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Making Biodiesel from Bulk Cooking Oil using an Alkaline Catalyst from Dolomite $\text{CaMg}(\text{CO}_3)_2$ ash

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ABSTRACT: The manufacture of Biodiesel from Bulk Cooking Oil using Dolomite as a catalyst is a potential alternative to produce environmentally friendly fuels. This study aims to optimize the process of transesterification of bulk oil with ethanol using calcined dolomite catalysts. The parameters studied included the comparison of ethanol molar to oil, reaction temperature, reaction time and catalyst concentration. The results show that the use of dolomite as a heterogeneous catalyst can improve the efficiency of converting bulk oil into biodiesel. The characteristics of biodiesel products are carried out by GC-MS analysis, to ensure that the quality is in accordance with biodiesel standards. Thus, the use of dolomite as a catalyst in the production of biodiesel from bulk oil offers an economical and sustainable solution in reducing dependence on fossil fuels.

KEYWORDS: Biodiesel, bulk oil, dolomite, heterogeneous catalysts, transesterification

I. INTRODUCTION

The global dependence on fossil fuels triggers the urgency to develop renewable and sustainable energy sources. Biodiesel, as an alternative to plant-based diesel fuel, promises to reduce greenhouse gas emissions and improve energy security. Bulk cooking oil, an abundant by-product that often causes environmental problems, has great potential as a raw material for biodiesel. The process of transesterification, which converts the triglycerides in cooking oil into fat esters (biodiesel) and glycerol, is the main method in biodiesel production.

Catalysts play a crucial role in accelerating the rate of transesterification reactions. Alkaline catalysts, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), are often used in industry. However, these homogeneous alkaline catalysts are susceptible to saponification and are difficult to separate from the product. Therefore, research on sustainable and economical heterogeneous alkaline catalysts is becoming increasingly important.

Dolomite, a carbonate mineral containing calcium and magnesium $[\text{CaMg}(\text{CO}_3)_2]$, has the potential to be an effective precursor to heterogeneous alkaline catalysts after calcination into dolomite ash. (Suprpto, 2006)

Dolomite ash offers advantages such as abundant availability, low cost, and moderate alkaline properties. This study aims to explore the potential of dolomite ash as a heterogeneous alkaline catalyst in the process of transesterification of bulk cooking oil, as well as optimize the reaction parameters to produce high-quality biodiesel. This research is expected to contribute to the development of biodiesel production technology that is more sustainable and economical. (Herlambang, 2008)

II. RESEARCH METHODS

2.1.1 Materials and Tools

- **Ingredients:**
 - Bulk oil (used cooking oil or non-refined palm oil)
 - KOH (Potassium hydroxide) as a homogeneous catalyst
 - Dolomite ($\text{CaMg}(\text{CO}_3)_2$) as a heterogeneous catalyst
 - Methanol (CH_3OH) as a reagent alcohol
- **Tools:**
 - Glass reactor (three-neck flask)
 - Hot plate with magnetic stirrer
 - Reflux condenser
 - Thermometer
 - Split funnel
 - Drying oven
 - Analytical scales
 - pH meter
 - GC-MS or FTIR (optional, for product analysis)

2.2 Research Procedure

2.2.1 Dolomite Catalyst Preparations

1. Dolomite is washed with distilled water to remove impurities.
2. Dolomite is dried in the oven at 110°C for 3 hours.
3. Dolomite is calcined at 800°C for 4 hours to convert it into an active form (calcium and magnesium oxide).

2.2.2 Transesterification Process

1. Bulk oil is filtered to separate solid impurities.
2. The oil is heated to 60°C to reduce moisture content (degumming).
3. **Methanol molar ratio: oil** is determined, generally 6:1 to 12:1.
4. The catalyst (KOH and/or dolomite) is added to the methanol and stirred until it dissolves.
 - If using **a combination of catalysts**, for example 1% by weight of KOH and 1% by weight of dolomite against oil.
5. The methanol-catalyst mixture is added to the oil and reacted in a reactor at $60\text{--}65^\circ\text{C}$ for 1–2 hours while stirring.

