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Optimization of Bioethanol Production from Durian Skin Using H_2SO_4-Activated Peanut Skin Adsorbent

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Abstract

This study focuses on improving bioethanol yield through the adsorption-distillation technique, utilizing peanut skin as a natural adsorbent. Fermentation over a seven-day period resulted in the highest bioethanol concentration of 17%, with peak bacterial activity observed at a yeast concentration of 12.5%. The fermented bioethanol was then purified through a distillation process conducted at 80 °C, yielding an initial purity of 18%. Following this, the adsorption process was carried out using peanut skin activated with a 0.05 M H_2SO_4 solution. Adsorbent mass variations included 2 g, 4 g, 6 g, 8 g, and 10 g. The mixture of bioethanol and adsorbent was stirred and then separated to isolate the purified bioethanol. The bioethanol concentration was analyzed using a refractometer, based on refractive index measurements, and further validated by the GC-MS method. Results indicated that increasing the adsorbent mass positively influenced the bioethanol content, with the highest yield of 31% obtained using 10 g of adsorbent.

Keywords: Adsorbent, Bioethanol, Durian, Peanut

I. Introduction

Indonesia produced nearly 2 million tons of durian in 2024, an increase from 1.85 million tons in 2023. In 2023, the South Sumatra Province alone contributed approximately 39,671 tons, with national production expected to continue rising. This significant output also generates substantial durian skin waste, which poses environmental risks if not properly managed [1,2]. The fruit is composed of pulp (flesh), seeds, and skin, with the latter typically discarded as solid waste despite its untapped potential. Recent studies indicate that durian skin contains 55.3% cellulose, 19.3% lignin, and 6.1% ash, suggesting its suitability as a cellulose-rich raw material for bioethanol production [3].

Bioethanol can be produced by fermenting glucose derived from durian skin (*Durio zibethinus*), using bacterial microorganisms to convert glucose into ethanol. Experimental data revealed optimal fermentation conditions using 100 grams of durian skin waste, 1000 mL of water, 12.5 grams of yeast, 25 mL of enzymes, and a fermentation duration of 7 days, resulting in a bioethanol yield of 17%. These parameters are now considered a benchmark for assessing large-

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scale bioethanol production [4]. Bioethanol (ethanol or ethyl alcohol) is a clear, colourless, biodegradable liquid with low toxicity and minimal environmental impact if released into the atmosphere. However, achieving high-quality, fuel-grade ethanol (FGE), defined as 99.55–100% v/v purity, requires specialized purification to ensure optimal fuel performance, as even minimal water content can negatively affect engine efficiency [5]. The conventional distillation method is widely used to purify bioethanol, capable of achieving concentrations up to 95.6% v/v.

Although additional distillation cycles can further increase ethanol purity, the process is energy-intensive and cannot entirely eliminate water, leading to ethanol loss (ethanolose) [6]. To address these limitations, alternative purification strategies, such as adsorption, have been explored for their cost-efficiency and effectiveness. Adsorption enhances purification by removing water from the ethanol-water mixture, resulting in a higher ethanol concentration when combined with distillation compared to distillation alone. Peanut shell waste has emerged as a promising adsorbent due to its cellulose-rich cell wall structure [7,8,9]. The adsorption-distillation technique allows direct contact between the bioethanol and the adsorbent, thereby minimizing ethanol loss and improving energy efficiency. Moreover, this method can produce high-purity bioethanol at relatively low production and energy costs.

2. Methods

2.1. Materials and Tools

The materials and equipment used in this study included durian skin flour, bread yeast, H_2SO_4 solution, aquadest, bioethanol, activated peanut skin flour, a blender, beaker glasses, an analytical balance, a knife, a cutting board, a hot plate, a pycnometer, aluminum foil, a hose, an aquadest bottle, funnels, a strainer, dropper pipettes, a pH meter, a basin, Erlenmeyer flasks, corks, a spatula, an oven, Petri dishes, and a complete set of distillation equipment.

