

Dear Prof. Frank Quina

Associate Editor ACS Omega

I wish to submit a manuscript entitled “Physical and Chemical Properties of Mixture Fuels (MF) between Palm Sap (*Arenga Pinnata* MERR) Bioethanol and Premium” for possible consideration.

Finally I wish to affirm the manuscript has been prepared in accordance with instructions to authors. I also hereby affirm that the content of this manuscript or a major portion thereof has not been published in a refereed journal, and it is not being submitted for publication elsewhere.

Thank you very much and I shall wait for your kind response.

Warm regards,

Dr. Ansar

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1 **Physical and Chemical Properties of Mixture Fuels (MF) between Palm Sap (*Arenga***
2 ***Pinnata* MERR) Bioethanol and Premium**

3
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12
13 **ABSTRACT**

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

24 **Keywords:** bioethanol, calorific values, palm sap, flame, viscosity

26 **1. INTRODUCTION**

27 The human need for fuel is currently increasing along with the development of the
28 motor vehicle industry.¹ The largest source of fuel used by motor vehicles comes from fossil
29 fuels.² This fossil fuel cannot be expected for a long period of time because the amount is
30 limited and cannot be renewed.^{3, 4}

31 Bioethanol has been developed in many countries as an energy source for fossil energy
32 substitution.^{5, 6} Bioethanol production in the United States is developed from corn to apply
33 bioethanol energy.⁷ Brazil has been developing bioethanol sourced from sugar cane by
34 conducting tests on vehicles since 1925.⁸ China and Thailand develop bioethanol from
35 cassava.⁹ South Korea has been developing biodiesel since 2002 and its consumption is
36 estimated to increase 0.5 percent per year.⁵

37 Brazil develops bioethanol from sugar cane at a low cost of 14 cent a dollar/liter.
38 Thailand with tapioca 18.5 cent a dollar/liter, and America using corn 25.5 cent a
39 dollar/liter.¹⁰ The success of Brazil in producing bioethanol from sugar cane on an industrial
40 scale, has led many countries to follow these strategic steps. Currently in Brazil
41 motorcyclists can fill fuel tanks with a mixture of 24% ethanol and 76% gasoline.¹¹ As in
42 Indonesia, the government has given serious attention to developing bioethanol by issuing
43 Presidential Instruction No. 1 of 2006 regarding the supply and use of biofuel as an
44 alternative fuel.^{12, 13}

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

50 Bioethanol can be produced from various types of plants, such as sugar cane, cassava,
 51 corn, sorghum, palm sap, or other types of plants.^{18, 19} Palm sap (*Arenga Pinnata* MERR) is
 52 very abundant in Indonesia (Table 1), so it has the potential to be processed into
 53 bioethanol.²⁰ This plant contains glucose, fructose, sucrose with a composition of about 0.4-
 54 0.5%, 0.5-0.6%, and 10-13% respectively.^{21, 22} The sugar content is quite high, so that palm
 55 sap has the potential to be processed into bioethanol.²³ So far, the use of palm sap is still
 56 very limited, namely only as the manufacture of palm sugar.²⁴

57 Table 1. Estimation area of palm sap in Indonesia²⁵

Province	Estimate of total area (ha)
Nanggro Aceh Darussalam	4,081
North Sumatera	4,357
West Sumatera	1,830
Bengkulu	1,748
West Jawa	13,135
Banten	1,448
Central Jawa	3,078
South Kalimantan	1,442
North Sulawesi	6,000
South Sulawesi	7,293
Southeast Sulawesi	3,070
Maluku	1,000
North Maluku	2,000
Papua	10,000

Total	60,482
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58

59 Bioethanol has become a very interesting topic and is always up to date in various
60 research communities in the world, from the production process to compatibility with motor
61 vehicles.^{1, 26} Some of the advantages of using bioethanol, including exhaust emissions more
62 environmentally friendly compared to premium fuels and Pertamina.^{27, 28} Bioethanol is a
63 potential fuel because the raw material can be renewed.²⁹

64 Bioethanol production must focus on plants that are abundant, but its use is not for
65 basic food needs. Brazil has been applying the bioethanol-gasoline mixture since the 1930s
66 and increased 50% in 1943.³⁰ Indonesia as a country that has a relatively similar
67 geographical condition to Brazil, has the potential to follow Brazil's path in utilizing
68 abundant natural resources to meet domestic energy needs. This is in line with Indonesia's
69 transportation system which mostly uses gasoline.¹³ Bioethanol can bring practical benefits,
70 if applied nationally in Indonesia.²⁸

71 Physical and chemical characteristics of bioethanol are very possible to be mixed with
72 gasoline.³¹ The need to meet energy demand with apprehensive environmental impacts and
73 limited fuel stock from fossil fuels has led researchers to look for renewable and
74 environmentally friendly energy resources, one of which is bioethanol.³² However, the
75 bioethanol production process is more complex and requires large investment capital.³³ The
76 main obstacle is bioethanol must be compatible with motor vehicle combustion systems.³⁴

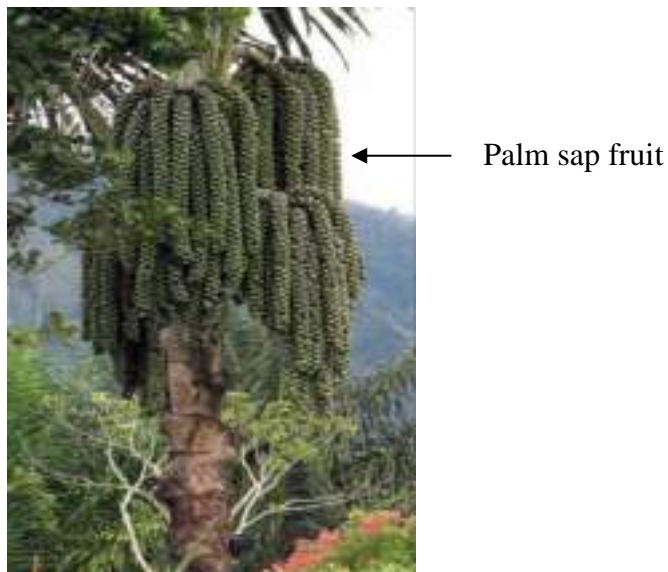
77 Based on the arguments above, in this paper the focus of the study is on the physical
78 and chemical properties of the fuel mixture of palm sap bioethanol with premium (MF).
79 Although there have been studies focusing on aspects of bioethanol production,^{35, 36} but it
80 is still urgent to conduct research that focuses to explain of the physical and chemical
81 properties of the palm sap bioethanol after it is mixed with premium fuel.

