

THE EFFECT OF THE COMPOSITION OF PALM SUCCUS BIOETHANOL AS A BLENDING AGENT IN PERTALITE (RON 90) FUEL ON THE PERFORMANCE OF A 4-STROKE GASOLINE ENGINE

Al Kautsar^{1*}, Maulana Muhammad¹, Faisal Muhtadin¹, Mahyuddin¹, Lindawati¹

¹ Department of Mechanical Engineering, Faculty of Engineering, Universitas Abulyatama, Jl. Blang Bintang Lama Km. 8.5, Lampoh Keude, Kuta Baro District, Aceh Besar Regency, Aceh 24415, Indonesia.

*Email: alkautsarm951@gmail.com

ABSTRACT

The research titled “The Effect of Palm Sap Bioethanol Composition as an Additive in Pertalite RON 90 Fuel on the Performance of a 4-Stroke Gasoline Engine” was motivated by the increasing demand for energy and the high dependence on fossil fuels, which contribute to environmental pollution. Therefore, the utilization of renewable energy has become one of the solutions that can be developed, one of which is through the use of bioethanol derived from sugar palm sap as an alternative fuel. Sugar palm sap bioethanol has a sufficiently high alcohol content, making it a potential additive in gasoline to improve combustion quality. This study aims to analyze the effect of palm sap bioethanol blend compositions in Pertalite RON 90 fuel on the exhaust gas emission characteristics of a four-stroke gasoline engine. The research method employed was an experimental approach, involving RON (Research Octane Number) testing and exhaust gas emission testing on a gasoline engine using various fuel blend variations. The tests were conducted using a gas analyzer to measure exhaust emission parameters, including carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO₂), oxygen (O₂), and the lambda value, which indicates the air-to-fuel ratio in the combustion process. The results of the study indicate that adding palm sap bioethanol to Pertalite fuel tends to reduce CO and HC emissions, suggesting more complete combustion within the combustion chamber. Additionally, the increase in CO₂ and O₂ levels indicates improved oxidation during combustion as the percentage of bioethanol in the fuel mixture increases. The lambda values obtained are within a range close to stoichiometric conditions, indicating a better balance of the air-to-fuel ratio during the combustion process. Based on these research results, it can be concluded that sugar palm sap bioethanol has the potential to be used as a more environmentally friendly fuel additive in gasoline engines without requiring significant engine modifications.

Keywords: palm sap bioethanol, Pertalite RON 90, exhaust emissions, gasoline engines, alternative fuels.

1. INTRODUCTION

1.1 Background

The rapid growth of the transportation sector in Indonesia has significantly increased the number of motor vehicles and consequently raised national fuel consumption. Fossil fuel-based gasoline, particularly Pertalite (RON 90), remains the dominant fuel used by the public due to its affordability and accessibility. However, the continuous dependence on petroleum fuels has become a major concern because fossil fuel reserves are limited and their combustion contributes to

environmental pollution through exhaust emissions such as carbon

monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO₂). These emissions are known to negatively affect air quality and contribute to global warming. Therefore, the development and utilization of renewable and environmentally friendly alternative fuels have become increasingly important in supporting sustainable energy systems.

One promising renewable fuel is bioethanol, which is produced through the

fermentation of biomass containing sugar, starch, or cellulose. Bioethanol possesses several advantageous properties, including a high octane number, oxygen content, and cleaner combustion characteristics compared to conventional gasoline. The octane number of bioethanol ranges from approximately 108–110, enabling it to improve combustion quality and reduce knocking in spark ignition engines. In addition, the oxygen contained in bioethanol promotes more complete combustion, which potentially decreases harmful exhaust emissions and improves engine efficiency.

Indonesia has abundant natural resources that can be utilized for bioethanol production, one of which is sugar palm sap derived from the aren tree (*Arenga pinnata*). Sugar palm sap contains high concentrations of fermentable sugars, typically ranging from 10–15% (b/v), making it an excellent raw material for bioethanol production through fermentation and distillation processes. Furthermore, aren trees grow naturally in tropical regions and do not directly compete with staple food crops, making them a sustainable feedstock for renewable fuel development. The utilization of sugar palm sap as a bioethanol source not only supports energy diversification programs but also provides economic opportunities for rural communities through the development of local bioenergy industries.

In automotive applications, bioethanol can be blended with gasoline as an oxygenated fuel additive to improve fuel characteristics. Several studies have reported that ethanol-gasoline blends can increase octane ratings, enhance combustion efficiency, and reduce exhaust emissions from spark ignition engines. The presence of oxygen molecules in ethanol assists the oxidation process during combustion, thereby lowering the formation of incomplete combustion products such as CO and HC. However, excessive ethanol content may reduce the calorific value of the fuel mixture and

affect engine performance due to differences in fuel properties such as volatility and air–fuel ratio requirements. Therefore, determining the optimal blending ratio is essential to achieve improved combustion performance while maintaining engine stability.

