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The characteristics of bioethanol fuel made of vegetable raw materials

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Abstract. The aim of this research is to identify the most potential vegetable raw as the material to make a bioethanol fuel as the alternative energy for gasoline. This study used experimental method. The high-level bioethanol was obtained through the process of saccharification, fermentation and stratified distillation. ASTM standards were used as the method of testing the chemical element (D 5501, D 1744, D 1688, D 512, D 2622, D 381), and physical test (D 1613, D 240, D 1298-99, D 445, and D 93). The result of the analysis showed that from the seven bioethanols being studied there is one bioethanol from *Saccharum of icinarum linn* that has physical and chemical properties close to the standard of bioethanol. Meanwhile, the others only meet some of the physical and chemical properties of the standard bioethanol.

1. Introduction

The energy crisis has swept across the world either in a developing country or a developed country. This is caused by the availability of fossil fuels which is very limited and nonrenewable. Thus, it is needed to look for the alternative energy that renewable. As reported by the world energy board that about 82% of the world's energy needs come from petroleum, natural gas and coal [1]. With the current fuel consumption rate, it is predicted that fossil fuel sources will be depleted for petroleum in 50 years, natural gas in 65 years and coal in the next 200 years [2]. However, a team of scientists from UC Davis claims that petroleum will be exhausted 90 years before the availability of technology that replaces petroleum. According to Debbie Niemeier, one of the study participants, and scientists have proven to develop renewable energy production will take longer than expected as total energy consumption. The Niemeier study suggests the possibility of renewable energy will not inflict damage, development, economics, and ecosystems [3]. Bio-renewable fuels can be considered renewable if they can be used within the boundaries of some areas. Renewability is determined by the ratio between reproduction and consumption, not growth rate [4].

In terms of development and exploitation of renewable energy sources, it seems to be articulated by the European renewable energy council. The European EREC Council and government from the European Union agreed that the target of renewable energy usage is 20% by the end of 2020 and 100% by 2050 [5]. While in Indonesia, the use of renewable energy has been regulated by the government through Presidential Regulation no. 5 of 2006 [6] on the target of national and renewable energy utilization policy until 2025, namely: for fuel oil 20%, 30% gas fuel, 33% coal, 5% biofuels, 5% geothermal, others (nuclear, biomass, Water, solar, wind, and liquid coal 7%).



A review of the related literature study showed that the researchers focused more on the use of bioethanol and biodiesel fuel in the gasoline engines and diesel engines. In which, the internal combustion engine needs a fuel with a relatively high energy. Globally, bio-renewable fuels (bioethanol and biodiesel) for the current transportation sector are available to replace gasoline and diesel fuel [7]. Currently, bio-renewable fuels are around 10% of the energy used in the world, that the major contribution of bioethanol production is in North America, South America, and Central America [8]. In America, biofuel production accounts for three-quarters of the world's total production. It has been used as an automotive engine fuel by the automotive industry [9]. The use of this fuels in the gasoline engines and diesel engines can lower the amounts of particles and emissions in the exhaust [10]. The level of octane in the bioethanol is higher and its emissions is lower than gasoline and diesel fuels. Moreover, it also can be directly used in the machine without modifying the machine components [11]. Other studies [12] that investigated the impact of combining bioethanol fuel-biodiesel fuel-and oil on engine emissions, found that the ppm quantity in exhaust emissions decreased, and there was an increase in the amount of carbon dioxide (CO₂). While, the application bioethanol of *amorphophallus paenifolius* as the mixture of gasoline fuel to the exhaust emissions and engine performance on 4 stroke engine gasoline 1 cylindrical, it resulted that E20 fuel can improve performance and decrease CO and HC emissions [13].

Compared with fossil fuel, bioethanol fuel has the following special quality: 1) It has a high-octane level; 2) It is able to reduce the level of particle emission that endangers health (CO); 3) It is similar to gasoline, so its use does not require engine modification; 4) It is also regarded as renewable fuel that does not have CO₂ emissions; 5) It has low-cost production; 6) It is an alternative solution in facing globalization since it is eco-friendly; 7) It can be made at home and low-cost production than fossil fuel; 8) The physical characteristic of bioethanol in its pure form is soluble in all proportions with water and also with ether, acetone, benzene, and some other organic solvents [14,15]; 8) And its characteristic chemical function are dominated by the OH-group, which can readily help reactions in chemical industries such as dehydration, halogenation, ester formation, and oxidation [15,16].

