01 Physical and Chemical Properties of Mixture Fuel

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Article

Physical and Chemical Properties of a Mixture Fuel between Palm Sap (*Arenga pinnata* Merr) Bioethanol and Premium Fuel

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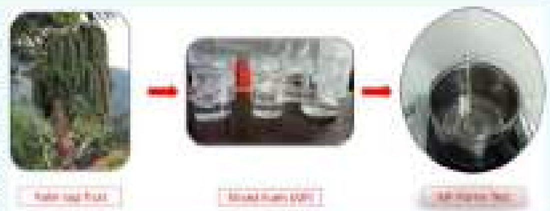
ABSTRACT: Along with the development of motor vehicle industry technology at this time, the fuel demand is also increasing while the supply is running low. Thus, alternative fuels are needed to meet these energy needs. This study aims to explain the physical and chemical characteristics of a fuel mixture (MF) between palm sap bioethanol with premium fuel. The results showed that the higher the bioethanol concentration of the palm sap, the higher the MF's viscosity, but the lower the heat of the fuel. This decrease is caused by differences in the heating value of the two fuels. The MF's high heat burn value is blue, while the low heat value of the flame is reddish yellow. The results of this study are very important as a basis for the development of bioethanol from palm sap as an environmentally friendly vehicle fuel substitute material.



1. INTRODUCTION

The human need for fuel is currently increasing along with the development of the motor vehicle industry.[1] The largest source of fuel used by motor vehicles is fossil fuels.[2] These fossil fuels cannot be expected to be around for a long period of time because their amount is limited and they cannot be renewed.[3,4]

Bioethanol has been developed in many countries as an energy source for fossil energy substitution.[5,6] Bioethanol production in the United States is developed from corn to apply bioethanol energy.[7] Brazil has been developing bioethanol sourced from sugar cane by conducting tests on vehicles since 1925.[8] China and Thailand develop bioethanol from cassava.[9] South Korea has been developing biodiesel since 2002, and its consumption is estimated to increase by 0.5% per year.[5]

Brazil develops bioethanol from sugar cane at a low cost of 14 cents a dollar per liter, Thailand with tapioca, 18.5 cents a dollar per liter, and America using corn, 25.5 cents a dollar per liter.[10] The success of Brazil in producing bioethanol from sugar cane on an industrial scale has led many countries to follow their strategic steps. Currently, in Brazil, motorcyclists can fill fuel tanks with a mixture of 24% ethanol and 76% gasoline.[11] As for Indonesia, the government has given serious attention to developing bioethanol by issuing Presidential Instruction no. 1 of 2006 regarding the supply and use of biofuel as an alternative fuel.[12,13]

Bioethanol is one type of biofuel that can be used as a substitute for fossil fuels.[14,15] The use of bioethanol as a fuel mixture is important to save the earth from global warming.[16] The development of bioethanol as an alternative fuel must be supported by several factors, including the availability of abundant raw materials, bioethanol-making technology available, and the existence of promising market opportunities and benefits.[17,18]

Bioethanol can be produced from various types of plants, such as sugar cane, cassava, corn, sorghum, palm sap, or other types of plants.[18,19] Palm sap (*Arenga pinnata* Merr, *A. pinnata*) is very abundant in Indonesia (Table 1), so it has the potential to be processed into bioethanol.[20] This plant contains glucose,

Table 1. Estimated Area of Palm Sap in Indonesia[21]

province	an estimate of the total area (ha)
Nanggro Aceh Darussalam	4081
North Sumatera	4357
West Sumatera	1830
Bengkulu	1748
West Java	13,135
Banten	1448
Central Java	3078
South Kalimantan	1442
North Sulawesi	6000
South Sulawesi	7259
Southeast Sulawesi	3070
Maluku	1000
North Maluku	2000
Papua	10,000
total	60,482

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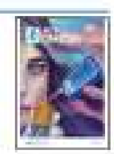

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fructose, and sucrose with a composition of approximately 0.4–0.5%, 0.5–0.6%, and 10–13%, respectively.[21,22] The sugar content is quite high, so palm sap has the potential to be processed into bioethanol.[23] So far, the use of palm sap is still very limited, namely, only in the manufacture of palm sugar.[24]

Bioethanol has become a very interesting topic and is always an updated study in various research communities in the world from the production process to compatibility with motor vehicles.[1,26] Some advantages of using bioethanol include exhaust emissions that are more environmentally friendly compared to premium fuels and Pertamax.[27,28] Bioethanol is a potential fuel because the raw material can be renewed.[29]