Pertalite, a gasoline fuel with a Research Octane Number (RON) of 90, is widely used in Indonesia and is suitable for medium-compression gasoline engines. Although several studies have investigated ethanol-blended fuels, research focusing specifically on sugar palm sap bioethanol as an additive for Pertalite fuel remains limited. Moreover, the influence of sugar palm sap bioethanol on exhaust emission characteristics and fuel octane value in four-stroke gasoline engines requires further investigation. Understanding these effects is important to evaluate the feasibility of utilizing locally produced bioethanol as a renewable fuel additive in practical automotive applications.

Therefore, this study aims to analyze the effect of sugar palm sap bioethanol blended with Pertalite (RON 90) on the exhaust gas emission characteristics and octane value of a four-stroke gasoline engine. Variations of bioethanol concentrations were prepared in several compositions, namely E5, E10, E15, and E20. The emission parameters evaluated include carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO₂), and oxygen (O₂), while fuel quality was analyzed through Research Octane Number (RON) testing. The results of this research are expected to provide scientific information regarding the potential of sugar palm sap bioethanol as an environmentally friendly fuel additive and contribute to the development of renewable energy utilization in Indonesia.

2. RESEARCH METHODS

Research methodology

2.1 Research Place

This research was conducted at two different locations based on the type of

testing performed. The Research Octane Number (RON) testing of the fuel samples was carried out at the Chemical Engineering Laboratory of Politeknik Negeri Lhokseumawe. Meanwhile, the exhaust gas emission testing was conducted at the Automotive Workshop of Balai Pelatihan Vokasi dan Produktivitas (BPVP) Banda Aceh using a gas analyzer on a four-stroke gasoline engine motorcycle. The overall research activities, including bioethanol preparation, fermentation, distillation, fuel blending, and data analysis, were conducted from the approval date of the final project proposal until the completion of the study in 2026.

2.2 Tools and Materials

2.2.1 Tools used

Distillation apparatus, airtight pot, copper pipe (¼ inch), tubeless tire valve, gasket sealant, hot water hose, pipe clamps, beaker glass, bioethanol collection container, screwdriver, cetane-octane analyzer, gas analyzer, and Honda CB150R LED motorcycle engine.

2.2.2 Materials used

The materials used in this research include sugar palm sap (*Arenga pinnata*), yeast (*Saccharomyces cerevisiae*), Pertalite (RON 90), and sugar palm sap bioethanol with fuel blend variations of E5, E10, E15, and E20.

2.3 Experimental Treatment Design

2.3.1 Independent Variables

This study used an experimental method with different variations of sugar palm sap bioethanol blended with Pertalite (RON 90). The experimental treatments consisted of five fuel compositions, namely:

E0 : 100% Pertalite

E5 : 5% bioethanol + 95% Pertalite

E10 : 10% bioethanol + 90% Pertalite

E15 : 15% bioethanol + 85% Pertalite

E20 : 20% bioethanol + 80% Pertalite

Each fuel sample was tested to determine its Research Octane Number (RON) and exhaust gas emission characteristics on a four-stroke gasoline engine using a gas analyzer. The emission parameters observed included carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO₂), and oxygen (O₂).

3. RESULTS AND DISCUSSION

3.1 Results of the Fermentation and Distillation Process Bioethanol Nira Sugar palm

Results of the Fermentation Process

Fermentation process done use sap sugar palm as material standard with addition of baker's yeast (*Saccharomyces cerevisiae*) which is more formerly destroyed before mixed to in sap sugar palm. Yeast activation is carried out For ensure microorganisms is at in condition active so that capable convert sugar content in sap sugar palm become alcohol optimally. During the fermentation process taking place, happening formation carbon gas bubbles dioxide (CO₂) and changes in the aroma of the liquid increasing fermentation resembles the aroma of alcohol. This is show that reaction fermentation walk with good. Besides that, the sweet taste of the sap sugar palm reduce in a way significant, which indicates that sugar has converted become ethanol.

Fermentation in progress for 7 days produce fluid fermentation with content enough alcohol For to be continued to stage distillation. Success of the fermentation process This show that use of baker's yeast with treatment destruction and activation give influence positive to effectiveness of the fermentation process bioethanol from sap sugar palm.