82 Many researchers have developed palm sap into bioethanol as a fuel mixture for motor
83 vehicles.^{20, 37, 38, 39} However, no valid data has been found about the viscosity, calorific
84 value, and flame after the palm sap bioethanol is mixed with premium. Therefore, it is
85 important to examine in order to reveal the viscosity, calorific value, and flame as physical
86 and chemical characteristics of fuel for motor vehicles. Thus, the purpose of this study is to
87 explain the physical and chemical characteristics of a fuel mixture between palm sap
88 bioethanol and premium.

89 METHOD AND MATERIAL

90 A. Material and Tools

91 The materials used are bioethanol from distillation palm sap (*Arenga Pinnata* MERR)
92 (**Fig. 1**) and premium type fuel with octane number 88 obtained directly from refueling in
93 Mataram, West Nusa Tenggara Province, Indonesia.



94
95 **Fig. 1.** Palm sap which is widely cultivated in Indonesia.²⁰

96 These ingredients are mixed with various variations of concentration (**Table 1**).

97 **Table 1.** Variation of concentrations between bioethanol palm sap with premium

No.	Palm sap bioethanol (ml)	Premium (ml)
-----	--------------------------	--------------

1	10	90
2	15	80
3	20	70
4	25	60
5	30	50

98

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

102

103 **B. MF Viscosity Measurement**

104 MF viscosity is measured using an open gravity capillary viscometer in the
105 temperature range of 20-30°C.⁴⁰ Mathematical the MF viscosity equation can be written:⁴¹

$$106 \quad F = \eta A \frac{V}{L} \quad (1)$$

107 with, F = force on the surface of the liquid, η = coefficient of fluid viscosity (Ns/m²), A =
108 liquid area (m²), V = moving wall velocity (m / s), L = distance of the two surfaces (m).

109

110 **C. Measurement of MF Calorific Value**

111 MF burn calorie measurement using bomb calorimeter type IKA C-5000 (**Fig. 2**). The
112 reaction that occurs in a bomb calorimeter can produce heat absorbed by water and bombs,
113 so that no heat is wasted into the air, so it can be written as:

$$114 \quad r_{\text{reaction}} = - (q_{\text{air}} + q_{\text{bomb}}) \quad (2)$$



115

116

Fig. 2. Bomb calorimeter type IKA C-5000.²⁰

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

118 $Q_{\text{water}} = m.c.\Delta T$ (3)

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

121 The amount of heat absorbed by the bomb calorie meter can be calculated using the
122 formula:

123 $q_{\text{bomb}} = C_{\text{bomb}}.\Delta T$ (3)

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

125

126 **D. MF Flame Test**

127 Flame tests were carried out to detect the presence of metal ion elements in MF
128 bioethanol at a premium by dipping cotton bad cotton washed with hydrochloric acid in the
129 MF liquid and then igniting it with fire (**Fig 3**). This flame test is to provide qualitative
130 information on the colors arising from the combustion process based on the light spectrum
131 of the electromagnetic radiation elements present in the sample. The flame that arises will
132 be adjusted to the table of chemical elements with the flame.⁴²



133
134 **Fig. 3.** MF bioethanol and premium flame test.²⁰

135

136 **E. Data Analysis**

137 The effect of variations in the concentration of palm sap bioethanol and premium on
138 the physical and chemical characteristics of the MF was analyzed using analysis of
139 variance.⁴³ If the F-count value is greater than the F-crit, it means that there is a significant
140 difference in the significance level of 95%. The most influential variable can be identified
141 using the DMRT (Duncan's Multiple Ranges Test).

142

143 **RESULT AND DISCUSSIONS**

144 **A. Viscosity of MF**

145 Palm sap bioethanol produced in this study is shown in **Fig. 4**. MF viscosity in
146 various concentrations of bioethanol and premium is shown in **Table 2**. In the table it
147 appears that the higher the concentration of the palm sap bioethanol, the higher the MF's
148 viscosity. Fuel viscosity can affect the fogging process. Fuels that have high viscosity are
149 difficult to atomize. Conversely, fuels with low viscosity are easier to be atomized. Fuels
150 that are more easily atomized, are also easier to ignite and also more perfect combustion.



151

152

Fig. 4. Palm sap bioethanol produced in this study.²⁰

153

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158

159

The results of the bioethanol test of palm sap were obtained a value of 4.7 mm²/s, while the premium was 7.2 mm²/s.⁴² After mixing the data obtained that the higher the concentration of bioethanol palm sap, the lower the MF's viscosity (**Table 2**). 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 Sulistiana² that the higher the addition of bioethanol, the lower the viscosity of the fuel.

Table 2. MF viscosity at various concentrations between bioethanol and premium.

No	Comparison of fuel mixes (%)		Viscosity of MF (mm ² /s)
	Bio ethanol of palm sap (ml)	Premium (ml)	
1	10	90	5.4
2	15	85	5.4
3	20	80	4.6
4	25	75	4.5
5	30	70	4.3

160

161 The results of the two-factor variance analysis show that the calculated F-value
 162 (153.963) is greater than the F-table value (3.490). This means that the variation in the
 163 concentration of bioethanol palm sap has a significant effect ($p > 0.5$) on the MF's viscosity
 164 (**Table 3**).

165 **Table 3.** Results of analysis variance two factors of MF viscosity parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	1.223	4	0.30575	0.007	0.999	3.259
Columns	19625.3	3	6541.7653	153.963	7.647E-10	3.490
Error	509.869	12	42.489083			
Total	20136.39	19				

166

167 **B. MF Calorific Value**

168 The calorific value of the fuel shows the heat produced from the combustion process.
 169 If the combustion is perfect, then the optimal thermal energy can be obtained. Separate test
 170 results obtained caloric value of ethanol palm sap is 10.126 kcal/g, while the premium is
 171 11.414 kcal/g. After mixing, the highest heating value of the MF was 11.107 kcal/g and the
 172 lowest was 9.445 kcal/g (**Table 4**).