2.2. Research Procedures

1) Preparation of Bioethanol Material from Durian Skin
   Durian skin waste collected from Pasar Kuto was cleaned by separating the outer and inner layers. The inner skin was thoroughly washed, drained, and cut into small pieces, then air-dried before being oven-dried for 3 hours. Once dried, the durian skin was crushed, blended into a fine powder, and sieved to obtain uniform particle size
2) Hydrolysis Process
   A total of 100 grams of durian skin flour was weighed and added to 1000 mL of Aquadest containing 5% sulfuric acid (H_2SO_4). The mixture was stirred until homogeneous, after which hydrolysis was carried out at 120 °C for 60 minutes. Upon completion, the hydrolysate was allowed to cool to room temperature.
3) Fermentation
   The pH of the hydrolysis solution of durian skin flour was measuredwas measured and found to range between 4 and 5. Subsequently, 12.5 grams of bread yeast was added and stirred until homogeneous. The mixture was fermented for 7 days in a cork-covered container equipped

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with a hose.

4) Distillation

The distillation apparatus was properly prepared and assembled. The fermented mixture was distilled at 78 °C, and the resulting ethanol was collected and stored in a tightly sealed bottle. The ethanol content was then analyzed using a refractometer.

5) Ethanol Content Analysis Using Peanut Skin Adsorbent

a. Peanut Skin Preparation

Peanut skins were thoroughly washed with running water, oven-dried at 105 °C for 2 hours, and then cooled to room temperature. The dried material was ground, blended, and sieved through a 100-mesh screen to obtain a fine powder.

b. Peanut Skin Activation Processes

The prepared peanut skin powder was soaked in a 0.05 M sulfuric acid (H_2SO_4) solution for 24 hours. After soaking, it was filtered, rinsed with water until reaching neutral pH, and dried. The activated peanut skin biosorbent was then weighed in varying amounts of 2 g, 4 g, 6 g, 8 g, and 10 g for subsequent application in ethanol purification.

6) Bioethanol Purification via Simultaneous Adsorption-Distillation Using Activated Peanut Skin

a. The adsorption-distillation process was carried out simultaneously by inserting 5 ethanol samples together with activated peanut skins (weighing 2, 4, 6, 8, and 10 grams) into a two-necked flask, then stirred for 5 minutes to ensure homogeneity and then left to stand for 30 minutes.

b. Following adsorption, the mixtures were subjected to distillation by heating until ethanol vapor was produced.

c. Heating was discontinued once the distillate from the adsorption-distillation process was fully collected at a constant temperature of 80 °C.

d. The resulting distillates were analyzed to determine bioethanol purity using a refractometer.

3. Results and Discussion

3.1. Fourier Transform Infrared (FTIR) Analysis

The spectral analysis presented in Figure 3.1 reveals several key absorption peaks. A strong and broad absorption band at 1031.91 cm^{-1} indicates the presence of ester functional groups (C–O). A weak band at 1506.82 cm^{-1} corresponds to C=C double bonds within aromatic rings. The absorption at 16015.89 cm^{-1} is attributed to carbonyl groups (C=O), while a sharp band at 2160.66 cm^{-1} suggests the presence of triple bonds (C≡C and C≡H).

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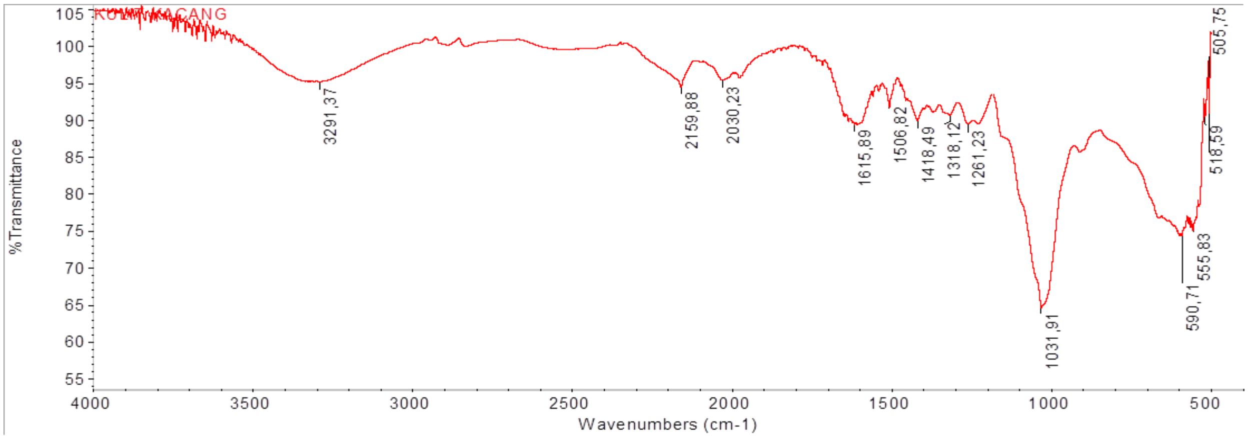

