0.83
P	1.27	P	0.227
Ca	1.14	S	0.212
Ti	0.465	Sb	0.184
K	0.453	K	0.084
Te	0.273	Sr	0.0705
S	0.214	Fe	0.044
In	0.139	Cl	0.0146
Sb	0.0991	Mn	0.0036
Cl	0.096	Zr	0.003
Mn	0.0959	Ba	0.0017
V	0.0332	Co	0.0013
Co	0.0249	Ni	0.0011
Cr	0.0139	Cu	0.001
Zr	0.012	Ta	0.0008
Zn	0.0089	Y	0.0006
Cu	0.0073	Zn	0.0005
Ni	0.0067	Ga	0.0004
Sr	0.0058	Pb	0.0004

Ba	0.0045	As	0,0001
Hf	0,0036	Ag	0,0001

Based on XRF test results, it can be concluded that bentonite is assumed to have dominant compounds in the form of SiO_2 (*Quartz*), CaO (*Lime*), Fe_2O_3 (*Hematite*), $FeTiO_3$ (*Ilmenite*), and Al_2O_3 *(Corundum)*. While TKNTT has dominant compounds in the form of CaO, $CaCO_3$ (*Calcite*), and $Ca(OH)_2$ (*Portlandite*). Where the presence of these compounds is discussed further in XRD analysis.

Analysis *of X-Ray Diffraction* (XRD)

Na-Bentonite and TKNTT XRD diffractograms are shown in Figure 3.

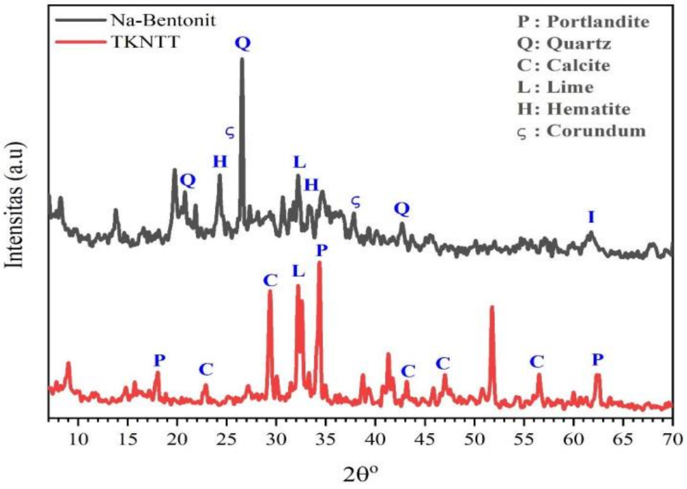

Figure 3. XRD Diffractogram of Na-Bentonite Catalyst and TKNTT

From the XRD analysis, there is a diffraction peak at 2▪ = 8.1°; 19.7°; and 34.6° with diffraction planes (001), (110), and (110) respectively being the diffraction pattern of Na-bentonite with a hexagonal structure (JCPDS No. 79-1910) (Guo et al., 2019). This shows that the pillarization of bentonite with Na metal has been successfully carried out. However, there is a diffraction peak at 2▪ = 20.7°; 26.5°; and 28.2° which is the diffraction peak of bentonite material (JCPDS No. 29-1499). This shows that there is still bentonite that does not react to form Na-bentonite (Naik & Meivelu, 2020).

Based on the results of XRF and XRD analysis, Na-bentonite indicates the presence of *Quartz* as the most dominant compound. Other crystalline phases such as *Lime*, *Corundum*, *Hematite*, and *Ilmenite were* identified as impurities. diffraction peaks *Quartz* with a hexagonal structure are at 2▪ = 20.7°; 26.5°; and 42.7° with the respective lattice planes (100), (011), and (200) according to JCPDS data No. 46-1045 (Wijaya et al., 2021). mineral compounds *Corundum* with the rhombohedral structure are indicated by the presence of 2▪ diffraction peaks at angles of 26° (012) and 37.8° (110) (JCPDS No. 10-0173). minerals *Hematite* and *Ilmenite* with a hexagonal structure were also found, each with a characteristic 2▪ diffraction peak at an angle of 24.2° (10-2); 33.2° (104), and 61.7° (12-4) according to JCPDS data No. 96-101-1241 for *Hematite* and JCPDS No. 96-101-1034 for *Ilmenite*.

