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Making Bioethanol from Cassava as an Environmentally Friendly Fuel Mixing Material

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Abstract: Bioethanol derived from cassava has the potential as an alternative energy material because cassava plants contain starch, sugar or cellulose which can be used in the process of making alternative and environmentally friendly fuels. This study aims to make bioethanol from cassava starch. This research method starts from material preparation to the process stage consisting of the fermentation process, distillation process, and the final stage, namely testing ethanol content and adding fuel. 5 kg of cassava is used to produce 98 ml of bioethanol distillation with 16% rendition. The combustion test was carried out to obtain a comparison of the calorific value between the fuel mixture - Bioethanol and fuel - Alcohol, Mixing partalalite - Bioethanol 1: 19 (95% partalaite: 5% Bioethanol) and fuel - Alcohol 1: 19 (95% partalite: 5 % alcohol). The results of the research obtained the calorific value of combustion of the partalalite - alcohol mixture: 11,649.48 kcal/kg, while for the partalalite - bioethanol mixture: 11,486.15 kcal/kg. So that the higher the concentration of ethanol mixed in partalite, the higher the calorific value.

Keywords: Bioethanol; Cassava; Distillation; Fermentation

Introduction

The use of fossil fuels as the main energy source leads to the accumulation of atmospheric greenhouse gases and ultimately global climate change (Jusakulvijit et al., 2021). The increasing demand for energy along with the increasing contamination of the atmosphere by combustion gases has opened the way for new, safe, effective and more easily obtained energy sources (Kumari et al., 2018; Rezania et al., 2020). Domestically and investigation of possible ways to produce energy from available resources (Surya et al., 2020). Especially from renewable and environmentally friendly raw materials, which are becoming increasingly needed, bioethanol is an alternative energy produced from sugar carbohydrates and lignocellulosic biomass (Arnata et al., 2021).

One alternative energy that is currently being developed is the use of bioethanol. Bioethanol is an environmentally friendly fuel and is a form of renewable energy that can be produced from plants. This bioethanol can be used as fuel in motorized vehicles such as cars, motorbikes, tractors and others. As a premium mixture in gasoline motorbikes, bioethanol is a renewable energy source (Junipitoyo, 2019).

Bioethanol is an alternative fuel processed from plants, which has the advantage of being able to reduce CO_2 emissions by up to 18%. There are 3 groups of plant sources of bioethanol: starch-containing plants (such as cassava, oil palm, tengkawang, coconut, kapok, jatropha curcas, rambutan, soursop, malapari, and nyamplung), sugary (such as molasses or molasses, palm sap, sugarcane sap), and sweet surgum sap), and cellulose fibers (such as sorghum stalks, banana stalks, straw, wood, and bagasse) (Kitson-Hytey et al., 2022). The point is that materials containing starch, glucose, and cellulose fiber can be used as fuel (Amalia et al., 2021).

Furthermore, the government's target of achieving a renewable energy mix of 23% by 2025 encourages Indonesia to utilize all potential resources including bioenergy (Althuri et al., 2022). One resource that has the potential to be developed is cassava, where Indonesia, as

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the fourth largest cassava producing country, produces around 20 million tons of cassava per year (Choo et al., 2021). Bioethanol can be produced from the activity of microorganisms to convert carbohydrates into environmentally friendly fuel (Hamsina et al., 2023). The microorganisms found in tape yeast are mold (Rhizopus oryzae, Amylomyces rouxii and Mucor sp.), yeast (Saccharomyces cerevisiae, Saccharomycopsis fibuliger, Endomycopsis burtonii) and bacteria (Pediococcus sp., Bacillus sp.), which can be used in the fermentation process in making bioethanol (Kassim et al., 2022).

