Asian Journal Science and Engineering
Vol. 2, No. 1, June 2023
https://attractivejournal.com/index.php/ajse

Analysis of Bioethanol Purification with Two Outlet Distillation System

Iqbal Zulfikar[1], Bambang Irawan[2*]
[1,2] Politeknik Negeri Malang, Indonesia

bambang.irawan@polinema.ac.id*

ARTICLE INFO
Article history:
Received
April 29, 2023
Revised
June 20, 2023
Accepted
September 04, 2023

Abstract

The purpose of this study is to analyzes of the process of purifying bioethanol produced by a distillation apparatus that uses two holes of different heights. The equipment used in this study is a distillation prototype tool which has two steam holes coming out of the vessel, with different height positions. The research method used is experimental. Data collection was based on the results of distillation experiments with the independent variable alcohol content in the solution, the dependent variable alcohol content resulting from the distillation process and the control variable is steam temperature and processing time. The results of the study were processed with statistics showing that the position of the holes affects the product resulting from the alcohol content in bioethanol, a high hole position will produce bioethanol with a greater alcohol content. The alcohol content in the solution that is put into the distillation vessel affects the distillation results, the greater the alcohol content, the greater the alcohol product. The interaction between the position of the holes and the alcohol content in the solution affects the amount of alcohol product in the bioethanol. input solution containing low alcohol cannot reach the distillation results of bioethanol with high alcohol content. Bioethanol through the top hole has a higher alcohol content than that through the bottom hole. The alcohol content in the solution affects the difference in the alcohol content produced between the upper and lower holes. Distillation can produce bioethanol with a high alcohol content of up to 96%, with a solution containing about 85% alcohol. This distillation process can be done privately so that everyone can make fuel for their own vehicles.

Keywords: Bioethanol Purification, Distillation System, Purifying Bioethanol

Published by CV. Creative Tugu Pena
ISSN 2963-6752
Website https://attractivejournal.com/index.php/ajse

INTRODUCTION

Bioethanol is currently needed to meet various needs. Bioethanol can be used as fuel for motor vehicles, especially as it is renewable, environmentally friendly and sustainable [1]. Bioethanol can be the best alternative fuel produced from residues and waste. Large amounts of agricultural residues are generated in the country, from which bioethanol can be produced in large quantities. Bioethanol derived from agricultural residues and waste can reduce dependence on fossil resources, reduce the environmental impact of fossil fuels, and improve engine performance [7]. Bioethanol is a renewable energy source that has an important role in improving the economy and environmental sustainability in developing countries. The ethanol economy has the potential to alleviate rural poverty, improve agriculture, drive local and national economic growth, create jobs, clean cooking for households, promote equality, reduce greenhouse gas emissions [8].

Bioethanol in the market is expensive, the higher the alcohol content is more expensive it is. At present, most of the fuel used for motorized vehicles uses fossil fuels and a few use fossil fuels mixed with bioethanol. It should be noted that bioethanol with a high alcohol content can be directly used to fuel gasoline-engined vehicles without being mixed with fossil fuels. Gasoline engines with a few modifications can use pure bioethanol fuel (E100). The bioethanol used for fuel does not need to be 100% alcohol but the alcohol content is 96% and the remaining 4% is water [2].

The general problem that occurs is how to make bioethanol with high alcohol content by self-production. By being able to make high alcohol content, the use of fossil fuels can be reduced, besides that in remote areas it will be possible to make fuel for their own vehicles. To solve this problem, research was carried out by making a prototype distillation apparatus whose shape was different from those on the market. This distillation prototype is to remove bioethanol vapor through two holes in different positions.

Distillation is a method of separating components from a liquid-liquid or liquid-solid mixture. The main distillation process depends on the boiling point of the components that are mixed. The boiling point of bioethanol and its mixture must be known so that the process can produce high purity [3]. Bioethanol made from fermentation usually contains a lot of water, gas and little solids. The distillation process is related to heat, so materials that have a low boiling point will evaporate first. The fermentation results contain various types of gases, so in the distillation process the gas will evaporate first [4]. Bioethanol production from sugarcane and sweet sorghum is used for household fuel needs. Bioethanol is a modern clean fuel that has characteristics similar to LPG [9].

