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Evaluating Glycerol's Performance as a Sustainable Dehydrator in Ethanol Purification

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Abstract
This research aims to evaluate the effectiveness of glycerol as a dehydrator in the process of purifying ethanol solutions. This study is a quantitative descriptive research aimed at analyzing the effectiveness of glycerol, derived from used cooking oil, as a water dehydrating agent in the ethanol purification process. Data obtained will be quantitative and statistically analyzed to evaluate glycerol's performance as a dehydrator. The research was conducted at the Chemistry Laboratory of Mandalika Education University (UNDIKMA) over a specific period according to the research schedule.Independent Variable is glycerol from used cooking oil as a dehydrating agent. The concentration of glycerol used is determined based on the percentage of glycerol in the ethanol solution. Dependent variable the effectiveness of ethanol purification, measured through the comparison of density and percentage of standard bioethanol and Controlled variables is Temperature and pressure during the dehydration process, duration of the purification process, and the initial ethanol concentration before purification. Data analysis uses a simple regression curve that follows Lambert Beer's law. In conclusion, the results obtained (increasing the ethanol concentration to 90.5%) show that glycerol is a very effective dehydrator in reducing water content, especially for solutions with high water content such as ethanol at an initial concentration of 23.3%.

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INTRODUCTION

Global warming has become one of the most significant challenges of this century. This phenomenon is marked by the rise in the Earth's average surface temperature due to human activities, particularly since the Industrial Revolution (Arabadzhyan et al., 2021; Chaudhry & Sidhu, 2022). The most significant contributors are the burning of fossil fuels, such as coal, oil, and natural gas, which produce substantial greenhouse gas (GHG) emissions (Zhao et al., 2022). These emissions amplify the greenhouse effect, trapping heat in the atmosphere and driving climate change with far-reaching consequences. The rise in global temperatures has triggered various environmental issues, including polar ice melting, sea level rise, prolonged droughts, and more frequent natural disasters. These conditions not only impact ecosystems but also human life, encompassing economic, social, and health aspects (Abbass et al., 2022; Box et al., 2019; Zhao et al., 2022).

As stated by Petrakopoulou et al. (2020) and Soeder (2021), the dominance of fossil fuels in meeting global energy needs is the primary driver of global warming. Fossil fuels currently supply over 80% of the world's energy, particularly for transportation, industry, and electricity generation. However, the combustion of fossil fuels generates carbon dioxide (CO_2), the most significant greenhouse gas contributing to global warming (Höök & Tang, 2013). Moreover, fossil fuel usage also results in air pollution, negatively affecting human health and the environment. Dependence on fossil fuels not only exacerbates the climate crisis but also creates economic challenges, such as energy price fluctuations and supply instability (Arabadzhyan et al., 2021; Myers et al., 2017).

To combat global warming, the transition to green energy has emerged as one of the most proposed solutions (Ab Rasid et al., 2021). Green energy refers to environmentally friendly, renewable energy sources that have minimal negative impacts on the environment. Examples include solar, wind, hydroelectric, and bioenergy. One rapidly developing form of green energy is bioethanol, a biomass-based fuel produced through the fermentation of organic materials such as sugarcane, corn, and cassava. As an alternative fuel, bioethanol holds significant potential to replace fossil fuels, particularly in the transportation sector (Bušić et al., 2018; Domínguez et al., 2021). The combustion of bioethanol generates lower carbon emissions than fossil fuels. Additionally, bioethanol is derived from renewable plants, making it more sustainable and capable of reducing dependence on fossil fuels while enhancing national energy resilience (Oladipo et al., 2023).

Bioethanol is one of the alternative fuels extensively developed to replace fossil fuels. Produced through the fermentation of biomass, bioethanol offers a renewable and environmentally friendly energy solution. However, its production process faces significant challenges, particularly concerning by-products such as acetic acid and water. These challenges affect the efficiency and sustainability of bioethanol as a fuel (Bušić et al., 2018; Conde-Mejía et al., 2016).

Bioethanol is produced through the fermentation of sugar- or starch-containing biomass, such as sugarcane, corn, or cassava. In this process, microorganisms like yeast convert sugars into ethanol and carbon dioxide. However, fermentation also generates by-products, including acetic acid and water (Domínguez et al., 2021). According to Kusworo et al. (2023) and Li et al. (2022), the bioethanol purification process aims to increase ethanol purity to meet fuel standards (typically 99.5% ethanol or higher). Ethanol and water mixtures form an azeotrope, a condition where both components boil at the same temperature. This makes separation using conventional distillation ineffective (Janković et al., 2024). Breaking the azeotrope requires advanced technologies, such as azeotropic distillation, zeolite utilization, or membrane processes. These technologies are often costly and energy-intensive, increasing production costs (Kusworo et al., 2023; Senatore et al., 2020).