The TKNTT diffractogram shows that $CaCO_3$ (*Calcite*) is the most dominant mineral compared to other minerals such as *Portlandite* and *Lime*. 2▪ diffraction peak which is owned by the form of the mineralTKNTT *calcite* with rhombohedral crystal system is shown at an angle of 22.8°;29.3°; 43.1°; 46.9°; and 56.5° have lattices with planes (012), (104), (202), (024), and (211) (JCPDS No. 47-1743). While the 2▪ diffraction peak which indicates the mineral $Ca(OH)_2$ is 18°; 34.3°; and 62.6° with (001), (101), and (201) respectively are diffraction patterns *Portlandite* with a hexagonal crystal system according to JCPDS data No. 44-1481 (Li et al., 2015). The 2▪ diffraction peak at an angle of 32.1° with the lattice plane (111) on both catalysts indicated the presence of CaO (minerals*Lime*)(JCPDS No. 96-100-0045). The presence of these compounds is in accordance with the results of testing using XRF.

Analysis *Scanning Electron Microscope* (SEM)

Analysis of Na-bentonite catalyst morphology and TKNTT using SEM with a magnification of 500 and 2000 x shown in Figure 4.

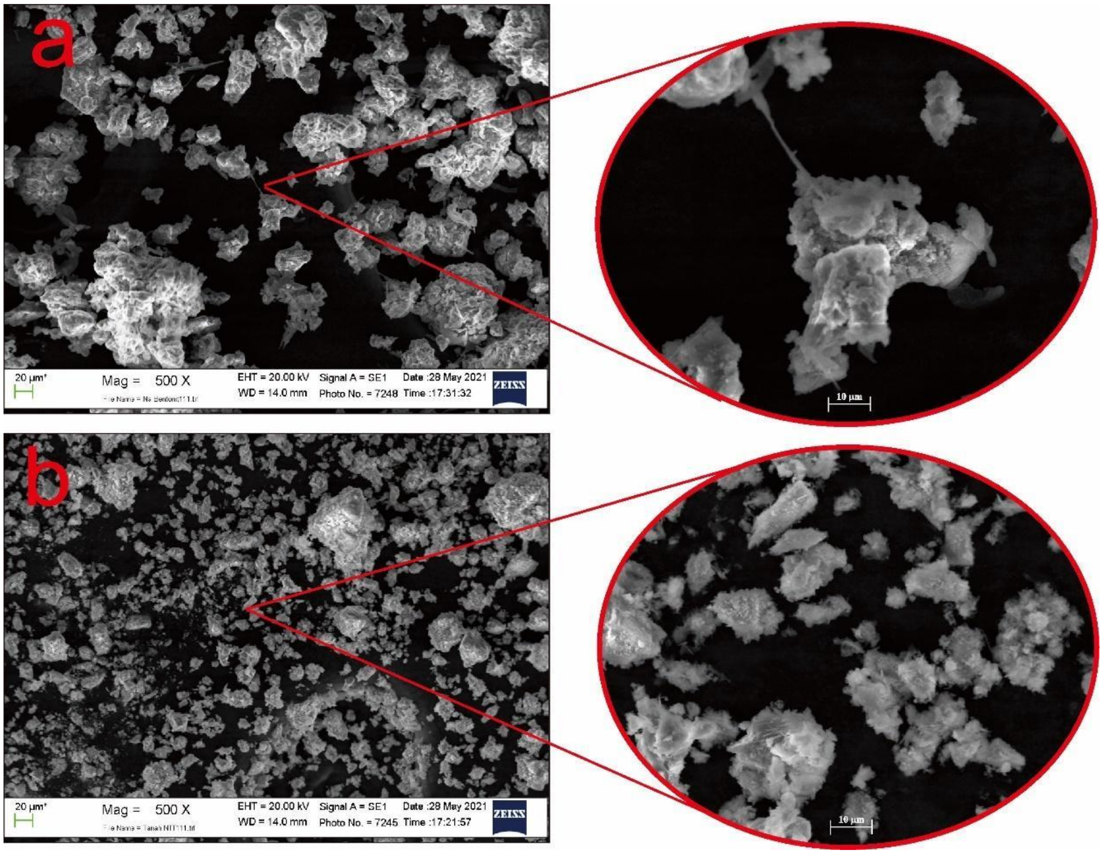

Figure 4. Microstructure of SEM catalyst a). Na-Bentonite and b). Summit at 500 and 2000 x magnification