Based on the reference [5] for a pressure of 1 atm shows that the boiling point of ethanol is $79{,}6^0$ C and the boiling point of water is 100^0 C. From these data, the steam temperature is made at $79{,}8^0$ C, the temperature is made so that the alcohol content in bioethanol can be high.

While conducting a comparative analysis between distillation systems with two outlets for bioethanol purification [11]. In this study, various operational parameters were explored to compare the efficiency, purity, and production cost between this system and other purification methods. The results show that the two-outlet distillation system has the potential to improve separation efficiency and reduce bioethanol production costs. For the mathematical model and numerical simulation of a two-outlet distillation system for bioethanol purification [12]. Through this approach, we investigated various operational scenarios and parameter variations to optimize the separation process. The simulation results show that this system has the potential to provide better separation results with lower energy consumption.

A study on the technological and economic aspects of a two-outlet distillation system for bioethanol separation [13]. Through this analysis, researchers present an evaluation of the process efficiency, investment cost, and operating cost of this system compared to other alternatives. These findings provide valuable insights for planning and decision-making in the implementation of bioethanol purification technologies. While applying a thermodynamic approach to optimize bioethanol separation using a two-outlet distillation system [14]. The results of the thermal and thermodynamic analysis helped identify the optimal operational conditions to achieve efficient and economical separation. The results of this study can be used as a basis for designing more energy-efficient purification processes.

Experimental investigation of a two-outlet distillation system for bioethanol recovery [15]. Experiments were conducted to measure separation efficiency, product purity, and other operational characteristics. These experimental findings provide empirical data useful in validating simulation models and informing best practices in the implementation of these distillation systems. Meanwhile, a dual-purpose optimization approach for a two-outlet distillation system in bioethanol purification [16]. Through this analysis, researchers sought to optimize separation efficiency and product purity simultaneously. The results provide insight into the compromises that may be necessary in approaching these dual goals.

Research that incorporates a sustainability perspective in analyzing a two-outlet distillation system for bioethanol separation [17]. By considering environmental and social aspects, researchers provide a more comprehensive picture of the advantages and impacts of this technology in a broader context. A study examining the performance evaluation of a two-outlet distillation system for bioethanol purification [18]. By comparing operational results and product quality with conventional distillation methods, researchers uncovered potential improvements in separation efficiency and product quality produced by the two-outlet system. Meanwhile, an in-depth comparison between two-outlet distillation systems and conventional distillation in bioethanol purification was conducted [19]. This research includes analysis of the efficiency, cost, and environmental impact of both methods, providing more in-depth information on the advantages and challenges of each approach. A study focusing on the integration of two-outlet distillation systems for better bioethanol purification [20]. Researchers demonstrated how this integration can increase separation efficiency, reduce energy consumption, and improve product quality, contributing to more sustainable refining efforts.

Research conducted a techno-economic analysis of a two-outlet distillation system for bioethanol purification [21]. By considering investment costs, operating costs, and separation yields, the researcher provides insight into the economic advantages and limitations of this approach, providing guidance for investment decisions. For a study that explores the concept of process intensification in bioethanol refining using a two-outlet distillation system [22]. The researcher described how this system can produce better separation by optimizing operations and reducing product loss. Another study focused on parameter optimization of a two-outlet distillation system for bioethanol separation [23]. Through simulation methods and sensitivity analysis, researchers identified the optimal operational conditions to achieve the best separation results by considering parameter variability.

Research focusing on improving energy efficiency in bioethanol purification with a two-outlet distillation system [24]. By analyzing energy use under various operational scenarios, researchers uncovered potential reductions in energy consumption in bioethanol separation. Research involving environmental life cycle analysis comparing the environmental impact of two-outlet distillation systems in bioethanol refining [25]. By considering aspects such as greenhouse gas emissions and resource use, researchers provided an overview of the environmental impact of this technology. The study examined the economic feasibility of a two-outlet distillation system for bioethanol separation. Cost and revenue analysis were measured based on day-to-day operations, and the results provide an overview of the potential profitability of applying this technology in the bioethanol industry.