The distillation process is capable of producing ethanol with a percentage of 95% or theoretically <97.20%. Industrial scale ethanol is produced through the hydration of alkene compounds with water vapor using a solid SiO_2 catalyst coated with phosphoric acid (Trakulvichean et al., 2019). The manufacturing process is carried out by flowing the reagent over a catalyst continuously (Rewlay-ngoen et al., 2021). This process is very fast and produces high purity ethanol, but is limited by the availability of raw material sources. Ethanol is an alternative fuel that can be used as a substitute for gasoline fuel and as a mixture of gasoline fuel that can be injected directly into the combustion chamber. Ethanol, which is often also called ethyl alcohol with the chemical formula C_2H_5OH, can be made from the cooking, fermentation and distillation processes of several types of plants such as sugar cane, corn, cassava or other plants with high carbohydrate content (Arwin et al., 2019).

Bioethanol is produced from cellulose contained in biomass through acid hydrolysis, followed by a fermentation process, then distillation (Liu et al, 2023). Sources of biomass that are produced into bioethanol are cassava, sugar cane, sweet potatoes, and corn. The 2015-2019 Strategic Plan (Renstra) of the Ministry of Energy and Mineral Resources explains that in the next 13 years it is estimated that Indonesia's petroleum reserves will be depleted by 3.6 billion barrels (Syafri et al., 2020). To overcome this problem, alternative energy is needed as a substitute for fossil energy, one of which is alternative fuel derived from biomass such as biodiesel and bioethanol (Saggi et al., 2019).

Bioethanol has the characteristics of being volatile, flammable, soluble in water, non-carcinogenic, and does not have a negative impact on the environment (Ibrahim et al., 2022). Bioethanol has benefits for human consumption as an alcoholic drink (Ansar et al., 2020; Haregu et al., 2023). Apart from that, bioethanol can be used as fuel with a minimum content of 10% ethanol (Jiao et al., 2019; Lyu et al., 2021). Global energy demand is expected to increase by 30% by 2040, thus, accelerating the energy transition to renewable resources contributes to global energy security and a sustainable ecological environment (Suhartini et al., 2022). As a non-depleting source of green energy, biofuels are becoming increasingly important due to their advantages as a clean and renewable resource and have the potential to replace the consumption of petroleum in transportation (Lestari et al., 2020; Rewlay-ngoen et al., 2021).

The biofuel market compound annual growth rate (CAGR) will exceed 7% from 2022 to 2027 (Rahmatsyah et al., 2021). North America remains the leading region in the biofuel business, with Canada targeting an average blend of 15% bioethanol by 2030. As the largest country, China is expected to have the largest amount of lignocellulosic for biofuel utilization by 2070 (Wu et al., 2023). Production of bioethanol from cassava or cassava is carried out through 4 stages which include the preparation and processing of cassava raw materials which include the process of peeling, washing and grating the cassava. The next stage is the hydrolysis stage, namely the stage of changing cassava starch into glucose. This stage consists of a liquefaction process and a saccharification process (Winarso et al., 2015).

Method

The method used is making bioethanol from cassava starch with the material preparation stages up to the process stage (Wusnah et al., 2021). Where the process stages consist of the fermentation process, distillation process, and the final stage, namely testing the ethanol content and adding partalite type fuel.

Work procedures

The work procedure in this research consists of several stages, namely:

Raw Material Preparation

Prepare 5 kg of cassava, then peel the skin of the cassava and wash it with water until clean. The cassava is then cut into pieces and crushed until it is small using a blender. After the cassava is crushed and small in size, it is steamed in a steamer for approximately 90 minutes.

Figure 1. Cassava

Fermentation Process

Take 5 kg of cassava that has been steamed for 90 minutes, then put it in a jar, then add 100 grams of NPK nutrient and 450 grams of ground yeast tape, each according to the predetermined variables, then close the jar tightly without any aeration for the predetermined period of time, to ensure the process is aerobic and prevent contamination (Karimi et al., 2021). The resulting liquid that forms on the surface of the cassava pulp is filtered until the water is separated and the filtered water is distilled to measure the alcohol content and pH.