2.2.3 Separation and Purification

1. Once the reaction is complete, the mixture is left in a separation funnel for ± 12 hours to separate **the biodiesel** (upper phase) and **glycerol** (lower phase).
2. Biodiesel is washed with warm water to remove residual catalysts and methanol.
3. Biodiesel is dried by oven at 105°C or using a desiccant.

2.3 Product Analysis

- Biodiesel **yield measurement (% yield)**
- Methyl ester content **testing** using FTIR or GC-MS (if available)
- Physical properties test of biodiesel: viscosity, density, acid number, etc. (optional)

III. RESULTS AND DISCUSSION

Gas Chromatography–Mass Spectrometry (GC-MS) analysis of the process of transesterification of bulk oil into biodiesel using dolomite as a catalyst.

Gas Chromatography–Mass Spectrometry (GC-MS) is used to identify chemical compounds resulting from the process of transesterification of bulk oil into biodiesel using **dolomite as a catalyst**. This analysis provides information about the **methyl ester components (FAME)** and other compounds that are formed during the process.

Main Compounds of Transesterification

Some of the main compounds from the GC-MS analysis that indicate the success of the biodiesel manufacturing process include:

Yes	Compound Name	Retention (minutes)	Area (%)	Description
1	Hexadecanoic acid, methyl ester (Methyl palmitate)	9.606	25.76%	The main component of FAME is palmitic acid.
2	9-Octadecenoic acid, methyl ester (E) (Methyl oleate)	10.468	26.48%	FAME of oleic acid.
3	Methyl stearate	10.576	2.09%	FAME of stearic acid.

Table 1. Key Compounds The results of GC-MS analysts who identified the Biodiesel Manufacturing Process.

These three compounds are the **main markers of biodiesel**, indicating that the transesterification reaction was successfully performed.

Dolomite's role as a catalyst

Dolomite ($\text{CaMg}(\text{CO}_3)_2$), once calcined, produces a **solid alkaline catalyst (CaO and MgO)** that is effective for transesterification. Dolomite supports the reaction between triglycerides (from bulk oil) and methanol, producing methyl esters and glycerol.

Additional Compounds Detected

In addition to FAME, there are several other compounds:

- **Triphenylphosphine oxide** (12,448 minutes, 37.59%) – likely a contaminant or byproduct of the chemical used in the preparation.
- **Seychellene, Diethyl phthalate** – minor, can come from contamination or solvent/sample compounds.

Some long hydrocarbons such as eicosane, triacontane, tetrapentacontane were also detected, likely from oil residues that did not fully react.