173 **Table 4.** MF calorific values for various concentrations between bioethanol and premium.

No.	Comparison of fuel mixes (%)		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

174

175 **Table 4** shows that the higher the concentration of bioethanol palm sap added to the
176 premium, the MF's calorific value decreases. This decrease is caused by the difference in
177 the heating value between the two fuels. The results of this study are in line with the research
178 of Budiprasojo and Pratama ³⁹ who reported that low heating value of fuel can affect high
179 heating value if mixed.

180 The National Standards Agency (BSN) has set bioethanol quality standards with a
181 minimum heating value of 5,000 kcal/g.⁴⁴ Based on the quality standards set by BSN, the
182 MF bioethanol and premium produced in this study were in accordance with the standards.

183 **Table 5.** Results of variance analysis two-factor for MF calorific value parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	0.870752	4	0.217688	0.005	0.99994	3.259
Columns	18509.81	3	6169.936	144.894	1.09E-09	3.490
Error	510.9863	12	42.58219			
Total	19021.66	19				

184

185 The results analysis of variance the two-factor show that the calculated F-value
186 (144.894) is greater than the F-table value (3.490) (**Table 5**). This means that the variation
187 in the concentration of bioethanol palm sap has a significant effect ($p > 0.5$) on the heating
188 value of the MF.

189

190 **C. MF Flame Test**

191 MF flame test results on variations in the concentration of palm sap bioethanol and
192 premium showed 2 different types of fire colors namely blue and reddish yellow. MF which
193 contains low concentrations of palm sap bioethanol produces a blue flame, while for high
194 concentrations produces a reddish yellow flame. This is in line with the report of McLinden
195 et al.⁴⁵ that the flame from bioethanol is not only blue, but also reddish yellow. The same
196 thing was reported by Polikarpov et al.⁴⁶ that at the time of combustion a blue flame
197 appeared at the bottom and reddish yellow at the top.

198 The blue combustion results indicate that the methane (CH₄) content in the MF has
199 been completely burned. The results of this study are in line with the research of Susanto et
200 al.⁴⁷ who reported that methane gas was marked with a blue flame. However, if the reddish
201 yellow fire means incomplete combustion and the flame is unstable. Cahyani⁴⁸ also reports
202 that the color of blue flame indicates high ethanol levels.

203 Comparison of the physical and chemical characteristics of the mixed fuel between
204 the palm sap bioethanol and premium from this study with several other studies is shown in

205 **Table 6.**

206 **Table 6.** Comparison of physical and chemical characteristics of mixed fuels.

Combined of fuel mixes	Value			References
	Viscosity at 40°C (mm ² /s)	Calorific (kcal/g)	Flame Test (color)	
Premium of RON 88	7.2	11.414	reddish yellow	[41]
20% bioethanol of liquid polypropylene - 80%	-	11.340	reddish yellow	[39]

Gasoline					
20% bioethanol of pineapple – 80% premium	-	7.331	-		[46]
30% bioethanol of Cassava flours - 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

207

208 The results of the two-factor variance analysis show that the calculated F-value
 209 (68.308) is greater than the F-table value (3.490) (**Table 7**). This means that variations in
 210 the concentration of bioethanol palm sap and premium affect the MF's flame. The blue flame
 211 color indicates high ethanol content.

212 **Table 7.** Results of analysis of variance two-factor of the MF's flame values.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	155.0324	4	38.75809	0.408	0.799	3.259
Columns	19472.58	3	6490.86	68.308	8.23E-08	3.490
Error	1140.277	12	95.02309			
Total	20767.89	19				

213

214

215

CONCLUSIONS AND SUGGESTIONS

216 **A. Conclusions**

217 1. High concentrations of palm sap bioethanol causes the MF viscosity is also higher,
218 but too difficult to obscure.

219 2. High concentrations of bioethanol palm sap can cause a decrease in the heat of MF
220 burns.

221 3. MF flames at a variety of concentrations of bioethanol palm sugar and premium
222 reddish yellow and reddish yellow. The blue color shows high ethanol content, while
223 the reddish yellow color shows low ethanol content.

224

225 **B. Suggestions**

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

229

230 **Acknowledgment**

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232 support provided, so this research activity could be carried out. Acknowledgments were also
233 conveyed to all those who have helped carry out this research.

234

235 **Conflict of Interest**

236 All authors declare that there was no conflict interest between authors and the founder.

237

238

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Physical and Chemical Properties of Mixture Fuels (MF) between Palm Sap (*Arenga Pinnata* MERR) Bioethanol and Premium

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ABSTRACT

Along with the development of the motor vehicle industry technology nowadays, 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 determine the physical and chemical characteristics of the fuel mixture (MF) of palm sap bioethanol with a premium. The results showed that the higher the bioethanol concentration of palm sugar, the higher the MF's viscosity, but the heat of the fuel decreased. This reduction 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 flame is reddish yellow.

Keywords: bioethanol, caloric values, palm sap, flame, viscosity

1. INTRODUCTION

The human need for fuel is currently increasing along with the development of the motor vehicle industry. The largest source of fuel used by motor vehicles comes from fossil fuels.¹ This fossil fuel cannot be expected for a long period because the amount is limited and cannot be renewed.²

Indonesia's petroleum reserves are currently around 7.99 billion barrels. If aren't found new reserves, so it will be predicted to be exhausted within the next 23 years.³ Because it is getting least, it is necessary to find renewable energy sources that can be produced continuously and sustainably.