Results of the Distillation Process

Fluid results fermentation furthermore processed through distillation For separate ethanol from mixture fluid fermentation. Distillation

process carried out in the range temperature 78–85 °C which is point boil ethanol . During the heating process , steam ethanol formed streamed through copper pipes going to condenser and undergoes a condensation process become liquid . Distillation results show that from 5 liters sap sugar palm can obtained bioethanol with volume ranging between 0.415 liters.

Variation in the volume of bioethanol produced influenced by the initial sugar content sap sugar palm , efficiency fermentation , as well as stability temperature during the distillation process .

Bioethanol obtained has a distinctive aroma alcohol and visually visible clear , which indicates that the distillation process ongoing with Good. Research Octane Number) Test Results

a) E5 (5% bioethanol + 95% Pertalite)



Figure 4.2 Test Samples (Ron) of Pertalite and mixture Bioethanol

As for the mixture from petrol with a total of 200 ml (one bottle) namely 190 ml Pertalite pure and mixed 10 ml of bioethanol , then obtained level octane 87.7.

b) E10 (10% bioethanol + 90% Pertalite)
 As for the mixture from petrol with a total of 200 ml (one bottle) namely 180 ml Pertalite pure and mixed 20 ml of bioethanol , then obtained level octane 89.0.

c) E15 (15% Bioethanol + 85% Pertalite)
 As for the mixture from petrol with a total of 200 ml (one bottle) namely 170 ml Pertalite pure and mixed 30 ml bioethanol , then obtained level 90.7 octane

d) E20 (20% Bioethanol + 80% Pertalite)

As for the mixture from petrol with a total of 200 ml (one bottle) namely 160 ml Pertalite pure and mixed 40 ml of bioethanol , then obtained level octane 89.7.

e.) E0 (Pertalite)

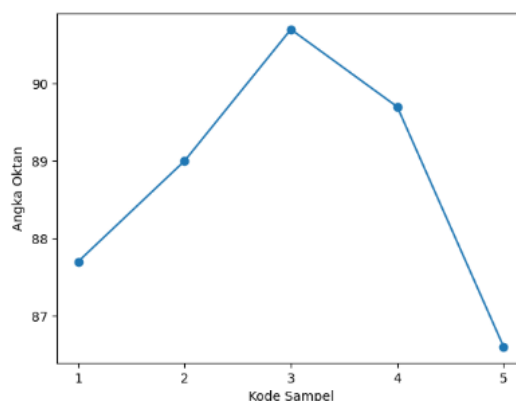
From the results of the RON (octane meter) test , it can be seen that known that octane content of pertalite pure only 86.5. The author purchased Pertalite at the Alue Awe Lhokseumawe gas station.

Table 3.1 RON (research octane number) test results

No.	Sample code	Octane Number
1.	1	87.7
2.	2	89
3.	3	90.7
4.	4	89.7
5.	5	86.6

Figure 4.3 Graph percentage mixture bioethanol with petrol

Based on chart connection between



percentage mixture bioethanol and numbers octane , visible that addition bioethanol to in material burn gas influential significant to improvement number octane . In the E5 mixture , the number octane recorded of 87.7, then increased on E10 mix to 89. Increased This show that addition bioethanol in amount small until currently capable increase resilience material burn to knocking symptoms .

Numerical value octane reach optimum conditions in a mixture of E15 with mark highest of 90.7. This is caused by nature bioethanol which has number octane tall as well as content oxygen capable increase quality internal combustion room burn engine . The E15 blend is rated as the most effective composition in increase number octane without lower characteristics base material burn.

However, in the E20 mixture, the figures octane experience A little decline to 89.7. The decrease This can caused by incompatibility characteristics material burn to test machines , such as change mark heat , rate evaporation , or insufficient mixing homogeneous . The lowest decrease occurs in the material E0 burn (without mixture bioethanol) with number octane 86.6, which indicates that Peralite pure own lowest anti - knock quality compared to mixture bioethanol tested.

In a way overall , graph show that addition bioethanol until limit certain capable increase number octane material burn , with The optimum composition is at E15. The addition bioethanol that exceeds optimum composition is not always produce improvement number significant octane , so that election percentage mixture bioethanol become factor important in its implementation as material burn alternative.