The energy from vegetable materials has the potential to contribute the future energy scenarios. The production of bioethanol is now widely known to bring a good environmental, economic, strategic, and infrastructure impacts [17]. It is a type of alcohol, which is produced from the fermentation of agricultural products containing sugar starch such as, sugarcane, corn, wheat, sweet, fruit, and so on [18].

Indonesia is a tropical country that is rich with plants (vegetable) as a source of basic materials to make bioethanol and biodiesel, so the opportunity to produce bioethanol and biodiesel in large scale is very possible. Fuel derived from vegetable can be used for fuel, both in the form of bioethanol and biodiesel [19]. While the fuel from vegetables that must be continuously developed and already known its power for raw material bioethanol are *amorphophallus variabilis*, *musaceae*, *solanum lycopersium*, *alocasia macrorrhiza*, *maranta arundinacealin*, sugar cane *saccharum officinarum linn*, and *suweg amorphophallus campanulatus*. As for biodiesel raw materials are palm, peanut, *jatropha curcas linn*, *gassibium herbaceum*, soybean, *ceiba pentandra*, coconut *cocos nucifera*, and *hellianthus annuus* [19,20].

The aim of this study is to analyze the characteristics of renewable fuel capability (bioethanol) from vegetable raw materials. From the results of this study, it is expected that we will get the type of potential material of biofuel, which can be used as a reference for the development of bioethanol fuel production in a larger scale.

2. Method

The high-level bioethanol obtained through the process of saccharification, fermentation, and stratified distillation up to 4 levels. Distillation is carried out by inserting the fermentation broth into the boiler for evaporation. Then, the steam goes into the distillation pipe. After that, the vapor is condensed through the condenser pipe. Finally, bioethanol will come out through the condenser hole.

The characteristics of chemical bioethanol capability that will be analyzed are the levels of its ethanol, methanol, water, Cu, Cl, and gum. While its physical properties include: heating value, density, viscosity, and flash point. The methods of testing the chemical properties are using ASTM standard (D 5501, D 1744, D 1688, D 512, D 2622, D 381) and its physical properties test is using ASTM standard (D 1613, D 240, D 1298-99, D 445, and D 93).

3. Result and Discussion

Laboratory test results of chemical properties of bioethanol from various types of vegetable raw materials are presented in Table 1, while the results of physical properties test are presented in Table 2.

Table 1. The results of chemical properties test of bioethanol from various types of vegetable.

| No. | Material | Bioethanol content (%vol) | Methanol content (mg/l) | Water content (%vol) | Cu content (mg/kg) | Cl content (mg/l) | Gum content (mg/100ml) |
|-----|-------------------------------------|---------------------------|-------------------------|----------------------|--------------------|-------------------|------------------------|
| 1 | <i>Amorphopallus variabiliti</i> | 94 | 0.0049 | 0.202 | 0.072 | 17.758 | 5.2 |
| 2 | <i>Mucasea</i> | 93 | 0.0088 | 0.653 | 0.052 | 39.547 | 1.4 |
| 3 | <i>Solanum lycopersicum</i> | 94 | 0.0013 | 0.684 | < 0.01 | 35.354 | 6.5 |
| 4 | <i>Alocasia macrorrhiza</i> | 93 | 0.0052 | 0.353 | 0.095 | 19.651 | 11.5 |
| 5 | <i>Maranta arundinacealinn</i> | 94 | 0.0029 | 0.435 | 0.056 | 15.732 | 9.8 |
| 6 | <i>Saccharum officinarum linn</i> | 95 | 0.0024 | 1.035 | < 0.01 | 30.654 | 1.3 |
| 7 | <i>Amorphophallus campanulatus</i> | 93 | 0.0037 | 0.253 | 0.083 | 21.543 | 4.6 |
| 8 | Bioethanol Standard ^[21] | 99.5 min | 300 max | 1.0 max | 0.1 max | 40.0 max | 5.0 max |

