Moringa Leaves (Moringa Oleifera) Potential as Green Catalyst for Biodiesel Production

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Abstract. Moringa plant’s value can be improved by utilizing the leaves as green catalyst. This research aimed to examine moringa leaves as green catalyst for transesterification of coconut oil to produce biodiesel. Dry moringa leaf powder was calcined for 3 hours at 500 °C to make moringa leaf ash. Moringa leaf ash was characterized by using Scanning Electron Microscopy - Energy Dispersive X-Ray Spectroscopy (SEM-EDX). The analysis result showed that moringa leaf ash contains metal oxide such as potassium oxide (K2O) and calcium oxide (CaO) which act as catalyst in biodiesel production. Transesterification was carried out with coconut oil to methanol molar ratio of 1 : 9 and catalyst loading of 2% by weight. The variables observed in this study were the effect of reaction temperature and time on biodiesel yield. The best yield obtained was 98.18% at 60 °C and reaction time of 150 minutes. These results confirmed that moringa leaf ash can be utilized as green catalyst for synthesizing biodiesel.

1. Introduction
Moringa plant (Moringa oleifera) is a medium-size originated from South Asia, but has been found in many countries globally. This plant has many usage such as food source, fodder, fertiliser, and dye. Despite the high economical value, moringa tree is not well exploited and considered underutilized. Moringa leaves have high mineral content. Every 100 g of dry moringa leaf powder contains Ca (2.003 %), K (1.324 %), Mg (0.368 %), P (0.204 %), and Na (0.87 %) [1]. With high mineral content, moringa leaves have potential to be utilized as green catalyst for producing biodiesel after calcination process.

Calcination can decompose and increase the number of active site on the surface of a material. Active site depends on calcination condition, especially the calcination temperature. The increase of calcination temperature can affect molecules desorption and readjustment of atom position on catalyst surface, which also affect the active site. Calcination temperature can also affect the morphology of material. Increasing calcination temperature can enhance the porosity of catalyst. However, overheating may block the surface of catalyst hence decreasing the surface area [2,3]. In transesterification reaction for biodiesel production, catalyst with higher porosity and surface area is favored so that reactant molecules such as triglyceride can penetrate easily into the pores of catalyst [3]. Calcination temperature may range from 400 to 1000 °C depending on the biomass used to make biodiesel production.
catalyst [4]. The use of heterogeneous base catalysts derived from biomass is preferred because they have several advantages such as low price, non-corrosive, easier catalyst separation from reaction products, environmentally friendly and reusable. In addition, the use of biomass waste can overcome the problem of environmental pollution.

Utilization of biomass as source of heterogeneous catalyst or catalyst support has been done in other researches. However, it was still limited to biomass from durian shell [3,5], waste date pits [6], flamboyant pods [7], corn cob [8], shea nut shell [9], palm shell [10], candlenut shell [11] and rice husk [12]. Utilization of moringa leaf as source of environmentally friendly heterogeneous catalyst (green catalyst) for biodiesel production has not been done before. Therefore, this research aimed to examine moringa leaves as green catalyst for transesterification to produce biodiesel from coconut oil.

2. Materials and Methods

2.1. Materials
Moringa leaves were supplied from local neighborhood in Medan. Coconut oil was purchased from local grocery store in Medan. Materials such as methanol and ethanol was purchased from local chemical store in Medan.

2.2. Moringa leaf ash preparation
Procedure of making moringa leaf ash was adapted from procedure done by Taslim et al. [8] with slight modification. Moringa leaves were washed with aquadest to clean them from impurities and then dried for 1 day under sunlight. The leaves were dried further with oven at 105 °C until constant weight, then crushed with ball mill, and sieved to 100 mesh. Sieved moringa leaf powder was calcined in the furnace for 3 hours at 500°C. Moringa leaf powder and ash were analyzed for their elemental and metal oxide composition. Moringa leaf ash was stored in sealed container for future use.

2.3. Transesterification
Firstly, 50 g of coconut oil was poured into a three-neck flask. Methanol with 9:1 molar ratio to coconut oil and moringa leaf ash at 2% of the amount of coconut oil were also added into the three-neck flask [13]. The mixture was heated until certain temperature while stirred with magnetic stirrer at 300 rpm. Reaction temperature range observed was 55, 60, and 65°C, and time range of 90-150 minutes. After a certain time, the reaction was stopped and the catalyst was filtered from the reaction product. The filtrate was poured into a separator funnel and left to set into 2 separate layers. The bottom layer (glycerol) was poured out of the funnel. The top layer (crude methyl ester) was washed with hot water at 70°C in the funnel. The mixture was shaken and left until it formed 2 layers again. The bottom layer (washing water) was poured out. The mixture was washed again until the washing water on the bottom layer became clear. The methyl ester was dried at 105°C using hotplate to remove water. The methyl ester was cooled down to room temperature, weighed, and analyzed. The analysis made were density, kinematic viscosity, purity, and yield.

3. Results and Discussion

3.1. SEM-EDX analysis
The SEM result of moringa leaf powder and ash at 3000 times magnification (calcined at 500 °C for 3 hours) is shown at figure 1. Figure 1 shows morphology change between moringa leaf powder and ash. The surface of moringa leaf powder is smoother and less porous compared to moringa leaf ash. Some small coarse particle can be found at the moringa leaf ash. Coarse surface and smaller particle size can increase surface area and active site of catalyst. Similar case was also reported by Taslim et al. [3,8], where calcination process causes reduction of particle size, increasing porosity and surface area of catalyst.
Result of SEM-EDX only shows the components as element. In order to find the amount of metal oxide (CaO and K$_2$O), Proust law can be used as shown in equation (1) [14].

$$\text{% mass CaO} = \left( \frac{M_r \text{ CaO}}{A_r \text{ Ca}} \right) \times \text{% mass Ca} \quad (1)$$

where $M_r$ is relative molecular mass and $A_r$ is relative atomic mass. Similar calculation is used for K$_2$O. From equation (1), CaO and K$_2$O content of moringa leaf ash calcined at 500°C are 12.74 and 14.14% respectively.