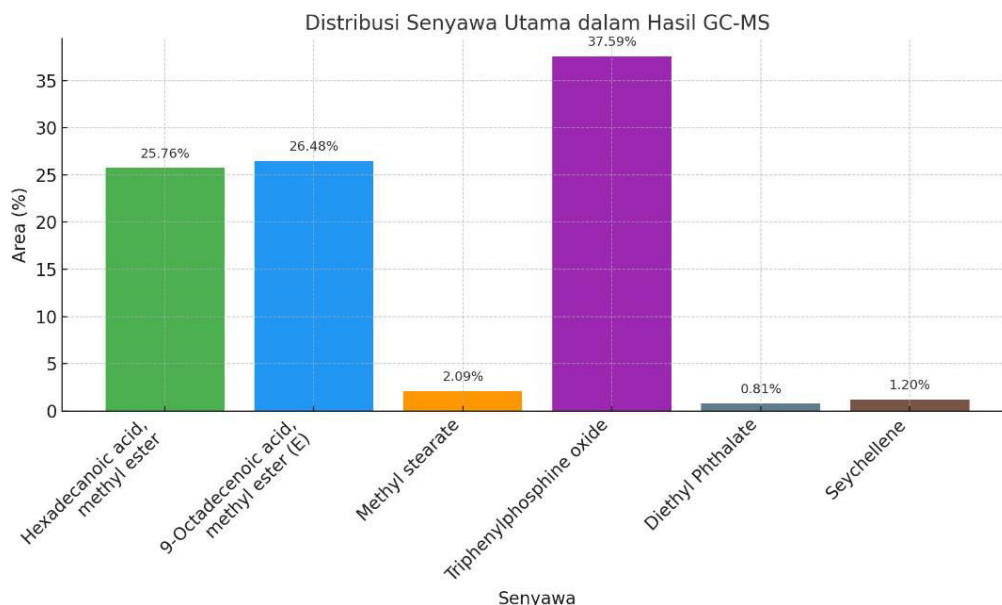


Figure 1. Indicate the distribution of the main compounds detected in the GC-MS test results of Biodiesel.

The graph above shows the distribution of the main compounds detected in the GC-MS test results of bulk oil- based biodiesel using dolomite as a catalyst. The explanation is as follows:

- **Triphenylphosphine oxide (37.59%)** is the dominant compound, likely derived from contaminants or side reagents.
- **Hexadecanoic acid, methyl ester (25.76%)** and **9-Octadecenoic acid, methyl ester (E) (26.48%)** are the two main FAMES, markers of transesterification success.
- **Methyl stearate (2.09%)** is also included in FAME but in smaller amounts.
- **Diethyl Phthalate (0.81%)** and **Seychellene (1.20%)** are minor compounds that may be derived from solvents or contamination.

The main focus is that about **54% of the area is derived from FAME compounds**, which indicates that biodiesel has been successfully formed in significant amounts.

GC-MS analysis was conducted to evaluate the success of bulk oil conversion to biodiesel through the process of transesterification with KOH (Potassium hydroxide) as a homogeneous catalyst.

GC-MS analysis was conducted to evaluate the success of converting bulk oil to biodiesel through the process of transesterification with **KOH (Potassium hydroxide)** as a homogeneous catalyst. The main focus is to detect the presence of **Fatty Acid Methyl Esters (FAME)** which signals the formation of biodiesel.

Key Components Detected

Based on GC-MS data from the KOH sample, the following compounds were identified with the largest area presentation:

Yes	Compound	Retention (minutes)	Area (%)	Description
1	Hexadecanoic acid, methyl ester (Methyl palmitate)	9.620	32.24%	FAME of palmitic acid
2	9-Octadecenoic acid, methyl ester (E) (Methyl oleate)	10.474	27.75%	FAME of oleic acid
3	Methyl stearate	10.581	2.46%	FAME of stearate acid

Table 2. GC-MS data from KOH samples

Total FAME = **62.45%** of the total area, indicating that transesterification is running efficiently.

1.1.2 Other Compounds Found

- **Triphenylphosphine oxide (15.92%)** – likely derived from reagents, not biodiesel products.
- **Diethyl Phthalate (8.54%)** – often appearing as a contaminant from solvents or plastic tools.
- **(Z)-3-Phenylacrylaldehyde (3.82%)** – a minor aromatic compound.
- **Silicon and benzothiazole derivatives** – derived from system contaminants or derivatives of compounds.

1.1.3 The Role of KOH in Transesterification

KOH is a **strong base-based homogeneous catalyst** that accelerates the reaction between triglycerides and methanol. This reaction produces methyl esters (biodiesel) and glycerol. The advantages of KOH include:

- Reactive and effective in low temperatures (around 60°C)
- Soluble in methanol

However, KOH also produces soap if the reaction occurs with water or high free fatty acids, which can lower the efficiency of biodiesel.