Bioethanol production must be focused on abundant plants, but its use is not for basic food needs. Brazil has been applying the bioethanol–gasoline mixture since the 1930s and increased its application by 50% in 1943.[30] Indonesia as a country that has a relatively similar geographical condition to that of Brazil has the potential to follow Brazil's path in utilizing abundant natural resources to meet domestic energy needs. This is in line with Indonesia's transportation system, which mostly uses gasoline.[11] Bioethanol can bring practical benefits if applied nationally in Indonesia.[28]

It is very possible to mix the physical and chemical characteristics of bioethanol with those of gasoline.[31] The need to meet energy demand with apprehensive environmental impacts and limited fuel stock from fossil fuels has led researchers to look for renewable and environmentally friendly energy resources, one of which is bioethanol.[32] However, the bioethanol production process is more complex and requires a large investment capital.[33] The main obstacle is that bioethanol must be compatible with motor vehicle combustion systems.[34]

Based on the arguments above, in this paper, the focus of the study is on the physical and chemical properties of the fuel mixture of palm sap bioethanol with premium fuel (MF). Although there have been studies focusing on aspects of bioethanol production,[35,36] it is still urgent to conduct research that focuses on explaining the physical and chemical properties of palm sap bioethanol after it is mixed with premium fuel.

Many researchers have developed palm sap into bioethanol as a fuel mixture for motor vehicles.[10,37−39] However, no valid data has been found about the viscosity, calorific value, and flame after the palm sap bioethanol is mixed with premium fuel. Therefore, it is important to examine and reveal the viscosity, calorific value, and flame as physical and chemical characteristics of fuel for motor vehicles. Thus, the purpose of this study is to explain the physical and chemical characteristics of a fuel mixture between palm sap bioethanol and premium.

2. METHOD AND MATERIALS

2.1. Materials and Tools. The materials used are bioethanol from distilled palm sap (*A. pinnata* MERR) (Figure 1) and premium-type fuel with an octane number of 88 obtained directly from refueling in Mataram, West Nusa Tenggara Province, Indonesia.

Figure 1. Palm sap is widely cultivated in Indonesia.

These ingredients are mixed with various variations of the concentration (Table 2).

Table 2. Variation of Concentrations between Bioethanol Palm Sap and Premium Fuel

no.	palm sap bioethanol (mL)	premium (mL)
1	10	90
2	15	80
3	20	70
4	25	60
5	30	50

The tools used are a viscometer, C-5000 calorimeter bomb, thermometer, test tube, analytical balance, oxygen cylinder, oxygen regulator, oxygen hose, test tube, and LPG gas stove.

2.2. MF Viscosity Measurement. MF viscosity is measured using an open gravity capillary viscometer in the temperature range of 20–30 °C.[40] Mathematically, the MF viscosity equation can be written[41] as

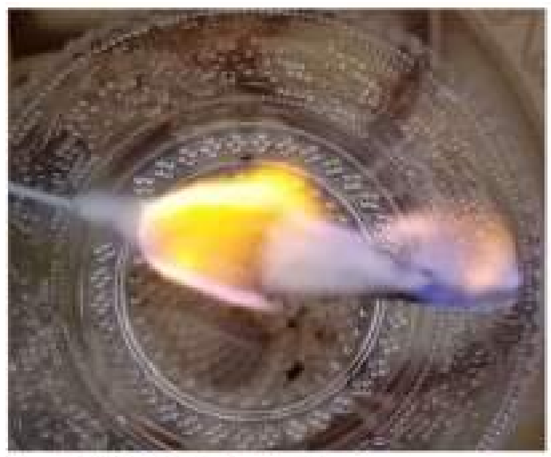

Figure 2. MF bioethanol and premium flame test.

$$F = \eta A \frac{V}{L} \quad (1)$$

with F as the force on the surface of the liquid, η as the coefficient of fluid viscosity (Ns/m^2), A as the liquid area (m^2), V as the moving wall velocity (m/s), and L as the distance of the two surfaces (m).