Purification Process

The fermentation results that have been analysed show that the alcohol content produced is still low because it contains a lot of water, so the next stage is ethanol purification. Before entering the purification process, the sample is treated to separate solid and liquid particles using a centrifuge process. The next step, namely the distillation process, is carried out using a distillator connected to a heater at a temperature above the boiling point of pure ethanol, namely in the range (78 – 99)^{0}C. The steam will rise and exit into the condenser so that the steam turns cold so that a pure liquid is obtained which is called distillate. Next, analyse the alcohol content, pH and colour (see figure 2).

Mixing Process of Bioethanol and Partalite Type Fuel

The resulting distillate is then mixed with partalite with a variable ratio of 5:95 or 1:19. Meanwhile, commercial ethanol with an alcohol content of 99% is mixed with partalite with the same variable ratio, namely 5:95 or 1:19. Next, analyze the heat of combustion in the process of mixing ethanol and partalite using a Bomb calorimeter.

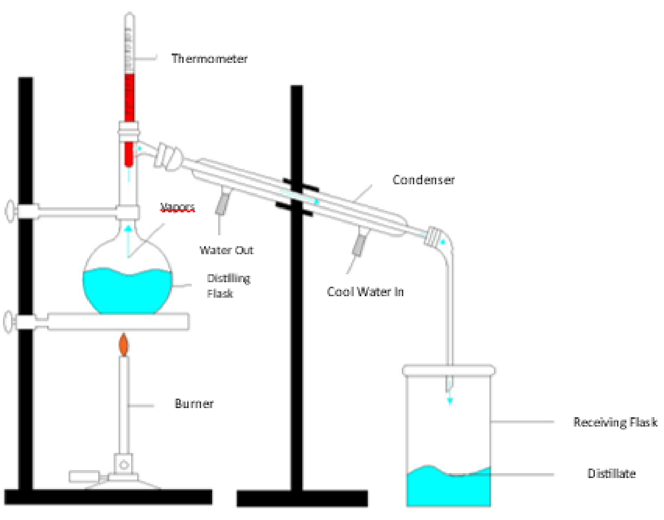

Figure 2. Distillation equipment

Characteristic Test

Bioethanol Content Testing

To test the ethanol content using an alcohol meter by dipping it into the results of the distillation process until it shows the percentage level (%) from the measurement results of the alcohol meter.

pH Test

Samples resulting from fermentation and distillation of bioethanol were tested using a pH meter. This measurement is carried out by dipping the pH meter electrode into the sample, until it shows a stable scale reading or number on the pH meter.

Result and Discussion

Based on the results of the research that has been carried out, it can be concluded that gasohol fuel with some mixture of ethanol and Pertamax is also ethanol and gasoline. The first stage is making ethanol from fermented palm sap. Then the ethanol distillation process is carried out to obtain a purity above 80%. The next stage is the process of mixing ethanol with gasoline and Pertamax where the concentration of ethanol that will be mixed with Pertamax and gasoline to become gasohol is varied from 80% to 98% ethanol with 1% intervals. The gasoline and Pertamax used for each sample was 7 ml, while ethanol was added while rotating in the test tube until the solution became one phase. By using 80% ethanol in the mixture, the ratio of gasoline: pure ethanol: water is 1: 11.65: 2.91 (in unit volume), while for 98% ethanol in the mixture the ratio of gasoline: pure ethanol: water is 1: 0.007: 0.001 (in volume units). For Pertamax, the minimum ethanol concentration mixed with Pertamax to form a single-phase emulsion is 88% with a composition of 1: 5.91: 0.81. The maximum concentration of ethanol mixed with Pertamax into a single phase emulsion is 97% with a volume ratio of Pertamax: pure ethanol: water is 1: 0.41: 0.02.