Na-bentonite micrographs have surface characteristics that appear as groups of agglomerated particles consisting of layers with smooth surfaces that are stacked on top of each other. From Figure 4 a, it can be seen that there is a porous character and the catalyst crystals are sphere-like *crystals*. Compared to Figure 4 b, the TKNTT catalyst has a rougher surface. This is assumed to come from the combination of $CaCO_3$, CaO, and $Ca(OH)_2$ which has a surface structure like a cube (*cubic*).

Catheterization of Alternative Fuels

Analysis *Fourier Transform Infrared Spectroscopy* (FTIR)

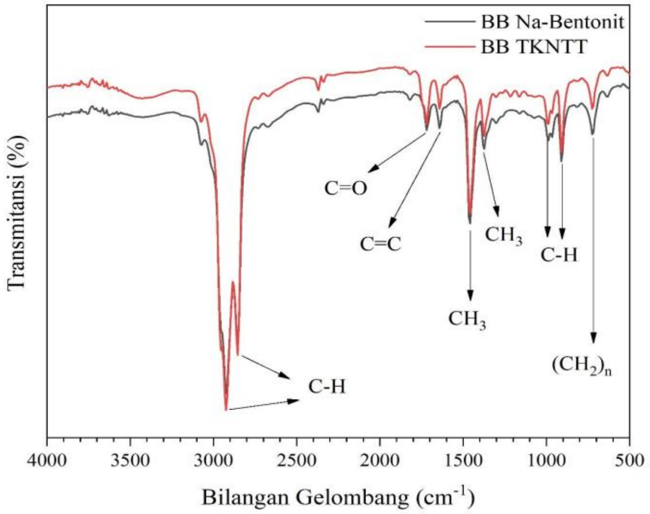

Figure 5. FTIR Spectra of Fuel from catalytic cracking using Na-Bentonite and TKNTT

The FT-IR spectra of the fuel (BB) resulting from the catalytic cracking of the CPO pretreatment distillate are shown in Figure 5. The FT-IR spectra of the two fuels resulting from catalytic cracking have identical characteristics in terms of the presence of functional groups present in the fuel. The summary of FT-IR spectra shown in Table 4. explains that there are absorption peaks at wave numbers 2924.09 and 2854.65 cm^{-1} which are identified as vibrations *stretching* CH asymmetric of the methylene group and vibrations *stretching* CH symmetry of the methyl group in the compound. alkane. This data is reinforced by the vibrations *bending* asymmetric and CH symmetry of the methyl group at wavenumbers 1458.18 and 1373.32 cm^{-1} (Stuart, 2005; Withrow, 2016). The weak absorption peak in the wavenumber region of 1720.50 cm^{-1} indicates that the fuel produced has a C=O group. The presence of the C=C group shown at wave number 1643.35 cm^{-1} indicates that there are olefin hydrocarbon compounds. The absorption peaks at wave numbers 964.41 and 910.40 cm^{-1} indicate the presence of a CH group. The presence of an absorption peak at a wavenumber of 725.23 cm^{-1} indicates that the fuel resulting from catalytic cracking is a long chain hydrocarbon compound, $(CH_2)n$. Each absorption peak contained in the fuel is a characteristic possessed by hydrocarbon compounds (Supeno et al., 2021).

Table 4. Summary of FT-IR spectra of fuel catalytic cracking

Wave Number (cm^{-1})		Type of Group	Vibration Type
BB Na-bentonite	BB TKNTT		
2924.09	2924.09	CH *asym*	Stretching
2854.65	2854.65	CH *sym*	Stretching
1720.50	1720,50	C=O	Stretching
1643,35	1643,35	C=C	Stretching
1458,18	1458,18	CH (CH_3) *asym*	Bending
1373,32	1373,32	CH (CH_3) *sym*	Bending
964,41	964,41	CH	Stretching
910,40	910,40	CH	Stretching
725,23	725,23	$(CH_2)n$	Stretching

Analysis of *Gas Chromatography-Mass Spectrometry* (GC-MS)

Alternative fuel *(biofuel)* produced from the cracking process using Na-bentonite and TKNTT catalysts then analyzed using the GC-MS instrument to analyze the fuel fraction contained in the sample and its constituent compounds. The chromatogram of the fuel produced from the catalytic cracking of the CPO distillate is shown in the figure below.