One promising purification technique is extractive distillation, with glycerol as a key component due to its high water-binding capacity (Bušić et al., 2018; Conde-Mejía et al., 2016; Li et al., 2022). Glycerol can be synthesized from used cooking oil, making this technology environmentally friendly. The hazardous nature of used cooking oil can be mitigated through an esterification reaction that produces glycerol as a by-product. This extractive distillation technology offers a highly effective solution for producing more sustainable energy. Based on these findings, it is essential to continue developing extractive distillation technologies for alcohol purification, as it presents a viable method for producing organic fuels that are both efficient and environmentally friendly.

METHOD

This study is a quantitative descriptive research aimed at analyzing the effectiveness of glycerol, derived from used cooking oil, as a water dehydrating agent in the ethanol purification process. Data obtained will be quantitative and statistically analyzed to evaluate glycerol's performance as a dehydrator (Conde-Mejía et al., 2016; Oladipo et al., 2023). The research was conducted at the Chemistry Laboratory of Universitas Pendidikan Mandalika (UNDIKMA) over a specific period according to the research schedule.

Research Variables

- **Independent Variable**: Glycerol from used cooking oil as a dehydrating agent. The concentration of glycerol used is determined based on the percentage of glycerol in the ethanol solution.
- **Dependent Variable**: The effectiveness of ethanol purification, measured through the comparison of density and percentage of standard bioethanol.
- **Controlled Variables**: Temperature and pressure during the dehydration process, duration of the purification process, and the initial ethanol concentration before purification.

Research Tools and Materials

1. Tools

- Simple distillation apparatus or azeotropic distillation system.
- Fourier-transform infrared spectrometer (FTIR).
- Pycnometer.
- Pipettes, graduated cylinders, separatory funnels, and volumetric flasks.

2. Materials

- Raw ethanol with an initial concentration of 80%.
- Glycerol derived from used cooking oil through a transesterification process.
- Used cooking oil as raw material for glycerol.
- Distilled water for washing and process control.

Research Procedure

1. Preparation of Glycerol from Used Cooking Oil

- Used cooking oil is processed through transesterification using methanol and a basic catalyst (KOH).
- Glycerol, a by-product of this process, is separated and purified by filtration and washing to remove residual catalyst and methanol.
- If necessary, glycerol is further purified using vacuum distillation or adsorption with activated carbon.

2. Preparation of Raw Ethanol Solution

- Ethanol solution with a specific initial concentration (e.g., 80%) is prepared for the dehydration process.
- The ethanol concentration is validated using FTIR or other analytical tools.

3. Dehydration Process Using Glycerol

- The raw ethanol solution is mixed with glycerol at varying concentrations (e.g., 5%, 10%, 15%, and 20% of the total volume).
- The mixture is heated at a specific temperature (e.g., 70–90°C) in a distillation system for a specific duration (e.g., 30 minutes to 1 hour).
- The separated ethanol vapor is condensed to produce purified ethanol.

4. Testing of Purification Results

- The ethanol content in the distillate is measured using a pycnometer.
- Organoleptic and flame tests are performed to assess ethanol quality.

5. Data Analysis

- Quantitative data (ethanol content and water content) are compared across different glycerol concentrations to determine the most effective concentration.
- Ethanol content is analyzed using the Lambert-Beer equation obtained through a standard ethanol calibration curve.

Data Analysis

1. Data Description

- Data are presented in tables and graphs, showing ethanol and water content at each glycerol concentration plotted on a calibration curve.

2. Statistical Analysis

- Simple regression analysis is used to evaluate the effect of glycerol concentration on ethanol content.

Research Limitations

1. The accuracy of glycerol processing from used cooking oil, which may affect glycerol's purity as a dehydrating agent.
2. Variations in temperature or pressure that are not fully controlled may influence purification results.