A study addressing process integration of a two-outlet distillation system in bioethanol recovery [26]. By integrating the separation steps with other parts of the bioethanol production plant, this study shows the potential for improving the overall efficiency of the operation. Meanwhile, a study discussed advanced control strategies for a two-outlet distillation system in bioethanol purification [27]. By implementing more advanced controls, this study shows how separation performance can be improved and product quality more consistent. Meanwhile, a study conducted a comparison between various configurations of two-outlet distillation systems for bioethanol refining [28]. Through performance comparison analysis, the researcher provides guidance on the relative advantages and applicability of each configuration. Research that discusses technological innovations in two-outlet distillation systems for improved bioethanol purification [29], [30]. Researchers explain how the use of new technologies can improve separation efficiency, reduce waste, and minimize environmental impact.

The process of making bioethanol requires a large amount of energy. To save energy, bioethanol production can use solar energy. Solar energy generators can use solar cells and generate electrical energy. With this energy, the distillation vessel is heated with electrical elements from solar energy, making it economical and environmentally friendly [6]. Simulation of the calculation of the bioethanol production process from waste paper through acid and hydrolysis in terms of energy and production costs [10].

This study aims to analyze the purification process of bioethanol produced by a distillation apparatus which has two holes with different heights. The analysis carried out is the effect of the alcohol content in the solution on the distillation results that come out of the two holes.

METHOD

The research method used is experimental. Data collection was based on the results of distillation experiments with the independent variable alcohol content in the solution, the dependent variable alcohol content resulting from the distillation process and the control variable is steam temperature and processing time.

Tools and equipment

The tools and equipment used are as follows

1. Alcohol meter
2. Measure glass
3. Distillation apparatus
4. Thermometer
5. Hygrometers
6. Heating stove
7. Flame regulator
8. Cooling water pump

Figure 1 Distillation apparatus

Stages of Analysis

a) Data collection using a distillation apparatus;
b) Enter raw materials in the form of bioethanol solution with varying alcohol levels;
c) Determine the time that will be used for the distillation process;
d) Determine the temperature of the steam in the top hole channel;
e) Measure the alcohol content produced by the upper and lower holes;
f) Measure the volume of distillation results;
g) Process the results of different alcohol content with statistics.

The result of bioethanol purification analysis is to increase the alcohol content from a low concentration solution to a high alcohol content. The results of this purity analysis were compared between the downhole and top-hole passages and were assisted with statistical analysis. The analysis follows the steps as below;

Enter raw materials in the form of bioethanol solution

Enter the bioethanol solution containing alcohol from low to medium into the distillation apparatus. The solution that is put in starts from 10%, 20%, 30%, 40%, 50%, and specifically to get a high alcohol content, enter bioethanol with a content of 85%.

Determining the time used for the distillation process

The time for the distillation process is 60 minutes. The processing time is made the same for all types of different alcohol levels, this aims to be comparable between those with low to medium and high levels.

Determining the steam temperature

The temperature for the distillation process is 79.8^0 C. This temperature is the temperature of the steam that is in the outlet pipe leading to the top hole and which goes to the condenser. The temperature is made the same for all processes.

Figure 2 Effect of altitude on steam temperature

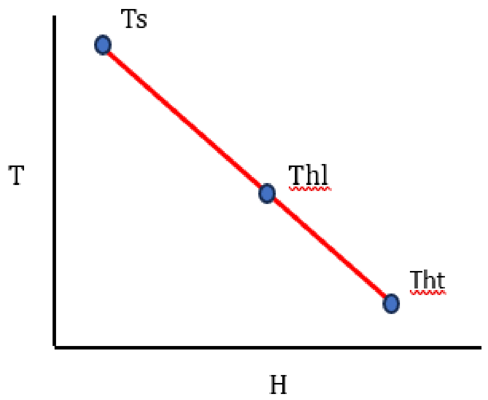

Figure 2 shows the effect of the steam height in the distillation vessel. The higher the presence of steam in the vessel, the lower the temperature because it is far from the heating surface.

Ts > Thl > Tht

Where: Ts = temperature of the vapor at the surface of the solution

Thl = steam temperature in the down hole

Tht = steam temperature at high position orifice

The temperature sensor in the form of a thermocouple is installed above, namely to measure the temperature of Tht. This Tht temperature will regulate the flame so that the purity of bioethanol can be high.