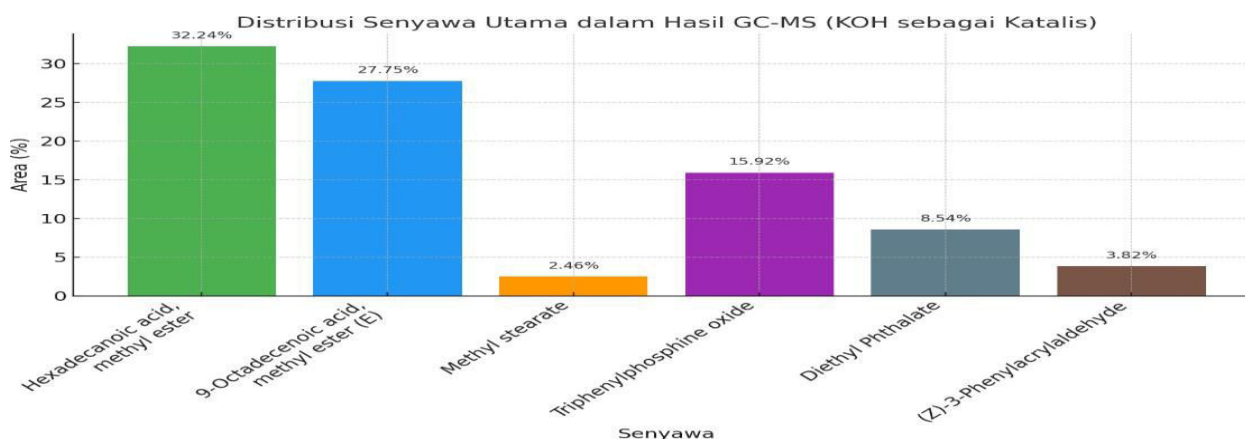


Figure 2. Distribution of the main compounds detected in the results of the GC-MS Biodiesel test with the KOH catalyst.

The graph above shows the distribution of the main compounds detected in the results of the GC-MS biodiesel test with the KOH catalyst. Explanation:

- **Hexadecanoic acid, methyl ester (32.24%)** and **9-Octadecenoic acid, methyl ester (27.75%)** are the two main FAME compounds—strong markers of the success of the biodiesel process.
- **Methyl stearate (2.46%)** is also included in FAME, although it is smaller.
- **Triphenylphosphine oxide (15.92%)** and **Diethyl Phthalate (8.54%)** are non-biodiesel compounds, likely derived from contamination.
- **(Z)-3-Phenylacrylaldehyde (3.82%)** is a minor aromatic compound.

The whole FAME reaches **62.45%**, showing high reaction efficiency.

The following is a comparison of the GC-MS test results between the two catalysts used in the production of biodiesel from bulk oil: Dolomite (heterogeneous) and KOH (homogeneous).

Comparison of FAME Compound Content

Main FAME Compounds	Dolomite (% area)	KOH (% area)
Methyl Palmitate (C16:0)	25.76%	32.24%
Methyl Oleate (C18:1)	26.48%	27.75%
Methyl Stearate (C18:0)	2.09%	2.46%
Total FAME	54.33%	62.45%

Table 3. Comparison of FAME Compound Content

- KOH produces a higher total FAME than dolomite.
- KOH is more efficient in converting triglycerides into biodiesel.

Presence of Non-FAME Compounds / Contaminants

Compound Contaminants	Dolomite (% area)	KOH (% area)
Triphenylphosphine oxide	37.59%	15.92%
Diethyl Phthalate	0.81%	8.54%
Others (siloxane, aromatic)	Minor	Minor

Table 4. Presence of Non-FAME compounds

- Dolomite exhibits more phosphorus contaminants (Triphenylphosphine oxide), which has the potential to degrade the quality of biodiesel.
- KOH produces less Triphenylphosphine oxide, but higher in Diethyl Phthalate, possibly from equipment or solvents.

