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Ethanol Purification through Distillation Method: Effect of Height and Packing Types on Ethanol Concentration

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Abstract:- Energy demand is increasing every year along with the growing global population. Ethanol can be synthesized through the fermentation of sucrose or carbohydrates with the assistance of microorganisms. Ethanol produced from fermentation often does not have the desired concentration; hence purification such as distillation is necessary. This study aims to investigate distillation using packing materials and packing height to enhance ethanol purity. The materials used in this study are 30% ethanol, distilled water, pumice, and ginger coral. The purification process begins with understanding the characteristics of the packing through SEM characterization, followed by the distillation process. Based on the research, ginger coral exhibits complex crystal patterns and varying porosity, while pumice shows different porosity and fibrous structure. The ethanol concentration with ginger coral packing can increase by 66.27%, and with pumice packing, it can increase by 65.09%. Additionally, the optimum ethanol concentration is achieved with the highest packing fill. This is due to the surface area of the packing, enabling more efficient mass transfer.

Keywords:- *Ethanol, Distillation, Packing, Alternative Energy, Ginger Coral, Pumice.*

I. INTRODUCTION

Energy demand is increasing every year as the human population around the world increases. Fossil resources are still the world's primary energy source, with 75% used for heat and energy production, 20% as fuel and the rest as chemicals [1]. However, the world's oil reserves can be depleted at any time because their regeneration is not proportional to their large use. Therefore, to overcome the depletion of energy from fossils, it is necessary to develop renewable alternative energy, one of which is bioethanol [2]. Bioethanol, which is ethanol from biological raw materials, is an environmentally friendly renewable alternative fuel that produces fewer greenhouse gas emissions, is biodegradable, and contributes to sustainability [3].

Ethanol (C_2H_5OH) or ethyl alcohol is one type of alcohol that can be a renewable bio-energy. Ethanol from biomass is a clear colorless liquid that is biodegradable and an environmentally friendly alternative fuel to power vehicles and as a substitute for gasoline [4]. Ethanol can be made through synthesis from alcoholic fermentation of sucrose or carbohydrates using of microorganisms. The main microorganisms used in ethanol fermentation include the yeast Saccharomyces cerevisiae. Ethanol production can come from plants containing starch or carbohydrates, where carbohydrates will be converted into ethanol by yeast. Ethanol has a higher oxygen content that makes the combustion process better and lower exhaust emissions, as well as a high octane number of 118 compared to gasoline [5]. The combustion of ethanol is slightly cooler than other fuels, which can extend the life of gasoline [6].

Ethanol from biomass can be divided into three groups, sugar-based, starch-based, and lignocellulosic. Sugar-based materials can be obtained from cane sugar, molasses, and fruits that can be directly converted into ethanol. Starch-based materials can be obtained from corn, cassava, potatoes, and plant roots which must first be hydrolyzed into sugar. Meanwhile, sources of lignocellulose can come from wood, agricultural waste, pulp waste, and paper waste, all of which must be converted into sugar with the help of acids or enzymes [6].

The bioconversion process of hydrolysis is generally carried out to convert long polymers such as carbohydrates into simple sugars. In starch hydrolysis can be done by two methods, namely enzyme hydrolysis and acid hydrolysis. The fermentation process is carried out to convert simple sugars into ethanol which involves microorganisms such as yeast, namely Saccharomyces cerevisiae. Yeast in the form of Saccharomyces cerevisiae is mostly used because it can break down glucose content well into ethanol and can last longer in the fermentation process. The ethanol that comes out of the fermentation process only contains 11.5-12.5% ethanol [7]. Therefore, the distillation process is necessary to obtain the desired purity specifications [8].

The distillation process is the process of separating ethanol after fermentation using yeast. In the distillation process, the purity of ethanol can increase to reach a purity of around 70% - 90% [9]. Distillation is used to separate components in solutions that have different boiling points (volatility) for both partially miscible and miscible solutions into their respective components. When the mixture of components is heated, the vapor will be dominated by volatile components [10]. Currently, the most widely used

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distillation to improve ethanol purity is tray tower and packed tower [11].

Packing type distillation separator column is a place of contact between vapor-liquid in distillation, absorption, or stripping columns. Packing has low pressure drop, good mass transfer efficiency, and high capacity. Types of packing are structured packing and random packing. Recent research has been directed at engineering a packing structure that meets the criteria for a small pressure drop but has a high mass transfer efficiency [12].

The production of ethanol from biomass has great potential for the sustainability of renewable energy. However, it requires a distillation process to increase the purity of ethanol. Therefore, this research will be studied related to distillation with packing materials and heights that can increase the purity of ethanol. This research uses coral and pumice packing material as packing material in the distillation separator by considering these two natural rocks have great potential to increase the purity of ethanol.