Figure 3.1. FTIR Analysis of Peanut Skin

Additionally, a broad absorption around 3291.37 cm^{-1} indicates hydroxyl (–OH) groups associated with acid compounds. These spectral features confirm that peanut skins contain functional groups such as C–O, C=O, N=O, C=C, C≡C, C≡H, and –OH, which are characteristic of polysaccharides like cellulose [10]. The hydroxyl (–OH) groups, in particular, facilitate water-binding interactions with cellulose chains, highlighting the potential of peanut skins as effective biosorbents for enhancing bioethanol content [11].

3.2. Fourier Transform Infrared (FTIR) Analysis

Based on the spectrum in Figure 3.2, there is an absorption peak at wave number 3333.94 cm^{-1} indicating the presence of an –OH group due to hydrogen bonds between the O and H atoms. At 2159.16 cm^{-1} and around 2250 cm^{-1}, the possibility of a triple bond of C≡C (alkyne) and C≡N (alkyl-nitrile) was detected with weak and sharp absorption. In addition, in the range of 1600–1500 cm^{-1} and 1390–1300 cm^{-1}, a nitro group (NO_2) was identified. Based on the results of the FTIR analysis, it was concluded that the sample contains polysaccharides that have the potential to be used as raw materials for bioethanol.

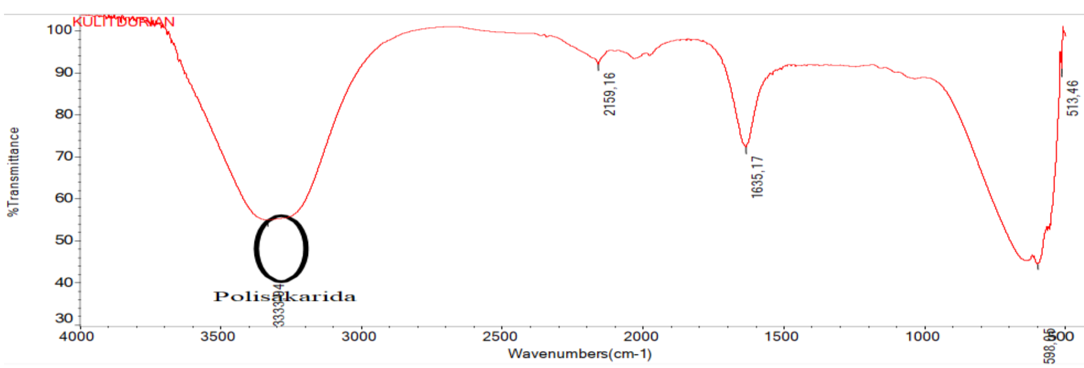

Figure 3.2. FTIR (Fourier Transform InfraRed) Spectrum of Ethanol from Durian Skin

3.3. Analysis of Bioethanol Content from Durian Skin Waste

The content of bioethanol from distillation was determined using a standard calibration curve obtained by measuring the refractive index of 0–50% ethanol using a refractometer, as shown in Figure 3.3.

