Bioethanol Producing Equipment Prototype Using Cassava Peel Using Microcontroller-Based Destillation Principles

Yefriadi, Nadia Alfitri, Anton Hidayat, Efendi, Nasrul, Yohanda Putera Maulana

Electro Department, [Politeknik Negeri Padang]

Abstract. Bioethanol is a biochemical liquid in the process of fermentation of sugars from carbohydrate sources using the help of microorganisms followed by the distillation process. Bioethanol can be used as a substitute for fuel oil depending on its purity. Bioethanol with 95-99% content can be used as premium substitution (gasoline), while 40% content is used as a substitute for kerosene. Cassava peel obtained from cassava plant products (Manihot esculenta Cranz or Manihot utilissima Pohl) is the main food waste in developing countries. Each kilogram of cassava can usually produce 15-20% of tuber skin. The cassava skin starch content is quite high, allowing it to be used as a source of bioethanol feedstock. In this research, the distillation process to produce bioethanol is carried out by controlling the temperature and pressure in the distillator so that the bioethanol produced can be maintained.

1. Introduction

Bioethanol is a biochemical liquid in the process of fermentation of sugars from carbohydrate sources using the help of microorganisms followed by the distillation process[1][2]. Bioethanol can be used as a substitute for fuel oil depending on its purity. The use of bioethanol is possible as a substitute fuel for gasoline because of ethanol-like characteristics of gasoline (gasoline)[3]. In addition, bioethanol is environmentally friendly because it has a relatively clean combustion result. This is because in the chemical structure there is an inherent oxygen atom in it. This will help improve the combustion reaction between ethanol and air.

Bioethanol is so popular in many countries, in the US for example that currently uses more than 52 billion liters of bioethanol as a fuel mixture annually[4]. however, the cost of bioethanol production is high compared to petroleum-based fossil fuels[5][6]. Currently, large scale fuel ethanol production is mainly based on sugar containing raw materials (i.e. sugarcane) and starch grains (i.e. corn, wheat and cassava) which are not desirable due to their food and feed value[7]. Lignocellulosic biomasses such as agriculture residues, woody biomass, and algae, industrial and municipal solid waste are the potential resources for bioethanol production worldwide[8]. They are not only renewable, but also low cost, abundant and sustainable. Rice straw, wheat straw, cassava peel, corn straw, and sugarcane bagasse are the major agricultural residues, which are suitable for large scale bioethanol production in terms of quantity of biomass available [9][10]. Moreover, starchy industrial
bio-masses such as waste from starch processing factories, potato food factories, and beverage and brewery factories are promising feedstock for high yield large scale production in tropical locations [11][12].

Ethanol is traditionally produced from feedstock high in sugar and/or starch content. A third possible feedstock is lingo-cellulose. These obsolete feedstocks are attractive, but the technology to convert cellulosic material to ethanol (sometimes referred to as ‘second generation’) is not yet commercially available. Most used feedstocks for fuel ethanol are wheat, corn, sugar cane and sugar beet. The sugars can be fermented to ethanol, while starch first has to be hydrolyzed to obtain free sugars. Next, the sugars are fermented to ethanol which is followed by a purification step yielding pure ethanol[13].

The process of extracting starch from cassava is a well-known technology. Cassava has been used as source of starch for decades. Cassava is high in starch content (70 – 85%, dry base / 28 – 35% wet base) and the starch from cassava is of a high quality compared to other starch sources. Cassava starch is used as raw material in many industries, among which paper-, food- and textile industries. Also the technology of producing ethanol from starch is internationally well developed[13].

Cassava peel obtained from cassava plant products (Manihot esculenta Cranz or Manihot utilissima Pohl) is the main food waste in developing countries. Each kilogram of cassava can usually produce 15-20% of tuber skin. The cassava skin starch content is quite high, allowing it to be used as a source of bioethanol feedstock[14]. In this research, the distillation process to produce bioethanol is carried out by controlling the temperature and pressure in the distillator so that the bioethanol produced can be maintained.