2.3. Measurement of the MF Calorific Value. MF burn calorie measurements were done using a bomb calorimeter, type IKA C-5000. The reaction that occurs in a bomb calorimeter can produce heat absorbed by water and bombs so that no heat is wasted into the air, so it can be written as

$$r_{\text{action}} = -(q_{\text{air}} + q_{\text{bomb}}) \quad (2)$$

The amount of heat absorbed by water can be calculated using the formula

$$Q_{\text{water}} = mc\Delta T \quad (3)$$

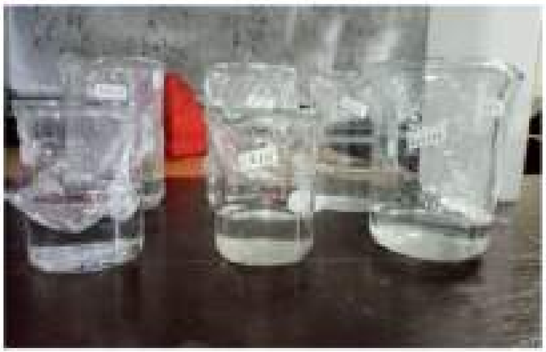

Figure 3. Palm sap bioethanol produced in this study.

Table 3. MF Viscosity at Various Concentrations between Bioethanol and Premium Fuel

no.	comparison of fuel mixtures (%)		viscosity of MF (mm^2/s)
	bioethanol of palm sap (mL)	premium (mL)	
1	10	90	5.4
2	15	85	5.4
3	20	80	4.0
4	25	75	4.5
5	30	70	4.3

where m is the mass of water (g), c is the heat type of water (J/kg °C), and ΔT is the temperature change (°C).

The amount of heat absorbed by the bomb calorimeter can be calculated using the formula

$$q_{bomb} = c_{bomb}\Delta T \tag{4}$$

where c_{bomb} = heat capacity of bomb (J/g °C) and ΔT is the temperature change (°C).

2.4. MF Flame Test. Flame tests were carried out to detect the presence of metal ion elements in the MF of bioethanol and premium fuel by dipping cotton buds washed with hydrochloric acid in the MF liquid and then igniting it with fire (Figure 2). This flame test is to provide qualitative information on the colors arising from the combustion process based on the light spectrum of the electromagnetic radiation elements present in the sample. The flame that arises will be adjusted to the table of chemical elements with their flames.[42]

2.5. Data Analysis. The effect of variations in the concentration of palm sap bioethanol and premium fuel on the physical and chemical characteristics of the MF was analyzed using analysis of variance.[43] If the F-count value is greater than the F-crit, it means that there is a significant difference in the significance level of 95%. The most influential variable can be identified using the DMRT (Duncan's multiple-range test).

3. RESULTS AND DISCUSSION

3.1. Viscosity of MF. Palm sap bioethanol produced in this study is shown in Figure 3. The MF viscosity in various concentrations of bioethanol and premium fuel is shown in Table 3. In the table, it appears that the higher the concentration of the palm sap bioethanol, the higher the MF's viscosity. Fuel viscosity can affect the fogging process. Fuels that have high viscosity are difficult to atomize. Conversely, fuels with low viscosity are easier to atomize. Fuels that are more easily atomized are also easier to ignite and also more perfect for combustion.

Table 5. MF Calorific Values for Various Concentrations between Bioethanol and Premium Fuel

no.	comparison of fuel mixtures (%)		calorific values of MF (kcal/g)
	palm sap bioethanol (mL)	premium (mL)	
1	10	90	11.107
2	15	85	11.015
3	20	80	10.324
4	25	75	10.152
5	30	70	9.445

The result of the bioethanol test of palm sap was a value of 4.7 mm^2/s, while that of the premium fuel was 7.2 mm^2/s.[12] After mixing, the data obtained showed that the higher the concentration of palm sap bioethanol, the lower the MF's viscosity (Table 3). This is thought to be influenced by the viscosity of bioethanol, which is lower than the premium viscosity. These results are in line with research reported by Tazi and Sulistiana[7] in that the higher the addition of bioethanol, the lower the viscosity of the fuel.

The results of the two-factor variance analysis show that the calculated F-value (153.963) is greater than the F-table value (3.490). This means that the variation in the concentration of palm sap bioethanol has a significant effect ($p > 0.5$) on the MF's viscosity (Table 4).

3.2. MF Calorific Value. The calorific value of the fuel shows the heat produced from the combustion process. If the combustion is perfect, then the optimal thermal energy can be obtained. Separate test results obtained show that the caloric value of palm sap ethanol is 10.126 kcal/g, while that of the premium is 11.414 kcal/g. After mixing, the highest heating value of the MF was 11.107 kcal/g and the lowest was 9.445 kcal/g (Table 5).