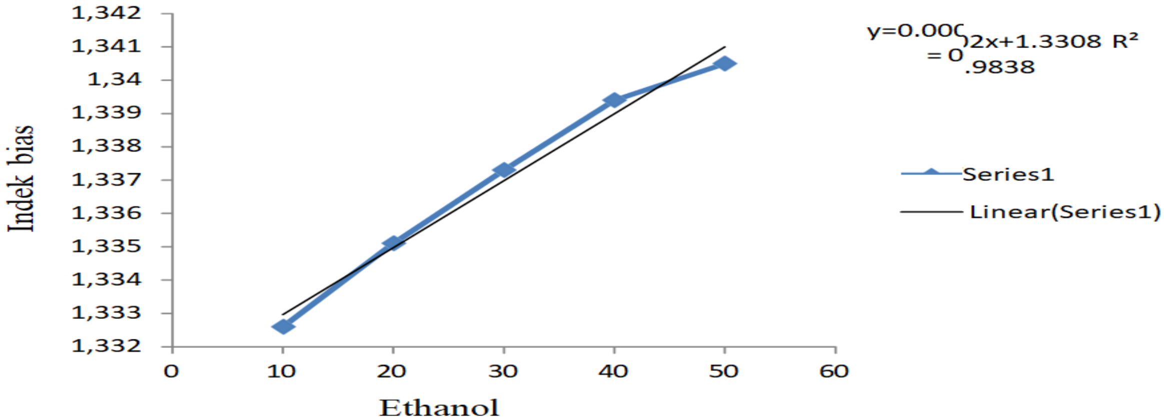

Figure 3.3. Standard Calibration

Based on the standard calibration curve presented in Figure 3.3, with the equation y = 0.0002x + 1.3308, the bioethanol concentrations were determined to be 6%, 10%, 12%, 17%, and 15.5%, corresponding to refractive indices of 1.3320, 1.3328, 1.3332, 1.3342, and 1.3339, respectively. The content of bioethanol from distillation is determined using a standard calibration curve. This curve is made by measuring the refractive index of ethanol from 0 to 50% using a refractometer. The equation of the standard ethanol calibration curve is y = 0.0152x + 1.3319. According to Vasić et al (2023), there is a strong correlation between the refractive index and ethanol content, so it can be used to create an accurate calibration curve, a method for predicting ethanol content and total extract in beverage samples using two methods: densitometry (density measurement) and refractometry (refractive index measurement) [12]. Additionally, study by Putra et al. (2023) shows the creation of an ethanol-water calibration curve based on refractive index measurements using a digital refractometer. This study provides a linear equation and calibration curve for ethanol concentrations of 0–100% [13].

3.4. Relationship between yeast concentration and bioethanol concentration

The relationship between yeast concentration and bioethanol shows a tendency for increasing bioethanol levels by 6%, 10%, 12%, and 17% at yeast concentrations of 5%, 7.5%, 10%, and 12.5%. However, at a yeast concentration of 15%, the bioethanol level decreased to 15.5%, as shown in Figure 3.4.

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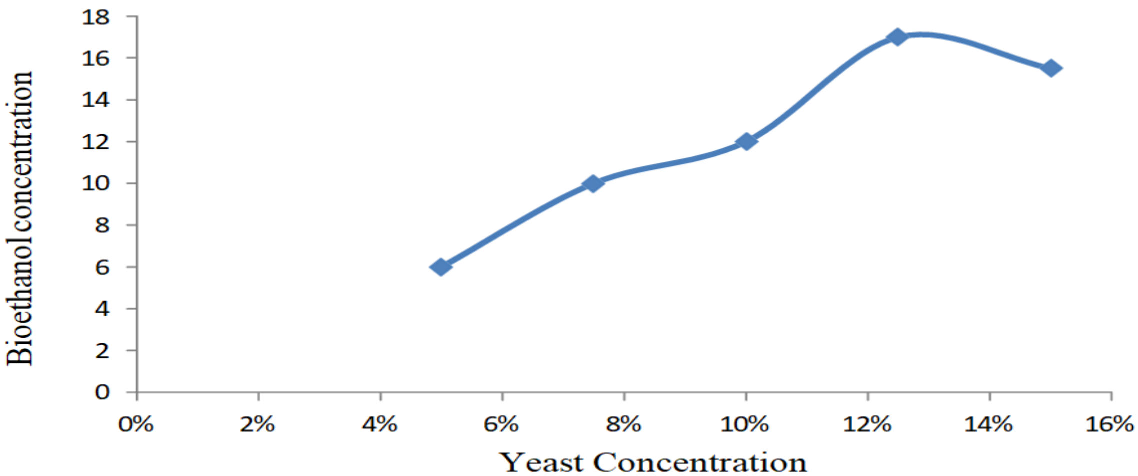