The result of EDX analysis from moringa leaf powder and ash are shown at table 1. Table 1 shows increasing mineral content after calcination process, especially the element K dan Ca. This is because the volatile compound and carbon in moringa leaf powder decreased after calcination. During calcination, biomass decomposed into gas product by thermal decomposition, causing formation of pores and increasing surface area [3].

![Figure 1. SEM analysis of (a) moringa leaf powder, (b) moringa leaf ash](image)

### Table 1. Elemental composition of moringa leaf powder and ash

| No. | Element | Composition | Moringa leaf powder | Moringa leaf ash |
|-----|---------|-------------|---------------------|------------------|
| 1   | C       |             | 57.38               | 23.56            |
| 2   | O       |             | 32.43               | 42.45            |
| 3   | Mg      |             | 0.37                | 2.12             |
| 4   | Al      |             | -                   | 0.49             |
| 5   | Si      |             | 0.18                | 2.92             |
| 6   | P       |             | 0.55                | 2.42             |
| 7   | S       |             | 2.32                | 2.99             |
| 8   | Cl      |             | -                   | 0.89             |
| 9   | K       |             | 3.81                | 11.73            |
| 10  | Ca      |             | 1.74                | 9.10             |
| 11  | Cu      |             | 0.73                | 0.71             |
| 12  | Zn      |             | 0.48                | 0.62             |

### 3.2. Transesterification

#### 3.2.1. Effect of reaction temperature on biodiesel yield.

In this research, the reaction temperature was varied from 55 to 65°C. The effect of reaction temperature on biodiesel yield is shown in figure 2. Transesterification was done with calcination temperature at 500°C, 2% catalyst loading, 1:9 molar
ratio of coconut oil to methanol, and reaction time of 2 hours. Figure 2 shows the optimum temperature was at 60 °C with biodiesel yield of 98.63%.

![Figure 2. Effect of reaction temperature on biodiesel yield at 1.9 molar ratio of coconut oil to methanol, 2 hours reaction time, and 2% catalyst loading](image)

Increasing reaction temperature will cause reacting molecules to be more active and increasing the chance of collision. Increasing reaction temperature also reduces reactant viscosity, causing higher reaction rate. However, further increasing the temperature will cause the methanol to vaporize and decreasing biodiesel yield [15]. Vaporized methanol causes methanol concentration in reaction mixture to decrease [16]. Optimizing the reaction temperature is important to cut the production cost. For this research, the optimum temperature was 60°C which is lower than methanol boiling point at 64.7°C.

3.2.2. Effect of reaction time on biodiesel yield. For reaction time variable, transesterification was carried out for 90, 120, 150, and 180 minutes. Figure 3 shows the effect of reaction time on biodiesel yield is shown in. Transesterification was carried out a 60°C, 2% catalyst loading, and 1:9 molar ratio of coconut oil to methanol. The initial guess for the variable was 90, 120, and 150 minutes. Though not significant, there was an increasing biodiesel yield to 98.63% at 150 minutes reaction time. However, the yield decreased to 95.67% after reaching 180 minutes. The optimum reaction time was at 150 minutes with yield of 98.63%.

![Figure 3. Effect of reaction time on biodiesel yield at 1.9 molar ratio of coconut oil to methanol, 60°C reaction temperature, and 2% catalyst loading](image)
Reaction time for systems with heterogeneous catalyst are longer than those with homogeneous catalyst. This is caused by mass transfer resistance [17]. As reaction time increases, viscosity of biodiesel decreases causing an increase in biodiesel yield. However, further increasing the reaction time will shift the reaction to the reactant side, causing the mixture viscosity to increase again. Increased viscosity will lower the biodiesel yield [18]. Optimum reaction time depends on the type of oil and catalyst used. Rasyid et al. [19] used coconut oil and NaOH/γ-Al2O3 as catalyst, obtaining 180 minutes as optimum reaction time with 90% yield. On the other hand, Taslim et al. [11] obtained optimum reaction time at 120 minutes with 96% as the best yield, using waste cooking oil and candlenut shell impregnated with KOH as catalyst.

3.3. Biodiesel properties

Some physical properties of the biodiesel obtained from this research with the optimum condition was compared with European standard (EU 14214) shown in Table 2. Table 2 shows that the synthesized biodiesel fulfilled the standards. The results of this early research show that moringa leaf ash can be utilized as green catalyst for transesterification of coconut oil for synthesizing biodiesel.

| Physical properties          | Unit | Biodeisel produced | EN 14214 |
|------------------------------|------|--------------------|----------|
| Methyl ester content         | %    | 98.86              | >96.5    |
| Density                      | kg/m³| 869                | 860-900  |
| Kinematic viscosity          | mm²/s| 4.5                | 3.5-5.0  |

4. Conclusion

Moringa leaves can be utilized as green catalyst for producing biodiesel after being calcined. The calcination result, moringa leaf ash contained some metal oxide such as K₂O and CaO. These oxides act as heterogeneous catalyst for biodiesel synthesis from transesterification of coconut oil. The highest biodiesel yield was 98.18% obtained at 60°C reaction temperature, reaction time of 150 minutes, catalyst loading of 2%, and coconut oil to methanol molar ratio of 1:9. The results obtained have fulfilled the European standard.

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