Operational Aspects of Catalysts

Aspects	Dolomite	KOH
Kind	Heterogeneous (solid)	Homogeneous (soluble in methanol)
Reusability	Reusable	Disposable
Purification	Easy to separate from the product	Intensive washing is required
Cost	Cheaper, natural	More expensive, pure chemistry
FAME Efficiency	54.33%	62.45%

Table 5. Operational Aspects of Catalysts

- Dolomite is more environmentally friendly and cheaper, but it produces biodiesel with slightly lower efficiency and higher contaminants.
- The choice of catalyst depends on the scale of production and the need for sustainability:
 - Large laboratories and industries may prefer KOH for efficiency.
 - Small-scale or communities can use dolomite as an economical alternative.

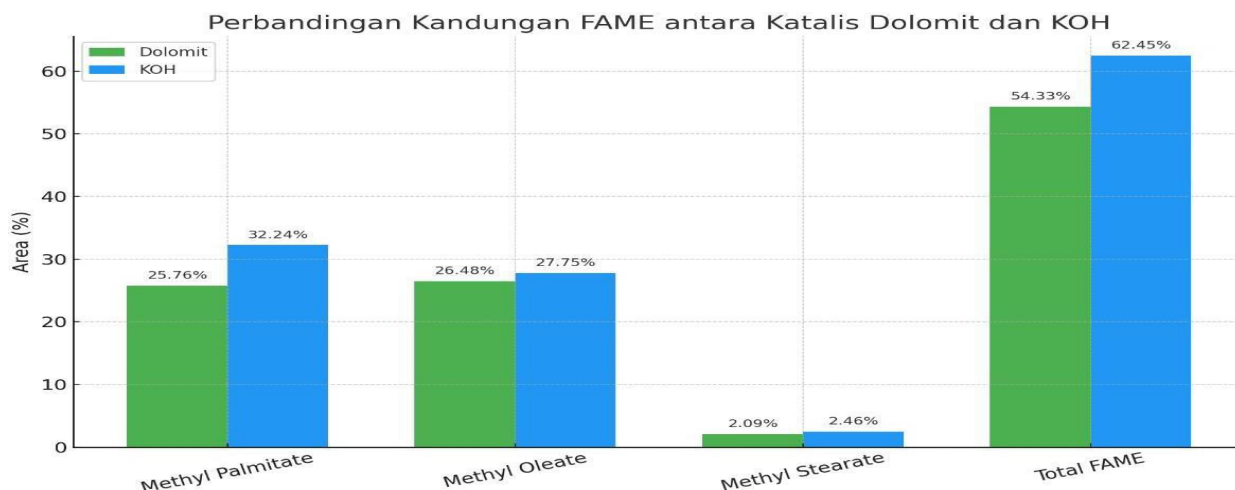


Figure 3. shows the comparison of the main FAME content between **the dolomite** catalyst and **KOH**

The graph above shows a comparison of the main FAME content between **the dolomite** catalyst and **KOH**. KOH results in higher concentrations of methyl esters for all major components, specifically **Methyl Palmitate** and **Total FAME**, which exhibit better transesterification efficiency.

Discussion and interpretation of the results of biodiesel quality tests from bulk oil processed using dolomite as a catalyst,

Analytical and Testing Laboratories
(PSM/CS/01-1)

WORKSHEET

Lab. No :
Section :
Sample : Biosolar / B-35 CN48
Analysis : Alcbram Javan'S Fonataba


Date Receiving :
Marking :

RESULT / DRAFT REPORT


PARAMETER	UNIT	RESULT			METHOD
			MIN	MAX	
Calculated Cetane Index	-	45.8	45	-	ASTM D4737-21
Density at 15 °C	Kg/m³	876.5	815	880	ASTM D4052-22
Kinematic Viscosity at 40 °C	mm²/s	4.326	2	5	ASTM D445-21e1
Flash Point PMcc	°C	52	52	-	ASTM D93-20
Water Content	Mg/kg	160	-	400	ASTM D6304-20
Ash Content	% wt	0.002	-	0.01	ASTM D482-19
Sediment Content	%WT	0	-	0.01	ASTM D473-22

Figure.4 biodiesel quality test results from processed bulk oil using dolomite as a catalyst,