Table 2. The results of physical properties test of bioethanol from various types of vegetable.

| No | Material | pH value (mg/l) | Heating value (kcal/kg) | Density (g/cm ³) | Viscosity (cSt) | Flash point (°C) |
|----|-------------------------------------|-----------------|-------------------------|------------------------------|-----------------|------------------|
| 1 | <i>Amorphopallus Variabiliti</i> | 2.5 | 6786 | 0.858 | 2.762 | 15 |
| 2 | <i>Mucasea</i> | 5.8 | 5524 | 0.824 | 2.149 | 12 |
| 3 | <i>Solanum Lycopersicum</i> | 5.3 | 5696 | 0.817 | 2.843 | 13 |
| 4 | <i>Alocasia Macrorrhiza</i> | 3.8 | 6445 | 0.836 | 1.961 | 16 |
| 5 | <i>Maranta Arundinacealinn</i> | 4.6 | 5969 | 0.796 | 3.054 | 14 |
| 6 | <i>Saccharum officinarum linn</i> | 8.5 | 8756 | 0.801 | 1.637 | 13 |
| 7 | <i>Amorphophallus campanulatus</i> | 4.7 | 5892 | 0.823 | 2.376 | 19 |
| 8 | Bioethanol Standard ^[21] | 6.5-9.0 | 6380 | 0.789 | 1.525 | 12 |

3.1 Chemical Properties of Various Vegetable Materials

Table 1 shows the results of laboratory tests of the chemical properties of bioethanol from various vegetable materials produced by 4-level distillation. The seven vegetable materials have bioethanol content above 90%, and the level of bioethanol that approaching the standard is *saccharum officinarum linn* (95%). Because *saccharum officinarum linn* has sucrose content that reached 19%, so its bioethanol content is higher than the others. Bioethanol is a fuel (*ethyl alcohol* with the chemical formula (C₂H₅OH) produced from biofuels. It is obtained from the fermentation and distillation process. Generally, it is classified into 3 groups, namely as the beverage (alcoholic), the alternative fuel (energy), and for the industrial solvent. In the fuel sector, bioethanol can be used as fuel because it is combustible. However, bioethanol can only be used as a mixture of gasoline fuel to raise the value of octane (*High Octane Mogas Component*) HOMC for gasoline.

The methanol content of organic chemicals in the form of toxic liquid, colorless, odorless, molecular weight 32.04, boiling at 64.7°C, volatile and flammable. The standard of bioethanol

stipulated that its methanol content should not exceed 300 mg/liter. From the results of the laboratory test, the lowest methanol content is *musacea* (0.0088 mg/l).

The results of laboratory tests showed that the lowest water content of bioethanol is from *amorphophallus variabilis*, it is 0.202% vol. The water content in fuel is one of the benchmarks of the fuel quality, the less water content in bioethanol, the better the bioethanol is. The maximum limit of water content is 1%, it is determined by the standard of ethanol quality. The water content more than 1% in bioethanol can cause damage to the inside of the furnace surface when burning process. Water can also cause a spark of flame at the tip of the burner, which can turn off the flame and lower the temperature of the flame.

Table 1 showed that the lowest copper content of the seven bioethanol is from bioethanol *solanum lycopersicum* and *saccharum officinarum linn* (<0.01). Whereas according to the standard of bioethanol, the maximum copper content is 0.1 mg/kg. Copper is a highly active metal that catalyzing the oxidation of hydrocarbons at low temperatures. Copper with concentrations that is greater than 0.012 mg/kg in gasoline can lead to a significant increase in the rate of gum formation.

Based on the result of chloride ion test (Table 1), all of seven bioethanol in this research are qualified to the standard (the standard is maximum 40 mg/l), and *maranta arundinacealinn* is the lowest one. The effect of chloride content on the fuel is if chloride enters the combustion chamber, it becomes crust since it is corrosive. Moreover, if the fuel has a high content of chloride ions it can make the burning process less efficient and harmful to the engine. Thus, the smaller the chloride ion content in bioethanol, the better the quality of bioethanol is.