Several countries have tried to find alternative new and renewable energy sources by utilizing plants that have the potential as raw material for making biofuel, known as biofuels.⁴ As in Indonesia, the government has given attention seriously to the development

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4 of this biofuel by issuing Presidential Instruction No. 1 of 2006 concerning the supply and
5 utilization of biofuel as an alternative fuel.⁵
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8 Bioethanol is one type of biofuel that can replace fossil fuels⁶. The development of
9 bioethanol as an alternative fuel is supported by several factors, including the availability of
10 abundant raw materials and the bioethanol making technology, the existence of market
11 opportunities and promising benefits.^{4,7}
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14 Bioethanol can be produced from various types of plants, such as sugar cane, cassava,
15 corn, sorghum, sugar palm, or other types of plants.⁸ These plants are very abundant in
16 Indonesia because they are easily grown. One of them is sugar palm. These plants contain
17 glucose, fructose, sucrose with a composition of about 0.4-0.5%, 0.5-0.6%, and 10-13%
18 respectively.⁹ The composition of sugar is pretty high, so palm sugar has the potential to be
19 processed into bioethanol.¹⁰ During this time, the use of palm sugar is still very limited,
20 namely only as of the manufacture of palm sugar.¹¹
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27 Bioethanol has become a very interesting topic and is always up to date in various
28 research communities in the world, from the production process to compatibility with motor
29 vehicles.¹² Some of the advantages of using bioethanol, including exhaust emissions more
30 environmentally friendly compared to premium fuels and Pertamina. Bioethanol is a
31 potential fuel because the raw material can be renewed.¹³
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35 Bioethanol production must focus on abundant plants, but it is not for primary food.
36 Some countries such as Brazil produce it from sugar cane, the United States from corn,
37 whereas Indonesia generally comes from sugar cane and palm sugar juice.¹⁴
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40 The bioethanol production process is more complex and requires a large investment.¹⁵
41 The main of an obstacle is bioethanol must be compatible with motor vehicle combustion
42 systems.¹⁶
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46 Among these alternatives, in this paper, the focus of the study is on the physical and
47 chemical properties of the mixture fuel (MF) between palm sap bioethanol with premium.
48 Although there have been studies focusing on aspects of bioethanol production.¹⁷⁻¹⁸, it is
49 still urgent to conduct research that focuses on the disclosure of the physical and chemical
50 properties of the sugar palm bioethanol after it is mixed with premium fuel.
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54 Many researchers have developed palm sap into bioethanol as a fuel mixture for motor
55 vehicles.⁷ However, the valid data has not been found about the viscosity, caloric value, and
56 flame after the palm sap bioethanol is mixed with premium.²⁰ Therefore, it is urgent to be
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investigated to find out the viscosity, caloric value, and flame as physical and chemical characteristics of motor vehicle fuel.

2. MATERIALS AND METHODS

Material and Tools. The ingredients used are palm sap bioethanol and premium. These ingredients are mixed with various variations of concentration (Table 1).

Table 1. Variation of concentrations between palm sap bioethanol with premium

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

MF Viscosity Measurement. The MF viscosity is measured using an open gravity capillary viscometer in the temperature range of 20-30°C.¹⁹ Mathematically the MF viscosity equation can be written:²⁰

$$F = \eta A \frac{V}{L}$$

with, F = force on the surface of the liquid, η = coefficient of fluid viscosity (Ns / m²), A = liquid area (m²), V = moving wall velocity (m / s), L = distance of the two surfaces (m).

Measurement of MF Caloric Value. The MF calorie value measurement using 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:²¹

$$q_{\text{reaction}} = - (q_{\text{water}} + q_{\text{bomb}}) \quad (1)$$

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

$$Q_{\text{air}} = m.c.\Delta T \quad (2)$$

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4 where, m = mass of water (g), c = heat type of water (J/kg°C), and ΔT = temperature change
5
6 (°C).
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8 The amount of heat absorbed by the bomb calorie meter can be calculated using the
9
10 formula:

$$11 \quad q_{\text{bomb}} = c_{\text{bomb}} \cdot \Delta T \quad (3)$$

12
13 where, c_{bomb} = heat capacity of bomb (J/kg°C) and ΔT = temperature change (°C).
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16 **MF Flame Test.** The MF flame tests were carried out to detect the presence of metal ion
17 elements in MF bioethanol at a premium by dipping cotton bad cotton washed with
18 hydrochloric acid in the MF liquid and then igniting it with fire. This flame test is to provide
19 qualitative information on the colors arising from the combustion process based on the light
20 spectrum of the electromagnetic radiation elements present in the sample. The flame that
21 arises will be adjusted to the table of chemical elements with the flame.
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28 **Data Analysis.** The effect of variations in the concentration of bioethanol of palm sugar and
29 premium on the physical and chemical characteristics of the MF was analyzed using an
30 analysis of variance (ANOVA). If the F-count value is greater than the F-crit, it means that
31 there is a significant difference in the significance level of 95%. The most influential
32 variable can be identified using the DMRT (Duncan's Multiple Ranges Test).
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39 3. RESULT AND DISCUSSIONS

40 **The MF Viscosity.** The MF viscosity in various concentrations between palm sap
41 bioethanol and premium is shown in Table 2. In the table, it appears that the higher the
42 concentration of the sugar palm bioethanol, the higher the MF's viscosity. Fuel viscosity can
43 affect the fogging process. Fuels that have high viscosity are difficult to atomize.
44 Conversely, fuels with low viscosity are easier to be atomized, easier to ignite, and also the
45 combustion more perfect.
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51 The results of the bioethanol test of palm sap were obtained a value of 4.7 cSt, while
52 the premium was 7.2 cSt.²¹ After mixing was shown that the higher the concentration of
53 palm sap bioethanol, the lower the MF's viscosity (Table 2). It was predicted to be
54 influenced by the viscosity of bioethanol which is lower than the premium viscosity. These
55 results are in line with the researcher reported by Yuliyanto and Widodo²² that the higher
56 the addition of bioethanol, the lower the viscosity of the fuel.
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Table 2. The MF viscosity at various concentrations between bioethanol and premium.

No.	Comparison of MF (%)		The MF viscosity (cSt)
	Bioethanol of palm sap (ml)	Premium (ml)	
1	10	90	5.4
2	15	85	5.4
3	20	80	4.6
4	25	75	4.5
5	30	70	4.3

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 3).

Table 3. Results analysis of variance two factors of MF viscosity parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	1.223	4	0.30575	0.007	0.999	3.259
Columns	19625.3	3	6541.7653	153.963	7.647E-10	3.490
Error	509.869	12	42.489083			
Total	20136.39	19				

The MF Caloric Value. The caloric value of the fuel shows the heat produced from the combustion process. If the combustion is perfect, the thermal energy will be optimal. Test results separately obtained caloric value of ethanol palm sap is 10,126 kcal/kg, while the premium is 11,414 kcal/kg. After mixing, the highest heating value of the MF was 11,107 kcal/kg and the lowest was 9,445 kcal/kg (Table 4.).

Table 4. The MF caloric values for various concentrations between bioethanol and premium.

