

Physical Characteristics of Bioethanol from Cassava (*Manihot Esculenta Crantz*) as a Fuel Mixed Gasoline

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ABSTRACT: A study has been conducted to produce bioethanol from cassava. Bioethanol is produced through a fermentation process followed by a three-stage distillation process to obtain bioethanol with an alcohol content of 95%. Furthermore, the bioethanol produced is then mixed with gasoline and then the specific gravity (SG) and calorific value are evaluated. As much as 5, 10, and 20% bioethanol were mixed into gasoline which was then called E10, E15, and E20. The pure bioethanol called E100 was also tested for its physical characteristics. The test indicates that the SG values in all research variables meet the permitted requirements for transportation vehicles except for E100. The calorific value of the mixed fuel does not meet the standards. However, the lower calorific value at E5 can meet the allowable standard but not for E10, E20, and E100.

KEYWORDS: bioethanol, gasoline, specific gravity, higher calorific value, lower calorific value.

I. INTRODUCTION

The recent shortage of fuel oil has had a very broad negative impact on various sectors of life. One of the first to be affected was the transportation sector [1,2]. The constant fluctuations in the supply and price of crude oil have opened a general awareness that the world's crude oil reserves are running low. Because petroleum is a non-renewable fuel, it must be considered seriously to find a replacement fuel. There are various renewable energy sources that can be used to produce alternative fuels to replace motor vehicles such as biodiesel made from palm oil and soybeans and bioethanol from biomass such as sugarcane, cassava, corn, palm juice and coconut juice [3–5].

One of the alternative fuels derived from renewable natural resources that is currently widely used is bioethanol. Bioethanol (C_2H_5OH) is a chemical produced from plant raw materials

containing starch such as cassava, sweet potato, corn or corn cob and sago [6]. From various natural sources, cassava is one of the food crops commonly grown by people in almost all parts of Indonesia. Fertile soil allows this plant to grow easily making it a potential plant to be considered as an alternative source of raw material for the manufacture of bioethanol fuel. The use of alternative fuels can provide various positive impacts, including environmentally friendly exhaust emissions, as well as the potential for the development of the agricultural industry.

Because of the great benefits of bioethanol, several studies have been carried out to examine the effect of blending bioethanol with gasoline on both engine and emissions performance as well as on the characteristics of the fuel mixture. LM Baena, M Gomez and JA Alderon[7] have conducted research by mixing bioethanol with gasoline and named E20. He found that stainless steel, aluminum and chrome steel exhibited low or even unaffected corrosion rates when immersed in E20. However, carbon steel is not very suitable in contact with E20. This research opens insight into which spare parts are suitable for vehicles if they will use bioethanol fuel or a mixture of bioethanol.

LS Khuong et al [8] investigated the effect of a mixture of bioethanol and gasoline on the lubricating characteristics of engine oil. The result obtained is that the fuel mixture is able to reduce the viscosity of the fresh oil. This can lead to higher wear due to the resulting thin layer. Likewise, the fuel mixture can increase the acid number so that it has the potential to cause metal corrosion.

Tangka JK et al [9] investigated the physico-chemical properties of blending bioethanol and gasoline. The bioethanol used is produced from maize (*Zea mays*), raffia (*Raffia vinefera*), and sugar cane (*Saccharum L*). The results show that the mixed fuel has a low energy density. The impact of

its use is that the engine torque decreases and the engine speed increases. Similarly, fuel consumption increases with the mixed fuel.

This research is proposed to understand more deeply the characteristics of a mixture of bioethanol and gasoline fuels. This study aims to explore the SG, higher and lower calorific value properties of the fuel mixture. Based on the results obtained, it is expected to provide a more complete insight into the characteristics of a mixture of bioethanol and gasoline for its intended use in vehicles.