Measure the alcohol content produced

Measure the alcohol content in the solution that will be put into the distillation apparatus and adjust it according to the independent variable. Measure the alcohol content produced by the distillation apparatus. Result measurements were made for those that came out of the top and bottom holes.

Calculate the difference in the alcohol content in the bioethanol produced by the top and bottom holes, also calculate the difference between the alcohol content in the different inputs produced by each hole.

$$\Delta Alh = Alht - Alhl$$

Where: Δ Alh = difference in alcohol content between holes

Alht = alcohol content produced from the top hole

Alhl = alcohol content resulting from the bottom hole

$$\Delta Alhl = Alhlj - Alhli$$

$$\Delta Alht = Alhtj - Alhti$$

Where: Δ Alhl = difference in alcohol content from the bottom hole with the input different solution.

Alhlj = alcohol content from the bottom hole when entering the solution to j

Alhli = alcohol content from the bottom hole when entering the i solution
Δ Alht = difference in alcohol content from the bottom hole with the input different solution.
Alhtj = alcohol content from the bottom hole when entering the solution to j
Alhti = alcohol content from the bottom hole when entering the solution i

Measure the volume of bioethanol

The volume of the bioethanol solution that is put into the distillation vessel is 1 liter, this applies to all solutions. Measure the volume of bioethanol resulting from distillation.

RESULT AND DISCUSSION

The results of the research are in the form of data as table below:

Table 1 Alcohol content in bioethanol

Intake alcohol level (%)	Alcohol level results (%)	
	Lower hole	Upper hole
	32	44
10	31	43
	33	44
Average (10)	32	43.66
	49	61
20	49	60
	50	60
Average (20)	49.33	60.33
	63	74
30	62	73
	63	73
Average (30)	62.67	73.33
	73	80
40	72	79
	73	79
Average (40)	72.67	79.33
	79	83
50	80	84
	80	84
Average (50)	79.67	83.67
	93	96

85	93	97
	92	96
Average (85)	92.67	96.33

Table 1 is processed with statistics and the results of statistical calculations with two-way anova show that:

- The results of the distillation of the alcohol content in the resulting bioethanol and based on the position of the holes show that the calculated F is much greater than the F table. $F_{count} > F_{table}$ shows that there is a significant influence from the position of the hole. If you look at the results from the table, it shows that the alcohol content of the top hole is higher than the bottom hole and this difference is quite large.
- The distillation results from a solution containing alcohol which is put into the distillation vessel shows that the F count is much greater than the F table. If $F_{count} > F_{table}$, then there is a significant effect of the alcohol content in the solution on the quality of bioethanol from the distillation process. The data table shows that the more alcohol content in the solution that is put into the distillation vessel, the greater the alcohol content in bioethanol.
- The result of the interaction between the alcohol content in the solution that is put into the distillation vessel and the position of the bioethanol vapor outlet has a significant effect. It is indicated to have an effect because in statistical calculations it shows that F count is greater than F table or $F_{count} > F_{table}$.

From table 1, the average value can be drawn as a graphic image as shown in Figure 3 below.

Figure 3 The effect of alcohol content on the distillation results

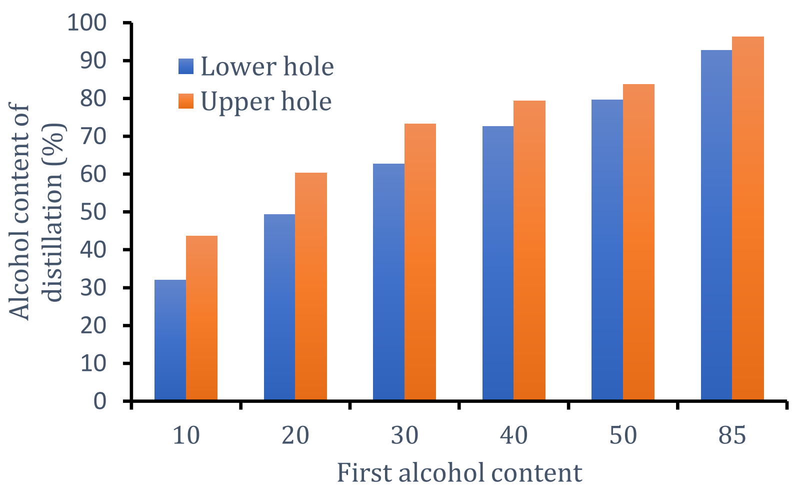

Figure 3 shows the effect of the alcohol content in the solution that is put into the distillation tube on the distillation results in the form of alcohol content in bioethanol.