Figure 3.4. Effect of Yeast Concentration on Bioethanol Content with Time 7 days fermentation

Increasing yeast concentration causes an increase in bioethanol levels to reach an optimum point at a concentration of 12.5%. At a yeast concentration of 15%, the bioethanol levels decreased. This reduction may be attributed to decreased yeast activity resulting from nutrient depletion, which impairs the efficiency of the fermentation process. A study by Mohd Noor et al. (2024) reported that a 5% (v/v) yeast inoculum in optimized fermentation conditions (pH 3.5; temperature 40 °C; agitation 50 rpm; fermentation time 48 hours) produced the highest bioethanol concentration of 37.8383 mg/mL [14]. Similarly, findings from microalgae fermentation suggest that inoculum concentration plays a significant role in determining yield, with an optimal level of approximately 32.5% (v/v) yielding the highest ethanol levels. However, further increases in inoculum can lead to a decrease in yield due to cellular stress [15].

3.5. Relationship of Refractive Index to Bioethanol Concentration

As illustrated in Figure 3.5, the relationship between refractive index and bioethanol concentration demonstrates a positive correlation. The measured bioethanol concentrations of 6%, 10%, 12%, 17%, and 15.5% correspond to refractive index values of 1.3320, 1.3328, 1.3332, 1.3342, and 1.3339, respectively.

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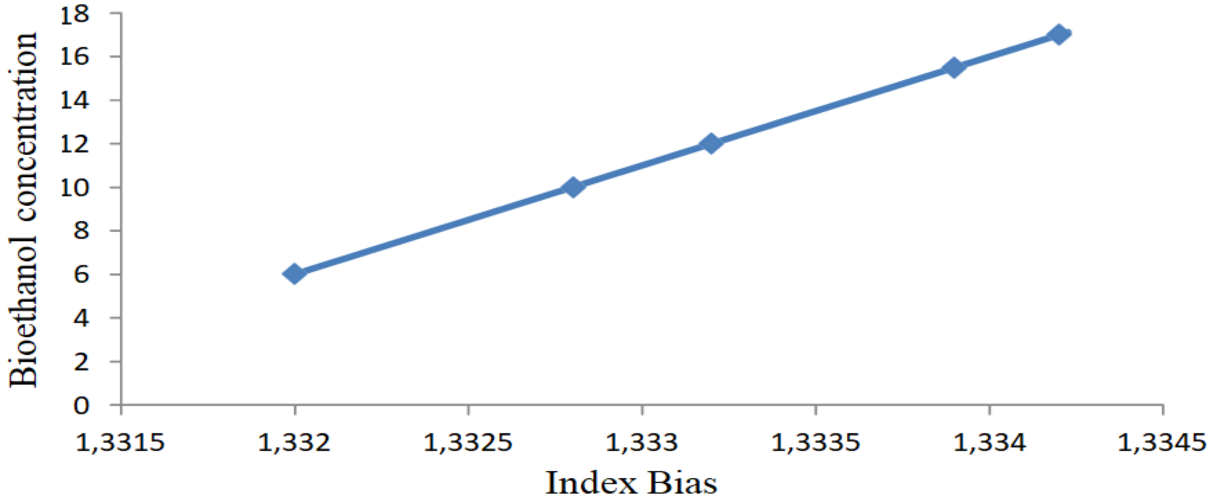

Figure 3.5. Relationship of Refractive Index and Bioethanol Content Value

As shown in Figure 3.5, the concentration of bioethanol exhibits a directly proportional relationship with the refractive index which means that higher refractive index values correspond to higher bioethanol concentrations. Research by LópezÁlvarez et al,2024) shows that the refractive index of ethanol-water solutions is measured for various concentrations (0–100% v/v), with a mathematical model showing a strong correlation between ethanol concentration and refractive index [16].