II. EXPERIMENTAL SETUP

The main research material used to carry out this research is cassava obtained from local agriculture. The research was started by peeling fresh cassava then washed and chopped into small pieces. Cassava is then dried in the open air for 3 days with the aim that it can be stored for a long time so that it can be reused in the future. This is also at the same time to reduce the water content of cassava. It is also intended to make it easier for cassava to be ground into a fine flour. The dried cassava was then crushed using a grinding machine to form flour. In carrying out this research, 4 kg of cassava flour was used. Several enzymes are used to promote the growth of anaerobic bacteria during fermentation. The enzymes used were 0.4 mg alpha-amylase and 0.25 mg gluco-amylase. Alpha-amylase has the function of hydrolyzing starch (polysaccharide) into dextrose. This process is known as the liquefaction stage. Likewise, 1 gram of yeast and 17 grams of urea and 3.5 grams of NPK fertilizer were added. The preparation of these compounds aims to provide nutrients to the fermenting microbes.

The next stage is the flour is cooked with water in a ratio of 1: 8 to a temperature of 110°C. Cooking aims to break down starch granules to facilitate contact with enzymes. After turning into mash then cooled until it reaches a temperature of

90°C. 0.4 mg alpha-amylase was then added to the mash then stirred to mix well and allowed to stand for 90 minutes.

Furthermore, the mash is cooled until the temperature reaches 55-60°C. 0.25 g of gluco-amylase was then added and then stirred until evenly distributed and left for 3 hours. Gluco-amylase plays a role in hydrolyzing dextrose into glucose. This process is known as the initial saccharification stage.

The next stage is the process of adding yeast. After 3 hours, the meal turned into two layers, namely a layer of water on the top and a precipitate of sugar (glucose). The meal is then cooled to a temperature below 35°C. Furthermore, 1 gram of yeast (*Saccharomyces Cerevisiae*), 17 grams of urea and 3.5 grams of NPK were added to the meal. The yeast functions to convert glucose into ethanol while urea and NPK function as nutrients for microbes. This process is known as the advanced saccharification stage. After the previous process is complete, the meal is then fermented for 3 days. After 3 days the fermented liquid turns into two layers, the bottom layer is a protein deposit (stillage), and the top layer is ethanol mixed with water.

The top layer liquid obtained from the fermentation process was then distilled for 1 hour to separate the bioethanol from water. The distillation process was repeated three times to reach 95% alcohol content. The alcohol content of the bioethanol obtained was then measured using an alcoholmeter. After obtaining bioethanol with an alcohol content of 95% then the bioethanol was mixed with gasoline (RON 88) so that the mixtures obtained were E10, E15, and E20, respectively.

The calorific value was tested using the 1341 Adiabatic Bomb Calorimeter. Data were collected three times for each fuel sample and then the average was taken. An empirical formula is used to determine the higher calorific and lower calorific value as follows:

$$HCV = \frac{[(m_a + m_k)C_{pa} \Delta T_a] - [yNK_p]}{m_f} \quad (J/gr)$$

$$LCV = HCV - X_{H_2O} L_{H_2O} \quad (J/gr)$$

Where:

HCV = higher calorific value (J/gr)

LCV = lower calorific value (J/gr)

$(m_a + m_k)C_{pa}$ = 10341.396 J/°C

ΔT = Changes in temperature due to sample combustion (°C)

NK_p = The calorific value of the lighter (9,62 J/cm)

y = Burned wire length (cm)

- m_f = Tested sample fuel mass (gr)
- X_{H_2O} = mass fraction of condensed water ($\frac{gr_{H_2O}}{gr_{fuel}}$)
- L_{H_2O} = latent heat constant H_2O at $25^\circ C$ (2442 J/gr)

The gasoline used in this study is produced by Pertamina, a state oil company from Indonesia. The properties of the gasoline can be seen in table 1 below.