The gum content in bioethanol will cause the evaporation process of the fuel to produce a precipitate on the surface of the fuel induction system and the stickiness of the inlet valve. The insoluble gum may also clog fuel filters. Laboratory test results (Table 1) showed that the lowest gum content was obtained in bioethanol *saccharum officinarum linn* (1.3 mg/100 ml) and the highest one is bioethanol *alocasia macrorrizha* (11.5 mg/100 ml), whereas the standard of bioethanol quality is maximum 5 mg/100 ml.

3.2 Physical Properties of Various Vegetable Materials

The physical properties of bioethanol from various vegetable materials produced by 4-level distillation are shown in Table 2. The pH value is a benchmark of acid strength in bioethanol fuel. It is a good indicator for knowing the potential of bioethanol corrosion as fuel. The results of laboratory tests of the seven bioethanol whose pH content meets the standard of bioethanol is *saccharum officinarum linn* that is 8.5 mg/l. Whereas, the standard of bioethanol is should be around 6.5-9.0 mg/l. And if a pH value <6.5 the fuel injector, the engine cylinder and fuel pump may fail to work. Moreover, when the ethanol pH value is > 9.0 parts of the fuel pump plastic will fail to work.

The laboratory test of heating value (Table 2) showed that the highest heating values, which was 8756 kcal/kg, was obtained from the bioethanol *saccharum officinarum linn* is 8756 kcal/kg. Whereas, the standart quality of heating value of bioenol is around 6380 kcal/kg. The heating value is the amount of energy released in the combustion process of the union volume or unity of time. The heating value of fuel determines the amount of fuel consumption per time unit. The higher the heating value of the fuel indicates the less the fuel consumes.

Referring to Table 2, the results of density test showed that the bioethanol that approaching the standard is *maranta arundinacealinn* (0.796 g/cm³) since the standard of bioethanol density is around 0.789 g/cm³. Density is the ratio of fuel mass to the volume of fuel at a temperature of 150°C. Density is measured by a device called a pycnometer and hydrometer. The pycnometer is a laboratory instrument used to measure the density of fluid type or volume accurately. The hydrometer is a tool

used to measure the specific gravity of a liquid with a ratio of fluid density and water density. This density greatly affects the quality of ignition of fuel.

The standard of viscosity on bioethanol is 1.525 cSt. While the Table 2 shows that the lowest viscosity is bioethanol *saccharum officinarum linn* (1.637 cSt). Fluid viscosity is a measurement of material resistance to a stream. Viscosity depends on the temperature. It decreases as temperature increases. It is measured by using a tool called viscometer. Viscosity is essential properties in the storage and use of fuel. If the viscosity of the fuel is too thick, it will make the engine difficult in pumping, igniting the burner, and flowing. In addition, the high-level viscosity in the fuel worsens the atomization, triggering the formation of carbon deposition on the cylinder wall of the engine.

Flashpoint is a flammability of fuel. It is also a parameter to know the impact of hazards during travel or fuel storage. The flash point standard of bioethanol is 12°C, and it is obtained by the bioethanol from *musacea*.

4. Conclusion

Based on the research objectives, the result and discussion of bioethanol performance characteristics of vegetable raw materials, it can be concluded that:

1. The highest ethanol content was obtained 95% vol in *saccharum officinarum linn*, the highest methanol content 0.0088 mg/l in *musacea* peels, the lowest moisture content 0.202% vol in *amorphophallus variabilis* tube, the lowest copper content <0,01 mg/kg in *saccharum officinarum linn* and *solanum lycopersicum*, the lowest chloride ion content of 15.73 mg/l in the *arundinaceal maranta* tube, and the lowest gum of 1.3 mg/100 ml in the *saccharum officinarum linn*.
2. The best acid/pH level is 8.5 in *saccharum officinarum linn skin*, the highest heating value 8756 kcal/kg in *saccharum officinarum linn skin*, the best density 0.819 g/cm³ in *arundinaceal maranta*, the best viscosity 1.837 cSt in *saccharum officinarum linn skin*, and the best flash point is 19°C in *amorphophallus campanulatus*.
3. Generally, bioethanol of vegetable raw materials that physical properties and chemical properties approaching standard is *saccharum officinarum linn* bioethanol.

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