Then Senam, 2009, discusses the advantages of bioethanol which is produced from the activity of microorganisms to convert carbohydrates into environmentally friendly fuel. Based on the description in this paper it can be concluded that in Indonesia there is an abundance of biological material containing carbohydrates which has the potential to produce bioethanol. The bioethanol produced can be used by mixing it with gasoline. Bioethanol can increase the octane number of fuel and can reduce environmental pollution. Bioethanol is known as an environmentally friendly fuel, because it is free from pollutant emissions.

Bioethanol can be made from plant raw materials that contain starch such as cassava, sweet potato, corn, sago and molasses. Cassava, sweet potato and corn are food crops that are commonly grown by people in almost all regions of Indonesia, so these types of plants are potential plants to be considered as sources of raw materials for making bio-ethanol or gasohol.

Even though the bioethanol utilization program as vehicle fuel at that time was still economically unfeasible, the program had other benefits, namely being able to reduce domestic fuel oil (BBM) consumption, encouraging energy diversification programs, encouraging the creation of energy utilization. Which is environmentally friendly (ethanol is a fuel that is clean from pollutants), stimulates the growth of supporting industries and encourages job creation and economic improvement in the region.

Cassava Starch Fermentation and Distillation

Prakoso and Santoso in Novianti and Sulandri (2014) in their research stated that the fermentation process in making breadfruit tape provides color changes, a distinctive aroma of tape, a soft texture and a sour taste. Ethanol levels varied, from the second day there was an increase until the third day. Furthermore, there was a decrease in ethanol levels up to 5 days after fermentation.

Factors that can influence the fermentation process so that low levels of ethanol are obtained are that during the fermentation process, apart from being converted to ethanol, glucose can also convert other products such as lactic acid, pyruvic acid and succinic acid. The resulting by-product in the form of acid can make the pH of the solution lower, causing the productivity of the microbes to decrease because the available nutrients have been used up or died.

In this research, the cassava fermentation process was carried out for 7 days until the aroma of tape alcohol was obtained. In the sample, 1 cassava tape was blended until smooth, then samples of 2 cassava tapes were cut into small sizes. Next, the fermentation results are then distilled. Before the distillation process is carried out, the two samples are treated with separation between solid and liquid particles using a centrifuge process, samples 1 and 2 which have been filtered are then put into a centrifuge tube. Then the results of the treatment of the two samples were subjected to stage 1 distillation, so that the alcohol content was obtained as shown in table 1.

Table 1. Results of Stage 1 Distillation Process

Samples	Alcohol Content (%)	Bioethanol Volume After Distillation (ml)	Yield (%)	pH
1	45	600	20	6.1
2	45	600	20	6.1

In the next process, samples 1 and 2 go through the distillation process stage 2, where in this process the alcohol content of samples 1 and 2 increases to an alcohol content of 90%. Samples 1 and 2 can be said to have turned into bioethanol by meeting the alcohol and pH standards resulting from stage 2 distillation as shown in table 2.

Table 2. Results of Stage 2 Distillation Process

Samples	Alcohol Content (%)	Bioethanol Volume After Distillation (ml)	Yield (%)	pH
1	90	98	16	6.8
2	90	98	16	6.8

Then, based on table 2, where samples 1 and 2 went through the distillation process I and II, the volume of the bioethanol sample decreased, this is because the water contained in the sample did not evaporate because it did not reach the boiling point. The principle of the distillation process itself is a method of separating mixtures which is based on the boiling point principle, so that the combined liquids can be separated based on the boiling point. Factors that influence the distillation process are the type of material being distilled, temperature, volume of material and distillation time.

Then the ethanol content obtained was very low because during the fermentation process the microbial growth in the cassava tape did not reproduce well, so the microbes were unable to produce high ethanol levels. Microbes are able to reproduce at a fermentation temperature of 25 -27^{0}C which states that the high or low level of alcohol produced after the fermentation process is related to the amount of yeast present.