The higher the alcohol content in the raw material will produce bioethanol with a higher alcohol content. It can happen like this because the more alcohol content the faster it will evaporate and the water will also evaporate but the amount will be small because the water vapor is still saturated steam.

From Figure 3 it can be seen that the more alcohol content in the raw material the difference in results is not that big. Examples of raw materials containing 40% alcohol with 50% will produce bioethanol with only a slight difference in alcohol content, namely around 7% for the bottom hole and 4% for the top hole. It could be like this because alcohol has relatively few resistance to evaporate and almost the same resistance to water molecules less and almost the same. The illustration is as shown in Figure 4.

Figure 4 Illustration of a water molecule with an alcohol molecule

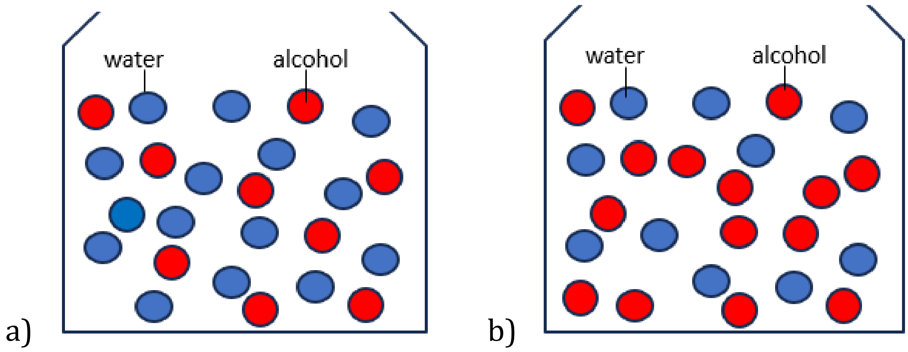

Figure 4 shows an illustration of water with alcohol in a distillation tube, where the volume of the two tubes is the same. Figure 4a) shows the amount of alcohol is less and the water is more. Figure 4b) shows the number of alcohol molecules compared to water molecules. The boiling point of alcohol is lower than air so the alcohol will evaporate first, but if there are many barriers, it will be difficult for the alcohol to evaporate. Then a solution with a high alcohol content will easily evaporate so that the amount of alcohol in the bioethanol will also be higher.

Figure 5 shows the difference in the distillation results of the top and bottom holes which are affected by the alcohol content in the solution that enters the distillation vessel.

Figure 5 Effect of alcohol content in solution on the difference in distillation results