Table 5 shows that the higher the concentration of palm sap bioethanol added to the premium fuel, the lower the MF's calorific value. This decrease is caused by the difference in the heating value between the two fuels. The results of this study are in line with the research of Budiprasojo and Pratama[39] who reported that the low heating value of fuel can affect the high heating value if mixed.

The National Standards Agency (BSN) has set bioethanol quality standards with a minimum heating value of 5000 kcal/g.[44] Based on the quality standards set by BSN, the MF bioethanol and premium produced in this study were following the standards.

The results of the two-factor analysis of variance show that the calculated F-value (144.894) is greater than the F-table value (3.490) (Table 6). This means that the variation in the

Table 4. Results of the Two-Factor Analysis of Variance of MF Viscosity Parameters

source of variation	SS	df	MS	F	P value	F crit
rows	1.223	4	0.30575	0.007	0.999	3.259
columns	19625.3	3	6541.7653	153.963	7.647×10^{-10}	3.490
error	509.869	12	42.489083			
total	20136.39	19				

Table 6. Results of Two-Factor Variance Analysis for MF Calorific-Value Parameters

source of variation	SS	df	MS	F	P value	F crit
rows	0.870732	4	0.217683	0.005	0.99994	3.259
columns	18509.81	3	6169.936	144.894	1.09×10^{-9}	3.490
error	510.9863	12	42.58219			
total	19021.66	19				

Table 7. Comparison of Physical and Chemical Characteristics of Mixed Fuel

	value			
combined of fuel mixes	viscosity at 40 °C (mm^2/s)	calorific (kcal/g)	flame test (color)	references
premium of RON 88	7.2	11.414	reddish yellow	41
20% bioethanol of liquid polypropylene−80% Gasoline		11.340	reddish yellow	39
20% bioethanol of pineapple−80% premium		7.331		40
30% bioethanol of cassava flour−70% gasoline		23		38
30% bioethanol of sugar molasses−70% gasoline	2.2	15		37
30% palm sap bioethanol−70% premium	4.7	10.126	reddish yellow	this research

concentration of palm sap bioethanol has a significant effect ($p > 0.5$) on the heating value of the MF.

3.3. MF Flame Test. MF flame test results on variations in the concentration of palm sap bioethanol and premium fuel showed two different types of flame colors, namely, blue and reddish yellow. MF that contains low concentrations of palm sap bioethanol, produces a blue flame while, with high concentrations, produces a reddish yellow flame. This is in line with the report of McLinden et al.[45] in that the flame from bioethanol is not only blue but also reddish yellow. The same thing was reported by Polikarpov et al.[46] in that, at the time of combustion, a blue flame appeared at the bottom and a reddish yellow one appeared at the top.

The blue combustion results indicate that the methane (CH_4) in the MF was completely burned. The results of this study are in line with the research of Susanto et al.[47] who reported that methane gas was marked with a blue flame. However, the reddish yellow fire means incomplete combustion and that the flame is unstable. Cahyani[48] also reports that the color of the blue flame indicates high ethanol levels.

A comparison of the physical and chemical characteristics of the mixed fuel between the palm sap bioethanol and premium fuel from this study with several other studies is shown in Table 7.

The results of the two-factor variance analysis show that the calculated F-value (68.308) is greater than the F-table value (3.490) (Table 8). This means that variations in the concentration of palm sap bioethanol and premium fuel affect the MF's flame. The blue flame color indicates high ethanol content.

4. CONCLUSIONS

The high concentrations of palm sap bioethanol cause the MF viscosity to also be higher, but too difficult to obscure. The higher the concentration of palm sap bioethanol, the lower the heating value of MF. The MF flame test results on variations in the concentration of palm sap bioethanol and premium fuel showed two different types of flame colors, namely, blue and reddish yellow. The blue color indicates high ethanol content, while the reddish yellow color indicates low ethanol content.

The physical and chemical properties of MF fuels still need to be studied comprehensively by conducting MF trials on various types of motorized vehicles. Besides, further research is needed on mixing palm sap bioethanol with other types of fuel.

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Notes

The authors declare no competing financial interest.

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Table 8. Results of Two-Factor Analysis of Variance of the MF's Flame Value

source of variation	SS	df	MS	F	P value	F crit
rows	155.0324	4	38.75809	0.408	0.799	3.259
columns	19472.58	3	6490.86	68.308	8.13×10^{-8}	3.490
error	1140.277	12	95.02309			
total	20767.89	19				

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