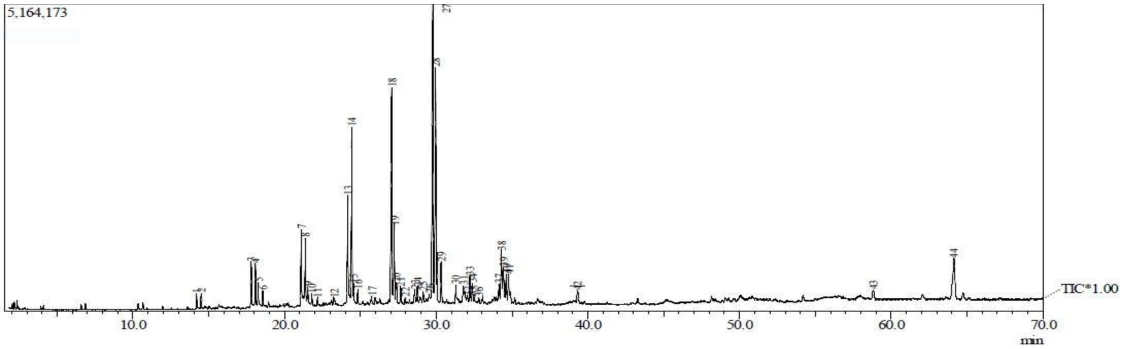

Figure 6. Chromatogram of GC-MS fuel resulting from catalytic cracking using Na-bentonite as a catalyst

The chromatogram in Figure 6 shows that there are 44 compound fractions identified in the fuel resulting from catalytic cracking using a Na-bentonite catalyst. The results of the GC-MS analysis showed that there were 5 constituent compounds with the highest peaks, which are summarized in Table 5.

Table 5. Chromatogram of compounds with the highest peaks from BB Na-bentonite

Peak	No. The highlight of	the compound name	Molecular formula	Retention Time (Minutes)	Area (%)
1	27	1-Undekena	$C_{11}H_{22}$	29.759	15.48
2	28	n-decane	$C_{10}H_{29.957}$	22	13.17
3	18	1-Dodecene	$C_{12}H_{24}$	27.052	10.29
4	14	n-Nonana	C_9H_{20}	24,423	7.71
5	13	3-Undecane	$C_{11}H_{22}$	24,170	5.35

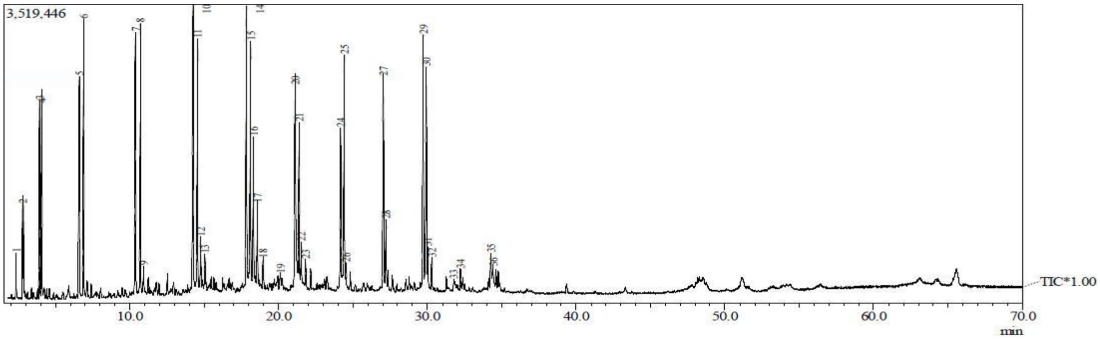

Figure 7. Chromatogram of GC-MS fuel resulting from catalytic cracking using TKNTT catalyst.