1. Calculated Cetane Index: 45.8

- **Minimum limit:** 45 (ASTM D4737-21)
- **Interpretation:** The cetane index value indicates the quality of biodiesel combustion. A value of 45.8 > 45 indicates **efficient combustion and good engine performance**.
-  **Meet standards.**


2. Density at 15 °C: 876.5 kg/m³

- **Standard range:** 815 – 880 kg/m³ (ASTM D4052-22)
- **Interpretation:** This density is within the standard range, indicating an **appropriate methyl ester (FAME) composition and not mixed with excess water or methanol**.
-  **Meet standards.**


3. Kinematic Viscosity at 40 °C: 4.336 mm²/s

- **Standard range:** 2 – 5 mm²/s (ASTM D445-21e1)
- **Interpretation:** Viscosity within good limits; essential for **spraying and atomization of fuel inside diesel engine injectors**.
-  **Meet standards.**


4. Flash Point PMcc: 52°C

- **Minimum limit:** 52°C (ASTM D93-20)
- **Interpretation:** The flash point indicates the minimum temperature of the fuel evaporating and forming a flammable mixture. A value of 52 °C is **the minimum threshold**; this indicates **there is a possibility that the residual methanol content is still slightly left**.
-  **Still passed the test, but the margin is very thin. Increased purification process is recommended.**


5. Water Content: 160 mg/kg

- **Maximum limit:** 400 mg/kg (ASTM D6304-20)
- **Interpretation:** Low water content is essential to **prevent corrosion and microorganisms in the fuel system**.
-  **Meet standards.**

6. Ash Content: 0.007 %wt

- **Maximum limit:** 0.01 %wt (ASTM D482-19)
- **Interpretation:** Ash indicates residual inorganic solids (such as catalysts, metal contaminants). This value indicates **a fairly good purification**.
-  **Meet standards.**

7. Sediment Content: 0 %wt

- **Maximum limit:** 0.01 %wt (ASTM D473-22)
- **Interpretation:** The absence of sediment indicates **the product is free of particulate matter or solid deposits**—this is important for **maintaining the performance of the fuel filter**.
-  **Meet standards.**

- All parameters meet the ASTM D6751 standard specification for biodiesel.
- Biodiesel produced from bulk oil using dolomite as a catalyst is declared FEASIBLE and SAFE to use as diesel fuel.
- However, the exact flash point value at the minimum limit (52 °C) needs to be observed and can be increased through:
 - Redistillation or vacuum distillation
 - More optimal washing & drying

Comparison of biodiesel quality test results from processed bulk oil using dolomite and KOH as catalyst,

The production of biodiesel from bulk oil can use homogeneous catalysts such as KOH or heterogeneous such as dolomite. Both have advantages and disadvantages in terms of reaction efficiency and quality of the final product. The following is a comparison of GC-MS results and physical-chemical testing of the biodiesel produced with each catalyst.

FAME Composition Comparison (GC-MS)

FAME Compound	Dolomite (% area)	KOH (% area)
Methyl Palmitate	25.76%	32.24%
Methyl Oleate	26.48%	27.75%
Methyl Stearate	2.09%	2.46%
Total FAME	54.33%	62.45%

Table 6. FAME Composition Comparison

GC-MS: KOH produces a higher FAME content, showing more efficient conversion than dolomite.

Physical and Chemical Test Results (Dolomite)

Parameters	Unit	Result	Min Limit	Max Limit	Status
Cetane Index	-	45.8	45	-	✓ Meet
Density at 15°C	kg/m ³	876.5	815	880	✓ Meet
Kinematic Viscosity (40 °C)	mm ² /s	4.336	2	5	✓ Meet
Flash Point PMcc	°C	52	52	-	△ Enough
Water Content	mg/kg	160	-	400	✓ Meet
Ash Content	% wt	0.007	-	0.01	✓ Meet
Sediment Content	% wt	0	-	0.01	✓ Meet

Table 7. Physical and Chemical test results (dolomite)

- KOH is more efficient in producing biodiesel, as seen from the higher total FAME.
- Dolomite still provides good results physically and chemically, with all parameters meeting ASTM standards.
- Dolomite excels in terms of economy and environmental friendliness, but KOH excels in reaction and product finishes.
- For high efficiency and maximum quality, KOH is suitable for industrial scale.
- For sustainability, ease of catalyst separation, and low cost, dolomite is suitable for the scale of communities or energy-independent villages.
- Further purification of dolomite products (especially to increase flash points) can improve the selling value and safety of the product.