Emission Test Results (Gas Analyzer)

A) E5(5% Bioethanol and 95% Peralite)



(a) (b)

Figure 4.4 (a) emission test results with E5 (b) mixture bioethanol and peralite E5

As for the mixture from Peralite Total 500 ml with comparison of 475 ml peralite pure and 25 ml Bioethanol then

you can get it The results of Co (carbon monoxide) 3.1% Hc (Hydrocarbon) 1,600 (ppm) and Co2 (carbon monoxide) dioxide) 12.2% and O 2 (oxygen) 1.8%.
 B) E10 (10% Bioethanol and 90% Peralite)



Figure 4.5 Results of emission tests with E10 bioethanol mixture

As for the mixture from Peralite Total 500 ml with comparison of 450 ml peralite pure and 50 ml Bioethanol then you can get it The results of Co (carbon monoxide) 2.2% Hc (Hydrocarbon) 900 (ppm) and Co2 (carbon monoxide) dioxide) 13.0% and O 2 (oxygen) 2.5%.

C) E15 (15% Bioethanol and 85% Peralite)



Figure 4.6 Results of emission tests with E10 bioethanol mixture

As for the mixture from Peralite Total 500 ml with comparison of 425 ml peralite pure and 50 ml Bioethanol then you can get it The results of Co (carbon monoxide) 1.5% Hc (Hydrocarbon) 700 (ppm) and Co2 (carbon monoxide) 1.5 % dioxide) 13.8% and O 2 (oxygen) 3.1%.

D) E20 (20% Bioethanol and 80% Peralite)



Figure 4.7 Results of emission tests with E15 bioethanol mixture

As for the mixture from Peralite Total 500 ml with comparison of 400 ml peralite pure and 100 ml Bioethanol then you can get it The results of Co (carbon monoxide) 0.9% Hc (Hydrocarbon) 550 (ppm) and Co2 (carbon monoxide) dioxide) 14.5% and O 2 (oxygen) 3.8%.

E) E0 (Peralite) Pure)



Figure 4.7 Results of emission tests with E20 bioethanol mixture

As for the mixture from Peralite Total 500 ml peralite pure then you can get it The results of Co (carbon monoxide) 3.8% Hc (Hydrocarbon) 1,600 (ppm) and Co2 (carbon monoxide) dioxide) 11.5% and O 2 (oxygen) 1.2%.

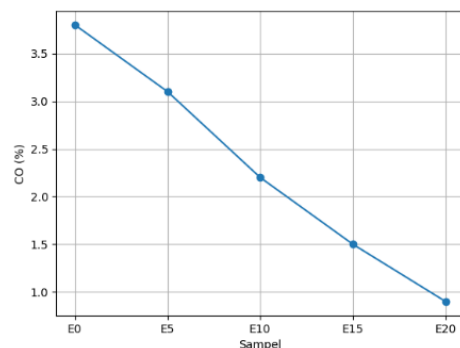
Following Test Results Table Using Gas Analyzer.

No	Sample	Co %	Hc (ppm)	Co2 %	O2 %
1.	E5	3.1	1,200	12.2	1.8
2.	E10	2.2	900	13.0	2.5
3.	E15	1.5	700	13.8	3.1

4.	E20	0.9,	550	14.5	3.8
5.	E0	3.8	1,600	11.5	1.2

Exhaust emission testing was conducted to determine the effect of sugar palm sap bioethanol blends on engine emission characteristics. The analyzed parameters included carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO₂), and oxygen (O₂). The results showed that increasing the bioethanol percentage reduced CO and HC emissions, indicating more complete combustion due to the oxygen content in bioethanol. E5 and E10 blends were considered safe for standard engines with improved emissions, while E15 showed the optimal combustion and emission performance. E20 produced the lowest emissions; however, the mixture became leaner because of the higher oxygen content in bioethanol. Meanwhile, CO₂ and O₂ emissions increased with higher bioethanol concentrations, indicating improved combustion efficiency. Overall, the use of sugar palm sap bioethanol as a fuel additive showed positive effects in reducing harmful exhaust emissions.

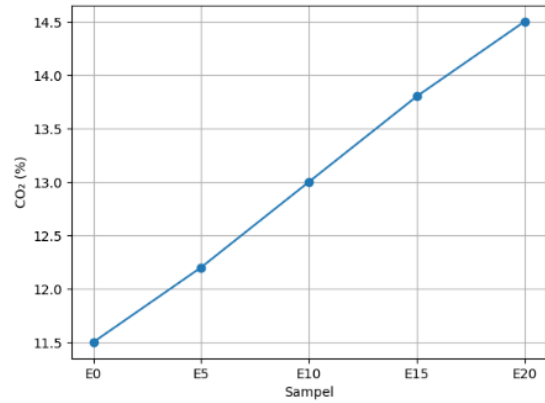
Chart Co (Carbon monoxide) levels against Sample Variations