The project BEST, Bioethanol for Sustainable Transport, deals with the introduction and market penetration of bioethanol as a vehicle fuel, and the introduction and wider use of ethanol vehicles and filling stations with ethanol on the market. During the project more than 70,000 ethanol vehicles and ethanol buses have been put in operation, evaluated and demonstrated. More than 300 pumps for high blend ethanol, E85 and ED95, have been opened at filling stations and low blends with petrol and diesel have been developed and tested. Through BEST the participating cities and regions aimed to prepare a market breakthrough for ethanol vehicles and for bioethanol as a fuel and also to inspire and obtain followers. During the project several incentives promoting bioethanol vehicles and bioethanol fuels have been introduced locally and sometimes also nationally. Also several sever barriers to further market penetration was faced and in some, but not all, cases overcome. The participating cities/regions are: BioFuel Region (SE), Brandenburg (DE), Somerset (UK), Rotterdam (NL), Basque Country and Madrid (ES), La Spezia (IT) Nanyang (China) Sao Paolo (Brazil) Co-ordinating City is Stockholm (SE). The project is co-financed within the 6th framework; Sustainable Energy Systems/Alternative Motor Fuels: Biofuel Cities. The project started in January 2006 and end of 2009[15].

E85 is a fuel blend that consists of 86 weight per cent anhydrous bioethanol, 11,6 weight per cent petrol and the remaining percentages being two types of denaturants and colouring. Flexifuel vehicles running on E85 can make a significant contribution towards the achievement of EU climate targets whilst supporting economic development in agriculture. Energy security and the resilience of transportation and the economy will be increased by diversifying the range of fuels on offer in the EU. E85 is a liquid fuel that can be used in dedicated or converted flexifuel vehicles, making it an ideal fuel type for a transport system based on the supply of liquid fuels. As flexifuel vehicles can operate on blend of bioethanol and petrol, as mentioned above, they are appropriate during the transition to a new transport system as users can change their fuel choice according to the availability of fuel. Depending on how bioethanol is produced, use of E85 in converted vehicles can significantly reduce emissions of fossil carbon dioxide (CO2), further details in BEST D9.21 Report on life cycle greenhouse gas impacts of ethanol supply chains at BEST sites, (2009) and the report BioEthanol for Sustainable Transport – Results and recommendations from the European BEST project, Final report, (2009)[15].
2. **Methodology**

The purpose of this study was to obtain bioethanol from cassava peel. By maintaining the stability of temperature and pressure in the distillation chamber during the distillation process, it is expected that the bioethanol produced has high levels. The equipment used is temperature sensor, microcontroller, pressure sensor, level sensor and so on, as can be seen in Figure 1. Bioethanol feedstock is made using cassava peel which is dried and finely ground into flour to be fermented to obtain feedstock of bioethanol. The feedstock is then distilled, during the distillation process the temperature and pressure in the distillation chamber is controlled.

![Block system diagram](image)

The distillation room is heated using an electric heater. Microcontroller accepts input from temperature sensor, level sensor and pressure sensor. Temperature sensor functions to detect the temperature in the distillation room. The level sensor functions to detect the lowest level of ethanol raw material in the distillation chamber, so that it can be known whether the raw material is still there or it is almost gone, while the pressure sensor is to determine the pressure in the distillation chamber. Keypad is a human machine interface, with this keypad the user can enter the desired temperature data in the distillation room. Pump for water circulation serves to cool the ethanol vapor in the pipe coming out of the distillation chamber so that the ethanol vapor becomes ethanol liquid. LCD display functions to display temperature and pressure data in the distillation chamber and the time the device is used. Buzzer or alarm serves to give a warning if an unexpected rise in temperature occurs, the buzzer will also sound if the raw material in the distillation chamber runs out. Data log functions to store time, temperature and pressure data in the distillation chamber.

The prototype of the distillation apparatus made in this study can be seen in Figure 2. The description of the picture is as follows; 1. control panel, 2. distillation chamber, 3. Cooling water, 4. Water cooling fan, 5. Bioethanol output hose.
3. Result and Discussion

Distillation equipment testing was carried out with two samples of 100ml and 200ml fermented cassava skin waste liquid. From the distillation process, 40 ml and 60 ml of bioethanol were obtained. The test is carried out for 10 minutes and 16 minutes. In table 1, the test results can be seen.

| No | Feedstock of bioethanol from cassava peel (ml) | Bioethanol results by the distillation process (ml) | Temperature (°C) | Duration (menit) |
|----|-----------------------------------------------|-----------------------------------------------|------------------|------------------|
| 1  | 100                                           | 40                                           | 90               | 10               |
| 2  | 200                                           | 60                                           | 90               | 16               |
| 3  | 500                                           | 260                                          | 90               | 30               |

As can be seen in table 1, using this tool takes 30 minutes to get a quarter liter of bioethanol, it can be estimated that it will take around 1 hour to get one liter of bioethanol if using this tool.