IV. CONCLUSION

General Conclusion: Biodiesel Production from Bulk Oil Using Dolomite Catalyst and KOH

1. Effectiveness Based on GC-MS Results

- **KOH produces biodiesel with a total FAME of 62.45%, higher than dolomite (54.33%).**
- The main compounds (methyl palmitate, methyl oleate, methyl stearate) were detected in both samples.
- **Dolomite produces more non-FAME compounds**, especially Triphenylphosphine oxide (37.59%), which can affect purity.

2. Biodiesel Quality from Dolomite (ASTM Test)

- All physical and chemical parameters **meet ASTM standards**, including cetane index, density, viscosity, water content, ash, and sediment.
- **Flash point = 52°C**, right at the minimum threshold. Attention needs to be paid to the purification process for storage safety.

3. Technical and Practical Comparison of Catalysts

Aspects	KOH	Dolomite
Types of catalysts	Homogeneous (soluble)	Heterogeneous (solid)
Reaction efficiency	High (FAME 62.45%)	Medium (FAME 54.33%)
Reusability	Cannot be reused	Reusable
Cost	More expensive	Cheaper and natural
Purification	Requires intensive washing	Easy to separate
Major contaminants	Diethyl phthalate (8.54%)	Triphenylphosphine oxide

Table 8. Technical and Practical Comparison of Catalysts

4.4.2 Final Conclusion

- **KOH is suitable for large-scale industries**, as it provides higher and more efficient yields.
- **Dolomite is suitable for community-scale production**, is more environmentally friendly, cost- effective, and is of good quality.
- Both catalysts **allow for ASTM compliant production of biodiesel**, with some differences in efficiency and refining requirements.

V. RECOMMENDATIONS

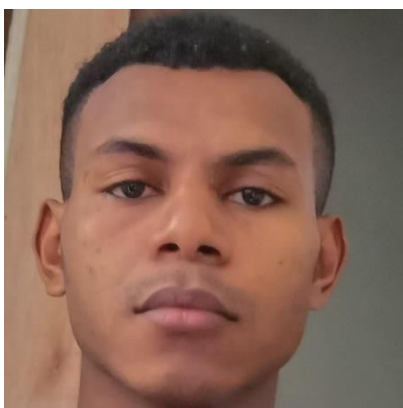
- Improve post-reaction purification for dolomite products to be safer and more stable.
- Use KOH when the primary goals are conversion efficiency and volume.
- Dolomite can be utilized in remote areas or energy independent as a sustainable solution.

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Brief Biography



Alcbraam Javan's Fonataba was born in Andorirempi on February 10, 1999. She completed her undergraduate education at the Chemistry Study Program, Faculty of Mathematics and Natural Sciences, Cenderawasih University in 2021 with a GPA of 3.04. Currently, he is pursuing his final S2 studies at Chemical Engineering at Diponegoro University. He has various work experiences, including as an oil and gas sample analyst at PT Sucofindo Indonesia, marketing staff at PT Masmedia Buana Pustaka, and has undergone field work practices at PLTU Holtekamp.

In addition to being active in the world of work, Alcbraam also has a strong organizational track record, including being an administrator of the Chemistry Student Association at UNCEN and the Chemical Engineering Postgraduate Student Association of FT UNDIP. He is also active as a volunteer in social and disaster activities. His technical expertise includes Microsoft Office, computer networks, and oil and gas laboratory analysis. He also has an interest in music, martial arts, and social activities.



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