No.	Comparison of fuel mixes (%)		The MF Caloric values (kcal/kg)
	Bioethanol of palm sap (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

Table 4 shows that the higher the concentration of palm sap bioethanol was added to the premium, the MF's caloric value decreases. The reduction is caused by the difference in the caloric value between the two fuels. The results of this study are in line with the research of Adityo and Budiprasojo²³ who reported that high caloric value will be low if mixed with low caloric value.

The National Standards Agency (NSA) has set bioethanol quality standards with a minimum caloric value of 5,000 kcal/kg.²³ Based on the quality standards set by NSA²⁴, the MF bioethanol and premium produced in this study were following the standards.

Table 5. Results of analysis of variance two-factor for MF caloric value parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	0.870752	4	0.217688	0.005	0.99994	3.259
Columns	18509.81	3	6169.936	144.894	1.09E-09	3.490
Error	510.9863	12	42.58219			
Total	19021.66	19				

The results of the analysis of variance two-factor show that the value F-calculated (144.894) 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 caloric value of the MF.

MF Flame Test. The MF flame test results on a variety of concentrations of palm sap and bioethanol concentrations showed blue and reddish-yellow color. Low concentrations of palm sap bioethanol obtained blue flame, while high concentrations obtained reddish-yellow flame (Figure 1). This is in line with the report of McLinden et al.²⁵ that the flame from bioethanol is not only blue but also reddish-yellow. The same reported by Polikarpov et al.²⁶ that at the time of combustion a blue flame appeared at the bottom and reddish yellow at the top.

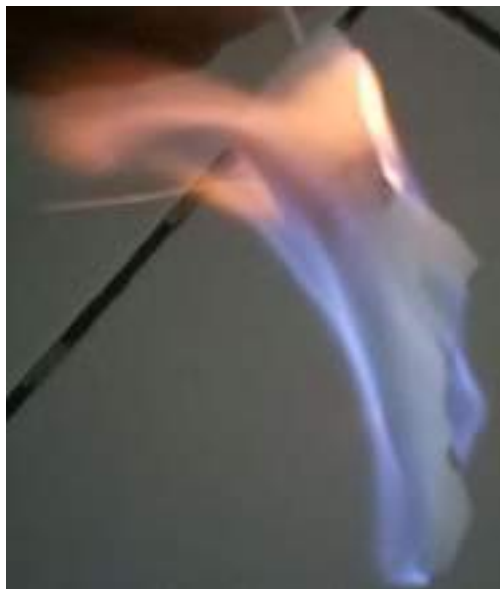


Figure 1. MF flame test

The blue flame indicates the methane gas content (CH_4) on the MF which can be used as fuel for motor vehicles. The results of this study are in line with the research of Susanto et al.²⁷ and Fahrizal et al.²⁸ who reported that methane gas was marked with a blue flame. If the reddish-yellow fire means that the combustion is incomplete and the flame is unstable. Cahyani and Anisah²⁹ also report that the color of the blue flame indicates high ethanol levels.

Table 6. Results analysis of variance two-factor of the MF's flame values.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	155.0324	4	38.75809	0.408	0.799	3.259
Columns	19472.58	3	6490.86	68.308	8.23E-08	3.490
Error	1140.277	12	95.02309			
Total	20767.89	19				

The results of the analysis of variance two-factor show that the F-calculated value (68.308) is greater than the F-table value (3.490) (Table 6). This means that variations in the concentration of palm sap bioethanol and premium affect the MF's flame. The blue flame color indicates high ethanol content.

CONCLUSIONS AND SUGGESTIONS

A. Conclusions

- 1
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- 4
- 5 1. High concentrations of sugar palm bioethanol caused the MF viscosity is also higher,
- 6 but too difficult to obscure.
- 7
- 8 2. High concentrations of palm sap bioethanol can cause a reduction in the heat of MF
- 9 burns.
- 10
- 11 3. MF flames at a variety of concentrations of palm sugar bioethanol and premium are
- 12 blue and reddish-yellow. The blue color shows high ethanol content, while the reddish-
- 13 yellow shows low ethanol content.
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18 **B. Suggestions**

19 The physical and chemical properties of MF fuels still need to be studied
20 comprehensively by conducting MF trials on various types of motorized vehicles. Besides,
21 research is needed for mixing bioethanol with other types of fuel further.
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1. The official language is appropriate. There are some spelling mistakes
2. The authors should be add the bioethanol production
3. The authors should be add the equipment which using to measure the properties of fuel and accuracy of the equipment
4. The authors should be compare the result with other study
5. The authors should be uncertainty experiment
6. The authors should be calculate energy consumption of the bioethanol production
7. The authors can added the reference related to bioethanol as below:
 - A perspective on bioethanol production from biomass as alternative fuel for spark ignition engine
 - Optimization of Bioethanol Production from Sorghum Grains using Artificial Neural Networks Integrated with Ant Colony
 - Enzymatic Hydrolysis Using Ultrasound for Bioethanol Production from Durian (*Durio zibethinus*) Seeds as Potential Biofuel

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**Physical and Chemical Properties of Mixture Fuels (MF)
between Palm Sap (Arenga Pinnata MERR) Bioethanol and
Premium**

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5 ***Pinnata* MERR) Bioethanol and Premium**
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31
32 **ABSTRACT**
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34 Along with the development of the motor vehicle industry technology at this time, the fuel
35 demand is also increasing, while the supply is running low. Thus alternative fuels are needed
36 to meet these energy needs. This study aims to explain the physical and chemical
37 characteristics of the fuel mixture (MF) between palm sap bioethanol with a premium. The
38 results showed that the higher the bioethanol concentration of palm sap, the higher the MF's
39 viscosity, but the heat of the fuel decreased. This decrease is caused by differences in the
40 heating value of the two fuels. The MF's high heat burn value is blue, while the low heat
41 value of flame is reddish yellow. The results of this study are very important as a basis for
42 the development of bioethanol from palm sap as an environmentally friendly vehicle fuel
43 substitution material.
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57 **Keywords:** bioethanol, calorific values, palm sap, flame, viscosity
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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 comes from fossil fuels.² This fossil fuel cannot be expected for a long period because the amount is limited and 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 0.5 percent per year.⁵