Visually, the results of bioethanol distillation can be seen in Figure 2a and 2b. Figure 2a when bioethanol has not gone through the distillation process, while Figure 2b is bioethanol which has passed the distillation process.

Fig.2 The prototype of the distillation apparatus
Figure 3, shows the relationship between time and temperature rise, from the graph shows that it takes about 25 minutes for the distillation device to reach 90\degree C, then the temperature in the distillation chamber is kept at 90\degree C. The distillation has a capacity of 4 liters and the heater used to heat it is with a power of 350 watts.

Furthermore, by using an alcohol meter, measurements of bioethanol grade produced from the distillation tool, and the results obtained by 60%.

4. Conclusion
From the tests conducted, conclusions can be made as follows:

1. The increase in temperature in the distillation chamber takes 35 minutes to reach 90\degree C.
2. The temperature control system works quite well, the temperature can be kept constant at 90\degree C.
3. The level of bioethanol produced is quite good at 60%, but cannot be used as fuel because to be mixed with gasoline the ethanol purity grade must reach 99.6% (fuel grade ethanol). This tool will be developed further in order to produce bioethanol with grade above 90% by varying the temperature of distillation, high ethanol grades will be obtained.

4. By using this tool, it is estimated that it will take around 1 hour to get one liter of bioethanol.

References

[1] K. Waldron, *Bioalcohol production Edited by*, no. 3. 2010.

[2] F. Applications, *The Biotechnology of Ethanol*, 2000.

[3] B. Murachman, D. Pranantyo, and E. Sandjaya, “Study of Gasohol as Alternative Fuel for Gasoline Substitution: Characteristics and Performances,” vol. 3, no. 3, pp. 175–183, 2014.

[4] R. K. Niven, “Ethanol in gasoline: Environmental impacts and sustainability review article,” *Renew. Sustain. Energy Rev.*, vol. 9, no. 6, pp. 535–555, 2005.

[5] R. F. A, *Accelerating Industry Innovation - 2012 Ethanol Industry Outlook*, 0306 ed. 2012.

[6] et al. Banerjee S, Mudliar S, Sen R, Giri B, Satpute D, Chakrabarti T, “Com- mercializing lignocellulosic bioethanol: technology bottlenecks and possible remedies,” *Biofuels Bioprod Biorefining*, vol. 4:7793, 2010.

[7] Ó. J. Sánchez and C. A. Cardona, “Trends in biotechnological production of fuel ethanol from different feedstocks,” *Bioresour. Technol.*, vol. 99, no. 13, pp. 5270–5295, 2008.

[8] A. Limayem and S. C. Ricke, “Lignocellulosic biomass for bioethanol production: Current perspectives, potential issues and future prospects,” *Prog. Energy Combust. Sci.*, vol. 38, no. 4, pp. 449–467, 2012.

[9] N. Sarkar, S. K. Ghosh, S. Bannerjee, and K. Aikat, “Bioethanol production from agricultural wastes: An overview,” *Renew. Energy*, vol. 37, no. 1, pp. 19–27, 2012.

[10] C. A. Cardona, J. A. Quintero, and I. C. Paz, “Production of bioethanol from sugarcane bagasse: Status and perspectives,” *Bioresour. Technol.*, vol. 101, no. 13, pp. 4754–4766, 2010.

[11] et al. Kosugi A, Kondo A, Ueda M, Murata Y, Vaithanomsat P, Thanapase W, “Production of ethanol from cassava pulp via fermentation with a surface engineered yeast strain displaying glucoamylase,” *Renew Energy*, vol. 34:1354–8, 2009.

[12] S. Linggang, L. Y. Phang, M. H. Wasoh, and S. Abd-Aziz, “Sago pith residue as an alternative cheap substrate for fermentable sugars production,” *Appl. Biochem. Biotechnol.*, vol. 167, no. 1, pp. 122–131, 2012.

[13] K. Kuiper, L., Ekmekci, B., Hamelinck, C., Hettinga, W., Meyer, S., Koop, “Bio-ethanol from Cassava,” *Proj. number PBIONL062937*, no. November, pp. 1–13, 2007.

[14] Z. Abidin, E. Saraswati, and T. Naid, “Bioethanol Production from Waste of the Cassava Peel (Manihot esculenta) by Acid Hydrolysis and Fermentation Process,” no. March, pp. 2–6, 2016.

[15] S. by the European and European, *The BEST experiences with distribution of bioethanol for vehicles*, no. 4. 2010.