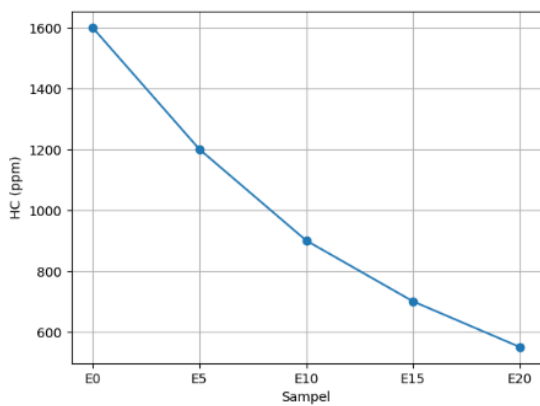
Meaning CO Level Graph (%)

1. Chart show that CO levels experienced decline along increasing percentage mixture bioethanol from E5 to E20.

- Highest CO value found in E0 of 3.8%, whereas mark lowest found in E20 is 0.9%.
- Decline CO levels indicate that burning become more perfect, because bioethanol contain oxygen that helps the oxidation process carbon. This is show that addition bioethanol influential positive in lower toxic gas emissions CO.



Graph of Hc (Hydrocarbon) levels against sample variations



Meaning HC Content Graph (ppm)

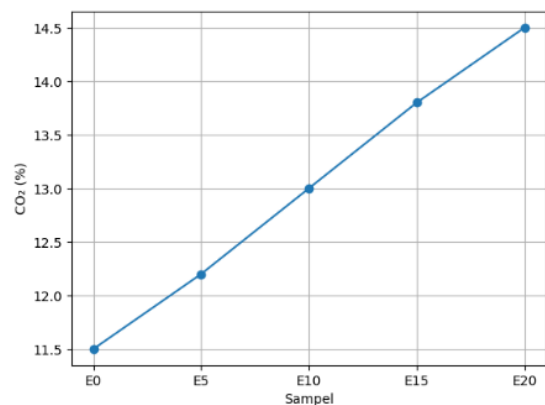
- HC graph shows trend decline significant from E0 to E20.
- Highest HC value occurs at E0 of 1,600 ppm, whereas mark lowest occurs at E20 at 550 ppm.
- Decline HC levels indicate decrease material burn that is not burnt perfect inside room burn.
- This matter caused by nature easy bioethanol evaporate and have number octane high, so that the combustion process become more stable and even.
- With Thus, the addition bioethanol capable increase quality burning machine.

Graph of CO₂ (carbon dioxide) levels against

Meaning CO₂ Level Graph (%)

- CO₂ graph shows improvement CO₂ levels along with increase level bioethanol in mixture material burn.
- CO₂ values increase from 12.2% at E5 to 14.5% at E20.
- The increase in CO₂ is indicator increasing burning perfect, because carbon in material burn more Lots oxidized to CO₂ compared to CO.
- This matter strengthen results CO and HC graph showing trend decline.
- With Thus, the increase in CO₂ is proportional backwards with harmful gas emissions

Chart O₂ (oxygen) levels against sample variation



Meaning O₂ Level Graph (%)

- O₂ graph shows trend improvement O₂ levels in exhaust gas from E0 to E20.
- O₂ value increases from 1.2% at E0 to 3.8% at E20.

3. An increase in O₂ indicates existence excess oxygen in waste gas combustion, which indicates the combustion process ongoing more efficient.
4. Contents oxygen natural in bioethanol contribute to availability oxygen during burning.
5. Condition This support more burning clean and reduce harmful gas emissions.

4. CONCLUSION

4.1 Conclusion

Based on the results of the research and discussion regarding the effect of palm sap bioethanol blends on gasoline engine exhaust emissions, the following conclusions can be drawn:

1. Palm sap bioethanol was successfully used as a fuel blend in E5, E10, E15, and E20 formulations.
2. The addition of bioethanol reduced harmful exhaust emissions, particularly CO and HC.
3. CO emissions decreased from 3.8% (E0) to 0.9% (E20), indicating more complete combustion.
4. HC emissions decreased from 1,600 ppm to 550 ppm, indicating a reduction in unburned fuel.
5. CO₂ emissions increased as the bioethanol content increased, indicating a more efficient oxidation process.
6. The increase in O₂ indicates more efficient combustion due to the oxygen content in bioethanol.
7. The lambda (λ) and AFR parameters were not used as primary parameters due to instrument limitations and the research focus on primary emissions.
8. Overall, sugar palm sap bioethanol has the potential to serve as an environmentally friendly alternative fuel to reduce motor vehicle emissions.

4.2 Suggestions

Based on the conclusions drawn, it is recommended that future studies analyze engine performance parameters such as torque, power, and fuel consumption, optimize the bioethanol production process, and conduct emission testing under various engine operating conditions using more accurate testing equipment.

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