One of the physical characteristics studied in this experiment is specific gravity. Specific gravity is the ratio between the density of the bioethanol and the density of water at the similar

temperature and pressure. Measurements are usually carried out under the same conditions (usually at a temperature of $15.5^\circ C$ and a pressure of 760 mmHg). After obtaining density data from bioethanol that has been produced, then the calculation of specific gravity is carried out using the following equation:

$$SG = \frac{\rho_{bioethanol}}{\rho_{aqua}}$$

Table 1. Physical and chemical data of Pertamina gasoline[10]

Characteristics	Unit	Range		Test method ASTM
		Without lead		
		min	max	
1. Octane number				
RON	RON	88.0		D 2699-86
MON		reported	reported	D 2700-86
2. Oxide stability	minute	360	-	D 525-99
3. Sulfur content	% mm	-	0.05	D 2622-98
4. Pb content	gr/l	-	0.013	D 3237-97
5. Distillation				D 86-99a
10% evaporation vol.	$^\circ C$	-	74	
50% evaporation vol.	$^\circ C$	88	125	
90% evaporation vol.	$^\circ C$	-	180	
Final boiling point	$^\circ C$	-	215	
residue	% vol	-	2.0	
6. Oxygen content	% m/m	-	2.72	D 4815-94a
7. Washed gum	mg/100 ml	-	5	D 381-99
8. Vapor pressure	kPa	-	62	D 5191/D 323
9. Density at $15^\circ C$	kg/m^3	715	780	D 4052/D 1298
10. Copper corrosion	blade minute	First class		D-130-94
11. Doctor test		Negative		
12. Mercaptan sulfur	% mass	-	0.002	D-3227
13. Visual appearance		Clear and bright		
14. Color		Red		
15. Coloring content	gr/100 l	0.13		
16. Odor		marketable		

III. RESULTS AND DISCUSSION

To obtain bioethanol with a high alcohol concentration, the distillation process was repeated three times at different temperatures as shown in table 2. In the second and third distillation processes, the distillation operating temperature was lowered to avoid the water content in the bioethanol from evaporating and lowering the alcohol content. Although the distillation operating temperature does not reach the boiling point of water, the water can evaporate. At the end of the third distillation, bioethanol with 95% alcohol

percentage was obtained. Repeated distillation proved to be very effective in increasing the alcohol content of bioethanol. However, the increase in alcohol concentration was accompanied by a decrease in the volume of the distillate. The final volume of bioethanol with a concentration of 95% is about 6% of the total liquid volume at the beginning of the distillation process. The results obtained are quite small, therefore this indicates that improvements are needed in the fermentation process so that the final results can be increased.

Table 2. Distillation process test data

Distillation stage	T (°C)	V _f (ml)	t _d (minute)	V _d (ml)	KE _d (% vol)
stage I	78	15200	60	1820	38
stage II	70	1820	60	915	87
stage III	62	915	60	840	95

where:

- T = distillation temperature (°C)
- V_f = volume of liquid during the distillation process (ml).
- t_d = duration of distillation process (minute)
- V_d = distillation volume produced (ml)
- KE_d = alcohol concentration at the end of distillation process (% vol)

Measurement of the specific gravity of the mixture of bioethanol and gasoline was carried out to determine the possibility of its use in engines. The allowable SG value for use on engines is 0.72-0.78 [11]. The results of the mixed SG measurements can be seen in figure 1 below.

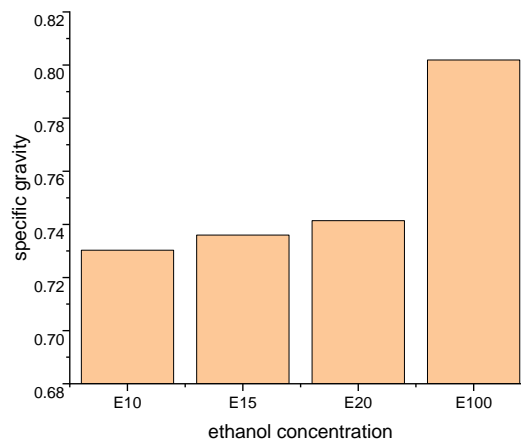


Figure 1. specific gravity of bioethanol-gasoline mixture fuel

The measurement results show that pure bioethanol (E100) has the highest specific gravity while E10 has the lowest value. In the bioethanol-gasoline mixture, the higher the concentration of bioethanol, the higher the specific gravity value. Thus, the specific gravity of the bioethanol-gasoline mixture is directly proportional to the amount of bioethanol concentration. The increase in SG of mixed fuel is due to the higher specific

gravity of bioethanol, which is 0.794 when compared to the specific gravity of gasoline, which is 0.72-0.78. The water content in bioethanol is also the reason for the high SG of mixed fuels. Although only 5% but because of the high density of water, the SG of the mixed fuel also increases. However, when referring to the permitted SG, all of the tested mixed fuels meet the requirements for use in engines.