Brazil develops bioethanol from sugar cane at a low cost of 14 cents a dollar/liter. Thailand with tapioca 18.5 cents a dollar/liter, and America using corn 25.5 cents a dollar/liter.¹⁰ The success of Brazil in producing bioethanol from sugar cane on an industrial scale has led many countries to follow these strategic steps. Currently in Brazil motorcyclists can fill fuel tanks with a mixture of 24% ethanol and 76% gasoline.¹¹ As in 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, 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) is

very abundant in Indonesia (Table 1), so it has the potential to be processed into bioethanol.²⁰ This plant contains glucose, fructose, sucrose with a composition of about 0.4-0.5%, 0.5-0.6%, and 10-13% respectively.^{21, 22} The sugar content is quite high, so that palm sap has the potential to be processed into bioethanol.²³ So far, the use of palm sap is still very limited, namely only as of the manufacture of palm sugar.²⁴

Table 1. Estimation area of palm sap in Indonesia²⁵

Province	An estimate of the total area (ha)
Nanggro Aceh Darussalam	4,081
North Sumatera	4,357
West Sumatera	1,830
Bengkulu	1,748
West Jawa	13,135
Banten	1,448
Central Jawa	3,078
South Kalimantan	1,442
North Sulawesi	6,000
South Sulawesi	7,293
Southeast Sulawesi	3,070
Maluku	1,000
North Maluku	2,000
Papua	10,000
Total	60,482

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4 Bioethanol has become a very interesting topic and is always up to date in various
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6 research communities in the world, from the production process to compatibility with motor
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8 vehicles.^{1, 26} Some of the advantages of using bioethanol, including exhaust emissions more
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10 environmentally friendly compared to premium fuels and Pertamina.^{27, 28} Bioethanol is a
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12 potential fuel because the raw material can be renewed.²⁹
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16 Bioethanol production must focus on abundant plants, but its use is not for basic food
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18 needs. Brazil has been applying the bioethanol-gasoline mixture since the 1930s and
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20 increased 50% in 1943.³⁰ Indonesia as a country that has a relatively similar geographical
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22 condition to Brazil, has the potential to follow Brazil's path in utilizing abundant natural
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24 resources to meet domestic energy needs. This is in line with Indonesia's transportation
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26 system which mostly uses gasoline.¹³ Bioethanol can bring practical benefits if applied
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28 nationally in Indonesia.²⁸
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32 Physical and chemical characteristics of bioethanol are very possible to be mixed with
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34 gasoline.³¹ The need to meet energy demand with apprehensive environmental impacts and
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36 limited fuel stock from fossil fuels has led researchers to look for renewable and
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38 environmentally friendly energy resources, one of which is bioethanol.³² However, the
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40 bioethanol production process is more complex and requires large investment capital.³³ The
41
42 main obstacle is bioethanol must be compatible with motor vehicle combustion systems.³⁴
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46 Based on the arguments above, in this paper, the focus of the study is on the physical
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48 and chemical properties of the fuel mixture of palm sap bioethanol with premium (MF).
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50 Although there have been studies focusing on aspects of bioethanol production,^{35, 36} it is
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52 still urgent to conduct research that focuses to explain of the physical and chemical
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54 properties of the palm sap bioethanol after it is mixed with premium fuel.
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58 Many researchers have developed palm sap into bioethanol as a fuel mixture for motor
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60 vehicles.^{20, 37, 38, 39} However, no valid data has been found about the viscosity, calorific

value, and flame after the palm sap bioethanol are mixed with premium. Therefore, it is important to examine to 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 MATERIAL

2.1. Material and Tools

The materials used are bioethanol from distillation palm sap (*Arenga Pinnata* MERR) (Fig. 1) and premium type fuel with octane number 88 obtained directly from refueling in Mataram, West Nusa Tenggara Province, Indonesia.

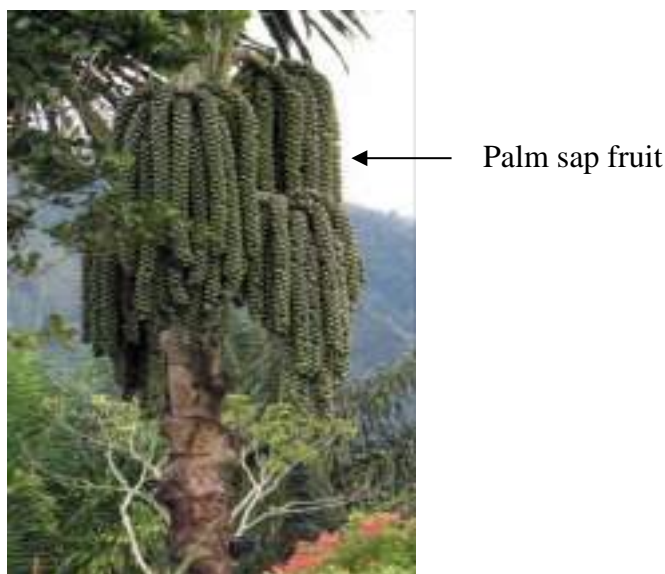


Fig. 1. Palm sap is widely cultivated in Indonesia.²⁰

These ingredients are mixed with various variations of concentration (Table 1).

Table 1. Variation of concentrations between bioethanol palm sap with premium

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 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 Mathematical the MF viscosity equation can be written:⁴¹

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

with, F = force on the surface of the liquid, η = coefficient of fluid viscosity (Ns/m²), A = liquid area (m²), V = moving wall velocity (m / s), L = distance of the two surfaces (m).

2.3. Measurement of MF Calorific Value

MF burn calorie measurement using bomb calorimeter type IKA C-5000 (**Fig. 2**). 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:

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



Fig. 2. Bomb calorimeter type IKA C-5000.²⁰

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

$$Q_{\text{water}} = m \cdot c \cdot \Delta T \quad (3)$$

where, m = mass of water (g), c = heat type of water ($\text{J}/\text{kg}^\circ\text{C}$), and ΔT = temperature change ($^\circ\text{C}$).

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

$$q_{\text{bomb}} = c_{\text{bomb}} \cdot \Delta T \quad (3)$$

where, c_{bomb} = heat capacity of bomb ($\text{J}/\text{g}^\circ\text{C}$) and ΔT = temperature change ($^\circ\text{C}$).