II. MATERIALS AND METHODS

A. Materials

The materials used in this research were 30% ethanol and distilled water purchased from CV. Indrasari (Semarang, Indonesia), pumice and ginger rock purchased from a natural stone shop in Semarang.

B. Methods

Size Reduction and Characterization of Packing with Scanning Electron Microscopy (SEM)

Pumice and ginger rock chunks have an average size of 7 cm. The chunks require pre-treatment before packing in the distillation column. Pre-treatment is carried out by means of size reduction, where pumice and ginger coral boulders are crushed to obtain pieces with an average boulder size of 0.5 - 1 cm. Then characterization was carried out to determine the surface pores of pumice and ginger coral. Characterization was carried out, namely Scanning Electron Microscopy (SEM) used to determine the morphology of the packing surface.

➢ *Packing Distilation of Ethanol*

The chunks have been reduced in size and have an average size of 0.5 - 1 cm and are put into the distillation column as packing according to the variable type of stone, namely pumice and ginger coral. Then, in the distillation column, the height of the packing contents is adjusted according to the variables, which is 40, 80, 120 and 160 cm alternately for pumice and ginger. In the boiler section, ethanol is added with a concentration of 30% then the distillation process is carried out at a temperature of 80ºC.

➢ *Analysis of Ethanol Content using the Densimeter Method*

The concentration measurement procedure after ethanol begins with weighing the empty pycnometer. The ethanol produced from fermentation is then taken as much as 10 mL and put into a pycnometer of the same size. Next, the step continues with weighing the pycnometer that has been filled with ethanol, calculating the density value, and comparing it with the pure concentration density data. The final ethanol density in the distillate as shown in Eq. (1):

$$\rho_{\text{final ethanol}} = \frac{(m_{\text{pycnometer+ethanol}})-(m_{\text{empty pycnometer}})}{V_{\text{pycnometer}}} \qquad (1)$$

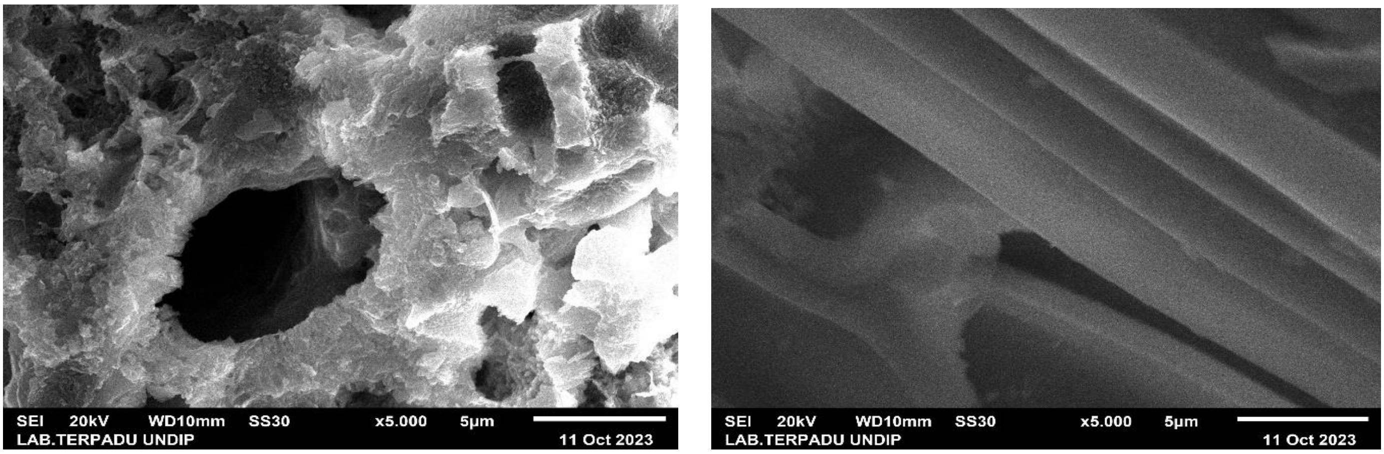
The final concentration of ethanol can be found in Eq. (2):

$$\frac{\rho_{\text{pure ethanol}}}{\rho_{\text{final ethanol}}} = \frac{\%_{\text{final ethanol}}}{\%_{\text{pure ethanol}}} \qquad (2)$$

III. RESULTS AND DISCUSSIONS

A. Scanning Electron Microscopy (SEM) Characterization Results of Ginger Coral and Pumice

The use of Scanning Electron Microscopy (SEM) method is crucial in the characterization of distillation packing made from ginger rock and pumice. With SEM, the microstructure of both materials can be seen. The characterization of ginger rock and pumice using SEM method as shown in Fig. 1 and Fig.2.