RESULTS AND DISCUSSION

Glycerol produced from the transesterification process of used cooking oil has added value as a biodiesel by-product. This research shows that glycerol can not only be used as a raw material for other chemical products, but also has potential as a dehydrating agent in extractive distillation processes. Utilizing waste such as used cooking oil into products of high economic value also contributes to the concept of a circular economy, where waste is reprocessed into useful materials. The glycerol used in this research is made from used cooking oil. The results are presented in figure 1 below.

Figure 1. Synthesis of glycerol from used cooking oil.

The glycerol in figure 1 is the black bottom part while the top part is biodiesel. In this process, 1 liter of used cooking oil is used. From 1 liter of used cooking oil, 50 mL of glycerol is obtained. To separate biodiesel and glycerol, a separating funnel is used. This glycerol is then used as a dehydrator for the ethanol sample solution.

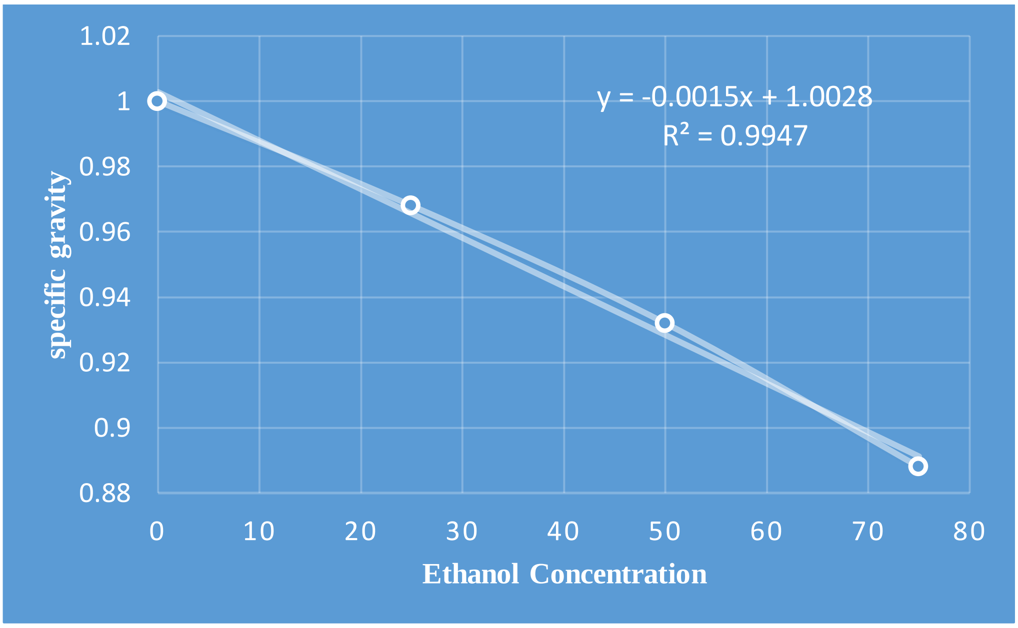
(Khalid et al., 2019a; Oladipo et al., 2023) reported that glycerol has high hygroscopic properties, so it is able to absorb water from the ethanol-water mixture during the extractive distillation process. This supports the purification of ethanol from an initial concentration of 23% to 90,5%. The effectiveness of glycerol as a dehydrator is supported by its molecular interaction with water through hydrogen bonds, which reduces the water content in the mixture. Thus, glycerol allows increasing the purity of ethanol without requiring more complex methods such as adsorption or the use of zeolite (Hulyadi, 2017).

In comparison, other materials such as salts or certain chemical molecules are also used to improve the separation of water from ethanol. Compared with other dehydration agents, glycerol has the advantages of availability from biodiesel waste, biodegradability, and low production costs. However, further research is needed to understand the efficiency of glycerol on a larger scale and higher purity (e.g., approaching 99% ethanol). The results of the researchers' findings show that glycerol has the ability to act as a dehydrator, this is proven by comparing the specific gravity of the distillate with the ethanol standard that was prepared previously. The correlation measurement of % ethanol with specific gravity is presented in table 1.

Table 1. Measurement of specific gravity of standard ethanol solutions

No	% Ethanol	Specific gravity
1	0	1
2	25	0.968
3	50	0.932
4	75	0.888

The extractive distillation process for 30 minutes produces ethanol with a fairly high concentration. This result is obtained from making a regression curve from the standards that have been obtained. From this standard regression curve, a linear regression equation is obtained which is used as a formulation for determining the ethanol concentration in the distillate. The regression curve is presented in Figure 2 below.