2.4. MF Flame Test

Flame tests were carried out to detect the presence of metal ion elements in MF bioethanol at a premium by dipping cotton bad cotton washed with hydrochloric acid in the MF liquid and then igniting it with fire (**Fig. 3**). 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 the flame.⁴²



Fig. 3. MF bioethanol and premium flame test.²⁰

2.5. Data Analysis

The effect of variations in the concentration of palm sap bioethanol and premium 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 Ranges Test).

3. RESULT AND DISCUSSIONS

3.1. Viscosity of MF

Palm sap bioethanol produced in this study is shown in **Fig. 4**. MF viscosity in various concentrations of bioethanol and premium is shown in **Table 2**. 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 be atomized. Fuels that are more easily atomized, are also easier to ignite and also more perfect combustion.



Fig. 4. Palm sap bioethanol produced in this study.²⁰

The results of the bioethanol test of palm sap were obtained a value of 4.7 mm²/s, while the premium was 7.2 mm²/s.⁴² After mixing the data obtained that the higher the concentration of bioethanol palm sap, the lower the MF's viscosity (**Table 2**). 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 Sulistiana² that the higher the addition of bioethanol, the lower the viscosity of the fuel.

Table 2. MF viscosity at various concentrations between bioethanol and premium.

No	Comparison of fuel mixes (%)		The 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	4.6
4	25	75	4.5
5	30	70	4.3

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 bioethanol palm sap has a significant effect ($p > 0.5$) on the MF's viscosity (**Table 3**).

Table 3. Results of analysis variance two factors of MF viscosity parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	1.223	4	0.30575	0.007	0.999	3.259
Columns	19625.3	3	6541.7653	153.963	7.647E-10	3.490
Error	509.869	12	42.489083			
Total	20136.39	19				

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 caloric value of ethanol palm sap is 10.126 kcal/g, while 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 4**).

Table 4. MF calorific values for various concentrations between bioethanol and premium.

No.	Comparison of fuel mixes (%)		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

Table 4 shows that the higher the concentration of bioethanol palm sap added to the premium, the MF's calorific value decreases. 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 Pratama³⁹ who reported that 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 5,000 kcal/g.⁴⁴ Based on the quality standards set by BSN, the MF bioethanol and premium produced in this study were following the standards.

Table 5. Results of variance analysis two-factor for MF calorific value parameters.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	0.870752	4	0.217688	0.005	0.99994	3.259
Columns	18509.81	3	6169.936	144.894	1.09E-09	3.490
Error	510.9863	12	42.58219			
Total	19021.66	19				

The results analysis of variance the two-factor show that the calculated F-value (144.894) is greater than the F-table value (3.490) (**Table 5**). This means that the variation in the concentration of bioethanol palm sap 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 showed 2 different types of fire colors namely blue and reddish-yellow. MF which contains low concentrations of palm sap bioethanol produces a blue flame, while for high concentrations produces a reddish yellow flame. This is in line with the report of McLinden et al.⁴⁵ that the flame from bioethanol is not only blue but also reddish-yellow. The same thing was reported by Polikarpov et al.⁴⁶ that at the time of combustion a blue flame appeared at the bottom and reddish yellow at the top.

The blue combustion results indicate that the methane (CH₄) content in the MF has been 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, if the reddish-yellow fire means incomplete combustion and the flame is unstable. Cahyani⁴⁸ 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 from this study with several other studies is shown in

Table 6.

Table 6. Comparison of physical and chemical characteristics of mixed fuels.

Combined of fuel mixes	Value			References
	Viscosity at	Calorific	Flame Test	
	40°C (mm ² /s)	(kcal/g)	(color)	
The premium of RON 88	7.2	11.414	reddish-yellow	[41]
20% bioethanol of liquid polypropylene - 80%	-	11.340	reddish-yellow	[39]

Gasoline					
20% bioethanol of	-	7.331	-	[46]	
pineapple – 80%					
premium					
30% bioethanol of	-	23	-	[38]	
Cassava flours - 70%					
gasoline					
30% bioethanol of sugar	2.2	15	-	[37]	
molasses - 70% gasoline					
30% palm sap bioethanol	4.7	10.126	reddish-yellow	This	
- 70% premium				research	

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 7**). This means that variations in the concentration of bioethanol palm sap and premium affect the MF's flame. The blue flame color indicates high ethanol content.

Table 7. Results of analysis of variance two-factor of the MF's flame values.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Rows	155.0324	4	38.75809	0.408	0.799	3.259
Columns	19472.58	3	6490.86	68.308	8.23E-08	3.490
Error	1140.277	12	95.02309			
Total	20767.89	19				

4. CONCLUSIONS

The high concentrations of palm sap bioethanol causes the MF viscosity is also higher, but too difficult to obscure. The higher the concentration of bioethanol palm sap, the lower the heating value of MF. The MF flame test results on variations in the concentration of bioethanol palm sap and premium showed 2 different types of fire 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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Conflict of Interest

All authors declare no conflict of interest.

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Title: "Physical and Chemical Properties of Mixture Fuels (MF) between Palm Sap (Arenga Pinnata MERR) Bioethanol and Premium"

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7 meet these energy needs. This study aims to explain the physical
8 and chemical characteristics of a fuel mixture (MF) between palm
9 sap bioethanol with premium fuel. The results showed that the
10 higher the bioethanol concentration of the palm sap, the higher the
11 MF's viscosity, but the lower the heat of the fuel. This decrease is
12 caused by differences in the heating value of the two fuels. The
13 MF's high heat burn value is blue, while the low heat value of the
14 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
15 environmentally friendly vehicle-fuel substitute material.