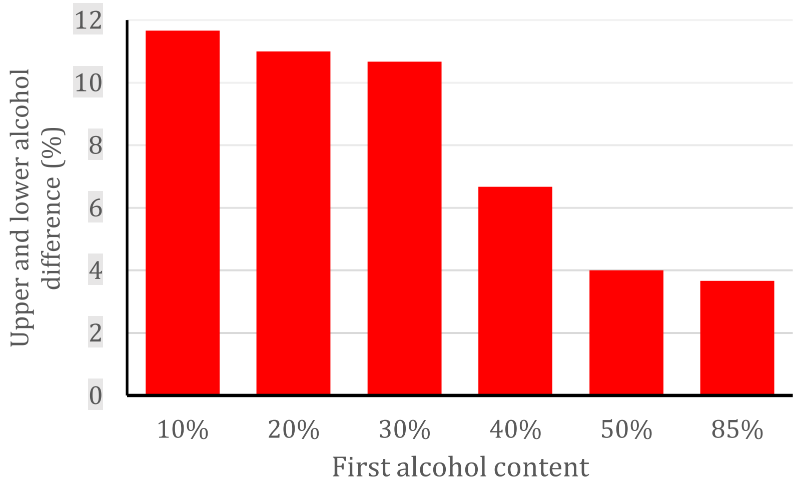

Figure 5 shows that the more alcohol content in the solution that enters the distillation tube will affect the difference in the alcohol content of the bioethanol product through the top and bottom holes. The alcohol content of 10%, 20% and 30% resulted in an average difference in the alcohol content produced by the upper and lower holes of 11%. This difference is quite large, it can happen like this because the density difference is quite large. Steam with a large density will exit through the lower hole and the lighter one can still rise and exit through the upper hole.

The alcohol content in the solution of 85% will make the difference in the content of the distillation results relatively small, namely only 3.5%. It can happen like this because the initial alcohol content is high so that there is only a little water as a barrier, as a result the density that enters the bottom and top holes is not a big difference.

Figure 6 Effect of alcohol content in solution on different product yields

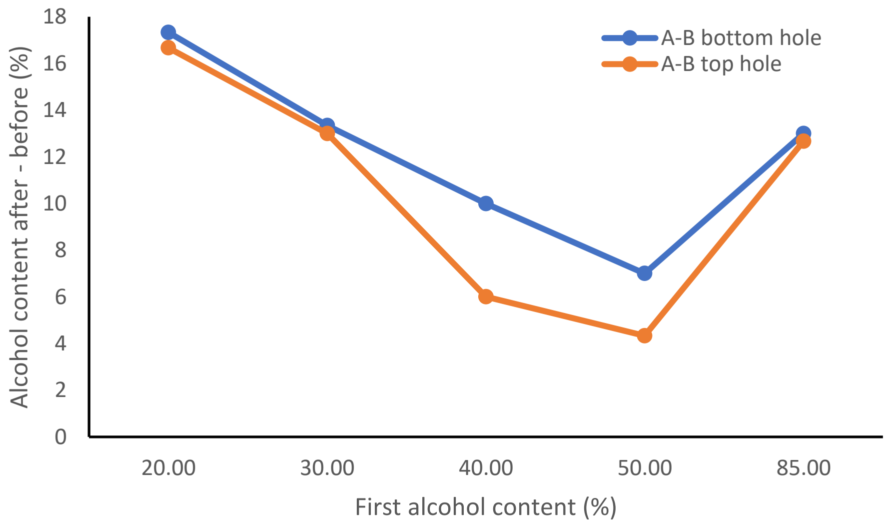

Figure 6 shows the effect of the alcohol content in the solution that is put into the distillation vessel on the difference in alcohol content resulting from the distillation process from the high solution minus the lower one (Δ Alhl and Δ Alht).

In the figure it can be seen that the difference between the bottom hole is bigger than the top hole or Δ Alht < Δ Alhl, this is due to the many alcohol molecules that join the water molecules. In addition, for the alcohol bottom hole, it is difficult to break through between the water molecules because they are pinched by the water molecules.

For the top hole, the difference is small because the water vapor that can rise is saturated steam and it is precisely this vapor that follows the alcohol molecule. In addition, because the density of water is greater than alcohol, it is difficult for water to rise. It should be noted that if you want to produce high alcohol content, care must be taken not to spark because the alcohol content of 90% and above is flammable.

CONCLUSION

The results showed that the position of the holes affected the product resulting from the alcohol content in bioethanol, a high hole position would produce bioethanol with a greater alcohol content. The alcohol content in the solution that is put into the distillation vessel affects the distillation results, the greater the alcohol content, the more alcohol products produced. The interaction between the position of the holes and the alcohol content in the solution affects the amount of alcohol product in the bioethanol. input solution containing low alcohol cannot reach the results of distillation of bioethanol with high alcohol content. Bioethanol through the top hole has a higher alcohol content than that through the bottom hole. The alcohol content in the solution affects the difference in the resulting alcohol content between the top and bottom holes. A solution containing about 85% alcohol can produce bioethanol with a high alcohol content of more than 96%, this can happen in the top hole. The alcohol content in the solution that enters to the distillation vessel will affect the difference in the alcohol content of the bioethanol product through the top and bottom holes.

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