(a) (b)

Fig 1: SEM Characterization of (a) Ginger Rock and (b) Pumice

SEM characterization was performed at 5000x as displayed in the figure above. Ginger rock shows complex crystal patterns and varied porosity, while pumice shows distinct porosity and fibrous structure. SEM characterization allows exploration of surface morphology, pore distribution, and interaction between liquid and gas phases in distillation packing.

B. Effect of Packing Type of Ginger Coral and Pumice on Ethanol Concentration

The packing used in this distillation process is pumice and ginger coral. The effect of packing pumice and ginger coral on ethanol concentration as shown in Figure 2.

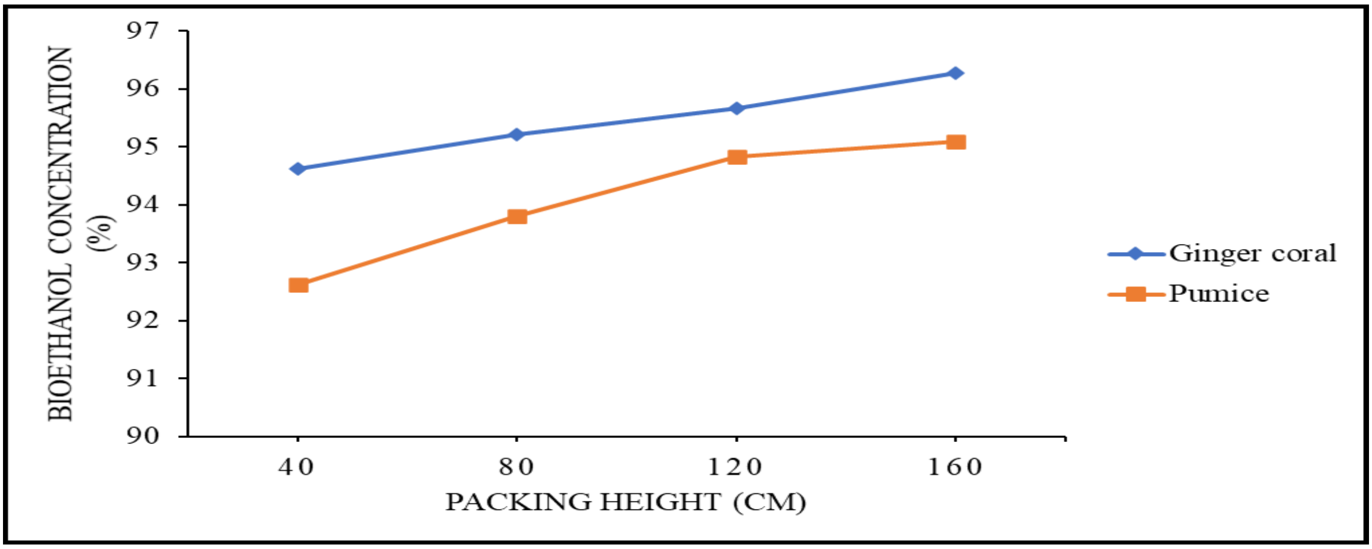


Fig 2: Effect of Packing Type on Final Ethanol Concentration with Initial Concentration of 30%

Based on its morphology, ginger coral has a larger pore size and more pores than pumice. Ginger coral has a larger average pore size of 10-40 µm [13]. While pumice has an average pore size of 5.8 µm, which is denser than ginger rock [14]. Pore intensity and pore size are closely related to porosity, where rocks are said to have high porosity if there are many holes (vesicles) or pores in the rock. Conversely, rocks are said to have low porosity if they appear compact, dense, or well cemented so that there are very few or even no pores in them [15]. The denser a material is, the greater its density, making it more difficult for fluid to pass through. Therefore, the greater the porosity (the more porous) the packing contact area with the fluid will be greater and the resulting ethanol concentration will also be greater [16].

C. Effect of Packing Height on Ethanol Concentration

This study used pumice and ginger coral at heights of 40 cm, 80 cm, 120 cm, and 160 cm as packing in a distillation column. The Impact of Packing Height on Ethanol Concentration as shown in Table 1.