Analysis of the calorific value of a fuel is intended to determine the amount of heat energy released by a fuel when a combustion reaction occurs. The higher calorific and lower calorific value of the tested fuel mixture can be seen in the figure 2 below.

The results above indicate that the greater the content of bioethanol in the fuel mixture, the lower the higher and lower calorific values. The decrease in the total calorific value of the mixed fuel was caused by the higher and the lower calorific value of bioethanol which were 59.33% lower when compared to those of gasoline fuel. The relatively low calorific value of bioethanol is due to the presence of oxygen molecules bound to

hydrocarbon compounds. The relative atomic mass of oxygen which is greater than that of carbon and hydrogen coupled with the low calorific value of oxygen causes the calorific value of bioethanol to be low. The low calorific value of the mixed fuel is also caused by the water content in the bioethanol-gasoline mixture, resulting in a decrease in the both higher and lower calorific value recorded. From the results obtained, the mixture of bioethanol-gasoline cannot meet the higher calorific value of the permitted gasoline fuel. However, for the lower calorific value, the bioethanol-gasoline mixture can meet the standard. The allowable higher calorific value is 46890 J/gr and 43710 J/gr for the lower calorific value.

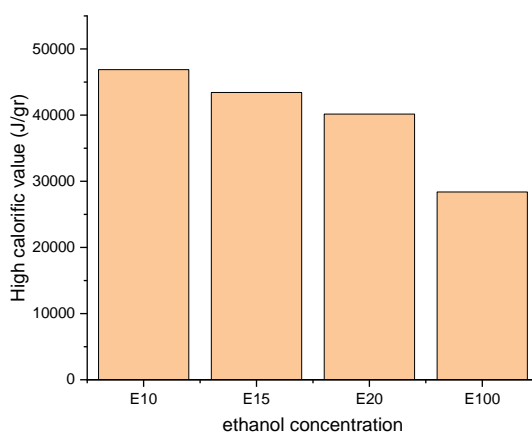


Figure 2. The higher calorific value of the bioethanol-gasoline mixture

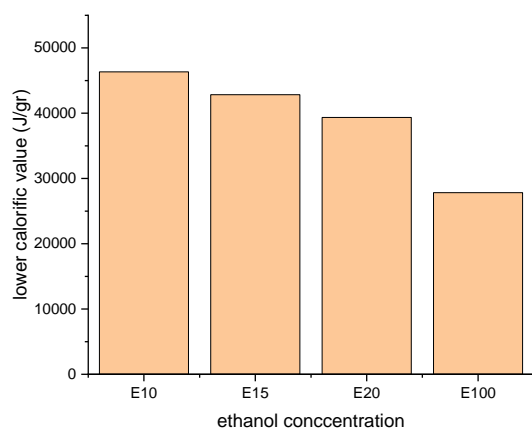


Figure 3. The lower calorific value of the bioethanol-gasoline mixture

IV. CONCLUSION

The cassava flour fermentation process using enzymes such as alpha-amylase and gluco-amylase along with yeast can produce bioethanol with an alcohol content of up to 95%. The physical characteristics of the fuel mixture of bioethanol and gasoline provide physical properties such as SG which can be permitted for use in engines.

However, in terms of calorific value, the 95% alcohol content in bioethanol is still not sufficient to meet the requirements to be mixed with premium. A higher alcohol content in bioethanol is required. However, if it is maintained using a 95% alcohol content, it is required to reduce the concentration of bioethanol to gasoline.

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