1. INTRODUCTION

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

21 Bioethanol has been developed in many countries as an energy
22 source for fossil energy substitution.^{5,6} Bioethanol production in
23 the United States is developed from corn to apply bioethanol
24 energy.⁷ Brazil has been developing bioethanol sourced from
25 sugar cane by conducting tests on vehicles since 1925.⁸ China
26 and Thailand develop bioethanol from cassava.⁹ South Korea
27 has been developing biodiesel since 2002, and its consumption is
28 estimated to increase by 0.5% per year.⁵

29 Brazil develops bioethanol from sugar cane at a low cost of
30 14 cents a dollar per liter, Thailand with tapioca, 18.5 cents a
31 dollar per liter, and America using corn, 25.5 cents a dollar per
32 liter.¹⁰ The success of Brazil in producing bioethanol from sugar
33 cane on an industrial scale has led many countries to follow their
34 strategic steps. Currently, in Brazil, motorcyclists can fill fuel
35 tanks with a mixture of 24% ethanol and 76% gasoline.¹¹ As for
36 Indonesia, the government has given serious attention to devel-
37 oping bioethanol by issuing Presidential Instruction no. 1 of 2006
38 regarding the supply and use of biofuel as an alternative fuel.^{12,13}

39 Bioethanol is one type of biofuel that can be used as a sub-
40 stitute for fossil fuels.^{14,15} The use of bioethanol as a fuel mixture
41 is important to save the earth from global warming.¹⁶ The devel-
42 opment of bioethanol as an alternative fuel must be supported by
43 several factors, including the availability of abundant raw materials,
44 bioethanol-making technology available, and the existence of
45 promising market opportunities and benefits.^{17,18}

Bioethanol can be produced from various types of plants, such 46
as sugar cane, cassava, corn, sorghum, palm sap, or other types of 47
plants.^{18,19} Palm sap (*Arenga pinnata* Merr, *A. pinnata*) is very 48
abundant in Indonesia (Table 1), so it has the potential to be 49
processed into bioethanol.²⁰ This plant contains glucose, 50

Table 1. Estimated Area of Palm Sap in Indonesia²⁵

province	an estimate of the total area (ha)
Nangro Aceh Darussalam	4081
North Sumatera	4357
West Sumatera	1830
Bengkulu	1748
West Jawa	13,135
Banten	1448
Central Jawa	3078
South Kalimantan	1442
North Sulawesi	6000
South Sulawesi	7293
Southeast Sulawesi	3070
Maluku	1000
North Maluku	2000
Papua	10,000
total	60,482

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51 fructose, and sucrose with a composition of approximately 0.4–
52 0.5%, 0.5–0.6%, and 10–13%, respectively.^{21,22} The sugar con-
53 tent is quite high, so palm sap has the potential to be processed
54 into bioethanol.^{2,3} So far, the use of palm sap is still very limited,
55 namely, only in the manufacture of palm sugar.²⁴

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

63 Bioethanol production must be focused on abundant plants,
64 but its use is not for basic food needs. Brazil has been applying
65 the bioethanol–gasoline mixture since the 1930s and increased
66 its application by 50% in 1943.³⁰ Indonesia as a country that has
67 a relatively similar geographical condition to that of Brazil has
68 the potential to follow Brazil's path in utilizing abundant natural
69 resources to meet domestic energy needs. This is in line with
70 Indonesia's transportation system, which mostly uses gasoline.¹³
71 Bioethanol can bring practical benefits if applied nationally in
72 Indonesia.²⁸

73 It is very possible to mix the physical and chemical char-
74 acteristics of bioethanol with those of gasoline.³¹ The need to
75 meet energy demand with apprehensive environmental impacts
76 and limited fuel stock from fossil fuels has led researchers to look
77 for renewable and environmentally friendly energy resources,
78 one of which is bioethanol.³² However, the bioethanol produc-
79 tion process is more complex and requires a large investment
80 capital.³³ The main obstacle is that bioethanol must be com-
81 patible with motor vehicle combustion systems.³⁴

82 Based on the arguments above, in this paper, the focus of the
83 study is on the physical and chemical properties of the fuel mix-
84 ture of palm sap bioethanol with premium fuel (MF). Although
85 there have been studies focusing on aspects of bioethanol
86 production,^{35,36} it is still urgent to conduct research that focuses
87 on explaining the physical and chemical properties of palm sap
88 bioethanol after it is mixed with premium fuel.

89 Many researchers have developed palm sap into bioethanol as
90 a fuel mixture for motor vehicles.^{20,37–39} However, no valid data
91 has been found about the viscosity, calorific value, and flame
92 after the palm sap bioethanol is mixed with premium fuel. There-
93 fore, it is important to examine and reveal the viscosity, calorific
94 value, and flame as physical and chemical characteristics of fuel
95 for motor vehicles. Thus, the purpose of this study is to explain
96 the physical and chemical characteristics of a fuel mixture
97 between palm sap bioethanol and premium.

2. METHOD AND MATERIALS

98 **2.1. Materials and Tools.** The materials used are bio-
99 ethanol from distilled palm sap (*A. pinnata* MERR) (Figure 1)
100 and premium-type fuel with an octane number of 88 obtained
101 directly from refueling in Mataram, West Nusa Tenggara Province,
102 Indonesia.

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

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

108 **2.2. MF Viscosity Measurement.** MF viscosity is measured
109 using an open gravity capillary viscometer in the temperature
110 range of 20–30 °C.⁴⁰ Mathematically, the MF viscosity equation
111 can be written⁴¹ as



Figure 1. Palm sap is widely cultivated in Indonesia.

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



Figure 2. MF bioethanol and premium flame test.

$$F = \eta A \frac{V}{L} \quad (1) \quad 112$$

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).
116

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
121

$$r_{\text{reaction}} = -(q_{\text{air}} + q_{\text{bomb}}) \quad (2) \quad 122$$

The amount of heat absorbed by water can be calculated using
the formula
124

$$Q_{\text{water}} = mc\Delta T \quad (3) \quad 125$$



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	4.6
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

$$q_{\text{bomb}} = c_{\text{bomb}} \Delta T \quad (4)$$

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

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

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.

The result of the bioethanol test of palm sap was a value of 4.7 mm²/s, while that of the premium fuel was 7.2 mm²/s.⁴² 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 Sulistiana² 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 Pratama³⁹ 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	0.870752	4	0.217688	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

combined of fuel mixes	value			references
	viscosity at 40 °C (mm ² /s)	calorific (kcal/g)	flame test (color)	
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		46
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 (CH₄) 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. Cahyani⁴⁸ 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.

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	8.23×10^{-8}	3.490
error	1140.277	12	95.02309			
total	20767.89	19				

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

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Title: Physical and Chemical Properties of Mixture Fuels (MF) between Palm Sap (Arenga Pinnata MERR) Bioethanol and Premium

Authors: * Ansar, * Sukmawaty, Sirajuddin Haji Abdullah Si, * Nazaruddin Ir, Erna Safitri .

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