Table 1: Effect of Packing Height on Final Ethanol Concentration with Initial Concentration of 30%

Packing Height (cm)	Ethanol Concentration (%)	
	Ginger Coral	Pumice
40	94.63	92.62
80	95.21	93.81
120	95.66	94.83
160	96.27	95.09

Table 1 shows the height of packing affects the ethanol concentration during the distillation process. The higher the packing in the distillation column, the greater the ethanol concentration obtained in the distillate. Packing height is the sum of the height of the separation media used in the distillation column. Packing height allows for more efficient mass transfer by providing more contact surface between the liquid phase and the vapor phase. With increasing packing height in a distillation column, the column can accommodate more "stages" for the separation of mixture components [17]. Each stage in a distillation column is a point where contact between the liquid phase and vapor phase occurs, allowing mass exchange between the two to fractionally separate the components of the mixture.

IV. CONCLUSION

Ginger rock showed complex crystal patterns and varied porosity, while pumice showed distinct porosity and fibrous structure. SEM characterization allows exploration of surface morphology, pore distribution, and interaction between liquid and gas phases in distillation packing. Ethanol concentration with ginger coral packing is higher than that of pumice packing. This is due to the larger contact area (surface area) of ginger coral packing which increases the concentration of ethanol produced. Ethanol concentration is getting bigger along with the increase in packing height. This is due to the contact area (surface area) on the packing which allows more efficient mass transfer.

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REFERENCES

[1]. Bušić, A., Mardetko, N., Kundas, S., Morzak, G., Belskaya, H., Šantek, M. I., Komes, D., Novak, S., & Šantek, B. Bioethanol production from renewable raw materials and its separation and purification: A review. Food Technology and Biotechnology, 56(3), 289–311, 2018.

[2]. Edeh, I. We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists, 2021.

[3]. Balat, M., & Balat, H. Progress in biodiesel processing. Applied Energy, 87(6), 1815–1835, 2010.

[4]. Mallholders, S. (2007). S Ustainable P Alm O Il P Roduction , 13–16, 2007.

[5]. Siswati, N. D., Yatim, M., & Hidayanto, R. Bioethanol dari Limbah Kulit Kopi Dengan Proses Fermentasi. 7–10, 2011.

[6]. Faustine, A. S., & Djamaan, A.Bioethanol Production from Various Agricultural Waste Substrate using Saccharomyces cerevisiae. 16(1), 7–13, 2021.

[7]. Elvers, B., Handbook of Fuels, WILEYVCH Verlag GmbH & Co. KGaA, Germany, 2008.

[8]. Onyeaka, H., Mansa, R. F., Michael, C., & Ling, V. Bioconversion of Starch Base Food Waste into Bioethanol. 1–11. 2022.

[9]. Manialup, B. H., Sangian, H. F., & Suoth, V. A. Pembuatan dan Pemurnian Etanol Dari Nira Aren dengan Menggunakan Teknik Destilasi Refluks. Jurnal MIPA, 7(1), 5, 2018.

[10]. Girsang, I. R., & Eliana, M. Performa Kolom Sieve Tray Dengan Penambahan Packing Serabut Pada Distilasi Etanol-Air (Vol. 2, Issue 1),2014.

[11]. Ramadani, T. A. Studi Penggunaan Packed Sieve Tray Column Pada Proses Pemurnian Etanol Melalui Proses Study of Packed Sieve Tray Column in Ethanol Purification Process Using Distillation Process, 2017.

[12]. Pilling, M., & Holden, B. S. Choosing trays andh packings for distillation. Chemical Engineering Progress, 105(9), 44–50, 2009.

[13]. Hamza, S., Slimane, N., Azari, Z., & Pluvinage, G. Structural and mechanical properties of the coral and nacre and the potentiality of their use as bone substitutes. Applied Surface Science, 264, 485–491, 2013.

[14]. Wang, X., Li, D., Bai, R., Liu, S., Yan, C., & Zhang, J. Evolution of the pore structure of pumice aggregate concrete and the effect on compressive strength. Reviews on Advanced Materials Science, 62(1), 2023.

[15]. Pang, M., Balcewicz, M., Ba, J., & Saenger, E. H. Geoenergy Science and Engineering Ac oustical-electrical models of tight rocks based on digital rock physics and double-porosity theory. 235 (January), 2024..

[16]. Orlando, J. R., Medina, L. C., Mendes, M. F., & Nicolaiewsky, E. M. A. HETP Evaluation Of Structured Packing Distillation Column. 26(03), 619–633, 2009.

[17]. Pöschmann, R., Paschold, J., Mueller, S., Harding, L., Brösigke, G., & Repke, J. Will laboratory and pilot plant columns soon become superfluous ? – A concept for the determination of structured packing characteristics in a measuring cell under distillation conditions. Separation and Purification Technology, 325(May), 124617, 2023.