The dose of yeast given can also have an effect. This study used the same dose of yeast for each sample. Regarding ethanol levels which are influenced by the dose of yeast used in fermentation, this is in accordance with the results of research by Berlian et al. (2016) which states that different doses of yeast indicate different ethanol levels. The higher the dose of yeast given, the higher the ethanol content produced.

This ethanol content can also be influenced by hydrolysis factors that occur during the fermentation process. The tape fermentation mechanism starts with the starch contained in cassava tape being hydrolyzed into glucose. The starch content in white cassava is different from yellow cassava. This can ultimately affect the ethanol content produced from fermentation.

Calorific Value of a Mixture of Partalite and Alcohol

The bioethanol concentration from distilled cassava was 90% mixed with partalite in a ratio of 1:19, the heating value was tested using a Bomb calorimeter, the results can be seen in table 3.

Table 3. Combustion Test

Samples 1 : 19	Test Results (Calorific Value)	
	Joule/g	kkal/g
Alcohol: Pertalite	48,762.4149	11,649.48
Bioethanol: Pertalite	48,078.7538	11,486.15

From the results of the combustion test carried out, based on table 3, a comparative value of the calorific value was obtained between the mixture Partalite–Bioethanol 1: 19 (95% Partalite: 5% Bioethanol) and Partalite-Alcohol 1: 19 (95% Partalite: 5% alcohol), shows the calorific value of combustion of the Partalite-Alcohol mixture: 11,649.48 kcal/kg, while for the Partalite-Bioethanol mixture: 11,486.15 kcal/kg.

Table 4. Standard Calorific Value of Bioethanol and Gasoline

Fuel	Calorific Value (kkal/g)
Bioethanol	5000
Gas	10.160

Source: National Standards Agency

Based on table 4, the standard calorific value between gasoline & bioethanol is that petrol has a calorific value of 10,160 kcal/gram, while bioethanol has a calorific value of 5000 kcal/gram. So, if you look at the results of the combustion test in table 3, the sample mixture of Pertalite: Alcohol is 11,649.48 kcal/g and Bioethanol: Pertalite is 11,486.15 kcal/g, indicating that with the mixing treatment of bioethanol and ethanol in Pertalite type fuel can increase its calorific value so that it can produce efficiency in its use. Then the results of this research relate to several previous studies, namely regarding the use of bioethanol to mix premium motor fuel which was carried out by (Muryanto, 2016). In the research, premium fuel was mixed with ethanol at 5, 10, 15, 20% and the combustion engine was tested at high revs, with the object being a four-stroke combustion engine. From this research, it was concluded that the addition of ethanol provides greater torque than pure premium fuel without a mixture. Other research conducted by (Anugrah, 2016) in his research shows that premium fuel with a mixture of 5% ethanol produces power and torque close to Pertamax, and premium fuel with a mixture of 15% ethanol has an octane value comparable to Pertamax.

Conclusion

Based on the research results, it can be concluded that the cassava plant which is widely found in Indonesia has the potential to be used as a raw material for mixing fossil fuels because it has a fairly high bioethanol content from cassava starch, namely 90% with a soaking of 16%. The use of bioethanol as a raw material for mixing fossil fuels can minimize the impact of polluting gas emissions into the air. Mixing bioethanol with partalite fuel can increase the calorific value of the fuel, resulting in efficiency in its use.

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Authors Contribution

Conceptualization, Ridwan, Hermawati, Hamsina; Data curation, Trinugie Aprin Paredatu, M. Tang, Djusdil Akrim, Ruslan Hasani; Methodology, Ridwan, Hermawati, Hamsina, Trinugie Aprin Paredatu, M. Tang, Djusdil Akrim, Ruslan Hasani; Visualization, Ridwan, Hermawati, Hamsina,;Writing–original draft, Trinugie Aprin Paredatu, M.Tang, Djusdil Akrim; Writing–review & editing, Ridwan, Hermawati, Hamsina, Trinugie Aprin Paredatu, M. Tang, Djusdil Akrim, and Ruslan Hasani.

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