The chromatogram in Figure 7 shows that there are 36 fractions of compounds identified in the fuel resulting from catalytic cracking using TKNTT catalyst. The results of the GC-MS analysis show that there are 5 constituent compounds with the highest peaks which are summarized in Table 6.

Table 6. Chromatogram of compounds with the highest peaks from BB TKNTT

Peak	No. Peak	Name of compound	Molecular formula	Retention time (minutes)	Area (%)
1	14	1-Nonene	C_9H_{18}	17,836	6,49
2	10	Undecene	$C_{11}H_{22}$	14,241	6,02
3	29	1-Dodecene	$C_{12}H_{24}$	29,725	5, 86
4	20	3-Undekena	$C_{11}H_{22}$	21,121	5,33
5	7	1-Oktena	C_8H_{16}	10,373	5,28

The results of the analysis of the fuel from the catalytic cracking of the CPO pretreatment distillate using the Na-bentonite catalyst showed that the biogasoline and biodiesel fractions were 61.36% and 38.63%, respectively. Meanwhile, using the TKNTT catalyst produced biogasoline and biodiesel fractions of 88.88% and 11.11%, respectively. Thus, in this study, the catalytic cracking of the CPO pretreatment distillate has the potential to produce more gasoline fractions than biodiesel fractions. The study of Supeno et al., (2021) produced fuel with a major fraction in the form of biodiesel from CPO using a Fe/Cr catalyst. Likewise, research conducted by Hutabarat (2021) conducted catalytic cracking using Na-Bentonite on saponified CPO to produce biodiesel fuel fraction. In this study, catalytic cracking was carried out in stages, where the results of the catalytic cracking using a Fe/Cr catalyst against the saponified CPO will be carried out again by catalytic cracking using Na-bentonite and TKNTT catalysts. From these data, it can be concluded that the catalytic cracking of saponified CPO produces a biodiesel fuel fraction, while the second catalytic cracking stage using Na-bentonite and TKNTT catalysts produces a major fraction of fuel in the form of gasoline.

Analysis of Bomb Calorimeter and CCI

Bomb calorimeter analysis was carried out to test the calorific value with the aim of knowing the number that states the amount of heat generated from the combustion process of a certain amount of fuel with oxygen. The standard calorific value of fuel based on the SNI-04-7182-2006 standard is 10,498 BTU/lb or about 5,832 cal/g. In this study, the calorific value of biodiesel combustion was 6101 cal/g using a Na-bentonite catalyst. Thus the fuel produced meets the Net Calorific Value according to the standard.

The cetane number (CN) is used to describe the ignition quality of diesel fuel. The ignition quality of diesel fuel can also be calculated using the Cetane Index (CI) method (EN ISO 4264, ASTM D 4737). The cetane number of a fuel is influenced by the elements contained in the fuel, such as the element carbon which is a source of combustion energy (Supeno et al., 2021). The standard cetane index that biodiesel must have is >45. Based on the CCI test results, the cetane index value was 62 using Na-bentonite catalyst. Based on the data obtained and summarized in Table 5, it can be concluded that the fuel obtained in this study can be used as an alternative fuel candidate in the form of biogasoline that has met the specified standards.

5. Conclusion

1. The results of XRD and XRF analysis show that Na-bentonite is mostly composed of Quartz (SiO2) minerals, while TKNTT is mostly composed of CaCO3 minerals. The morphology of the catalyst analyzed using SEM showed that both catalysts had a large and porous surface. Where the Na-bentonite catalyst appears as crystals that are shaped like spheres (sphere-like crystals) while the TKNTT catalyst is in the form of a cube (cubic).
2. In accordance with the results of the FT-IR and GC-MS analysis, it can be concluded that the fuel fractions produced are biogasoline and biodiesel fractions. The biogasoline fraction is 88.88% (TKNTT) 61.36% (Na-Bentonite) and the biodiesel fraction is 11.11% (TKNTT) and 38.63% (Na-Bentonite). combustion was 6101 cal/g determined using a bomb calorimeter, and a cetane index of 62 which was analyzed using CCI. Both types of hydrocarbon fuels have met the physical requirements that must be possessed by biogasoline fuel based on SNI standards.

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