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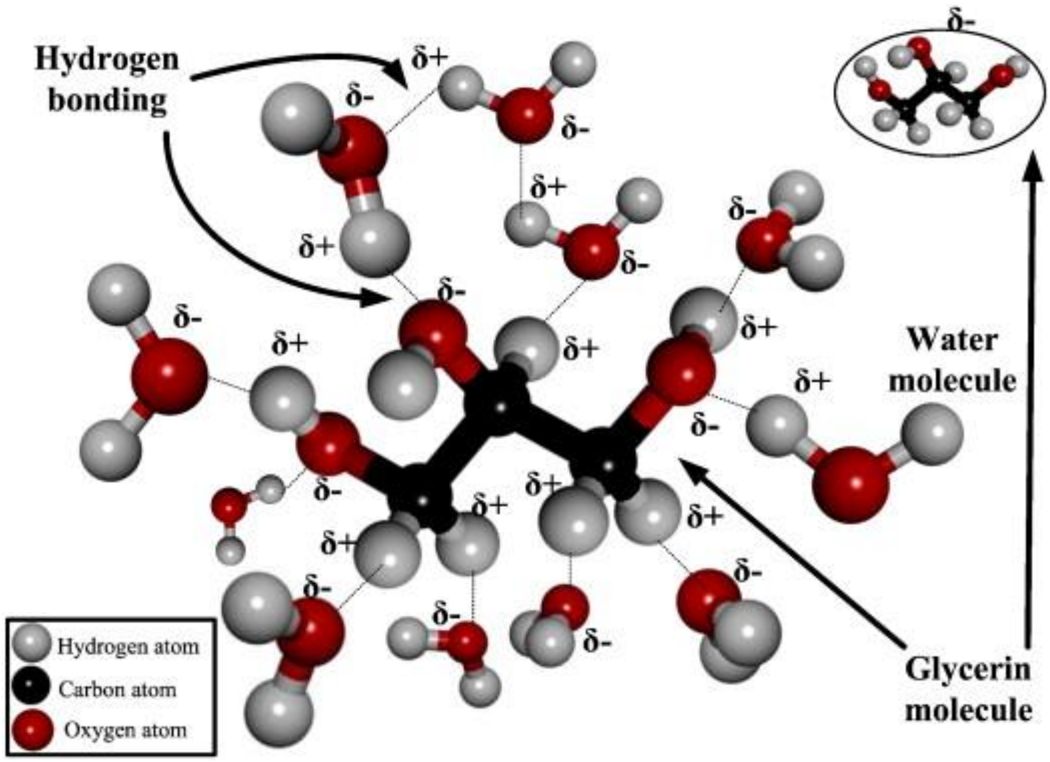

Figure 3. Glycerol interaction with water

Glycerol's ability to form hydrogen bonds is the basis for its application as a dehydrator. The extractive distillation process containing the three components glycerol, ethanol and water causes the water to be slightly attracted by the glycerol, making it easier for the ethanol to evaporate more easily. The high boiling point of glycerol also makes it difficult for glycerol and water to evaporate (Khalid et al., 2019b; Singh & Rangaiah, 2017). This property causes a reduction in the water content in the ethanol solution, thereby increasing the ethanol concentration. The results of increasing the distillate using a picnometer obtained a specific gravity of 0.867 g/mL. This specific gravity indicates changes in the composition of the solution after the dehydration process. Ethanol with a high concentration has a lower specific gravity than water, so these results are consistent with increasing ethanol levels. The use of glycerol can achieve a very high ethanol concentration, namely 90.5%. This shows that the dehydration method using glycerol can be an effective and efficient alternative, especially on a certain scale. The chemical and physical properties of glycerol, including its viscosity, make it ideal for use as a dehydrator under certain conditions. In this process, glycerol works by separating water without contaminating or changing the chemical structure of ethanol (Oladipo et al., 2023).

CONCLUSION

In conclusion, the results obtained (increasing the ethanol concentration to 90.5%) show that glycerol is a very effective dehydrator in reducing water content, especially for solutions with high water content such as ethanol at an initial concentration of 23.3%.

RECOMMENDATIONS

Based on the results obtained, several suggestions for further development are determining optimal parameters such as the ratio of glycerol to solution, temperature and pressure to increase efficiency. Comparing the costs of using glycerol with other dehydrating agents for industrial scale. Integrating other methods, such as adsorption or membranes, to achieve bioethanol purity of up to >95%.

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