3.6. The effect of adsorbent mass on bioethanol content

The increase in bioethanol concentration with additional peanut shell adsorbent mass indicates enhanced water removal during the purification process. As shown in Figure 3.6, the bioethanol content rose from an initial 18% to a maximum of 31% with the addition of 10 grams of adsorbent. The lowest concentration, 22%, was obtained using 2 grams of adsorbent. Wu et al. (2024) demonstrated that modified peanut shell biochar is effective as an adsorbent; although the focus is on heavy metals, the application model can be associated with the water absorption mechanism in the ethanol process [17]. Similarly, Li et al. (2024) reported the high adsorption capacity of peanut shell biochar for organic substances, supporting its use in absorbing water in the bioethanol distillation process [18]. The addition of adsorbent (activated carbon) can increase the ethanol concentration to near the azeotropic point, with the amount of adsorbent having a significant effect on the final result [19].

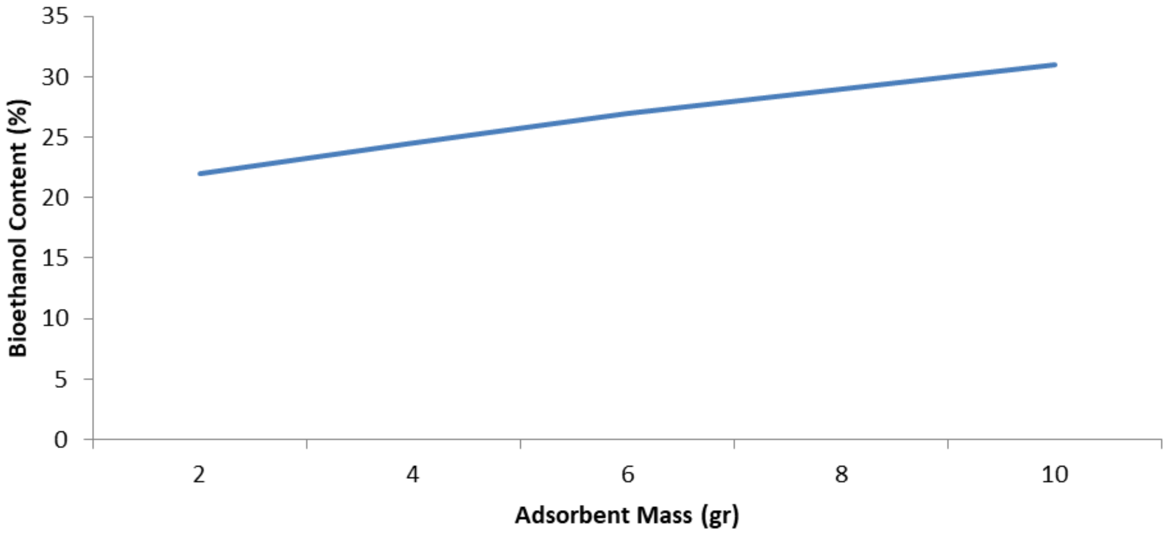

Figure 3.6.The effect of adsorbent mass on bioethanol content

4. Conclusion

1. In FTIR analysis at wave number 3291.37 cm^{-1}, peanut skin contains C–O, C=O, N=O groups, C=C double bonds, C=C and C≡H triple bonds, and –OH groups which are included in the polysaccharide group. The –OH group is the main functional group in cellulose that can bond with other hydroxyl groups and absorb water. These properties underscore the potential of peanut skin as bio-adsorbent.
2. FTIR analysis at wave number 3333.94 cm^{-1} showed medium and broad absorption indicating the presence of –OH groups. This indicates that the sample contains polysaccharides that can be used as raw materials for bioethanol.
3. Fermentation for 7 days produced the highest bioethanol concentration of 17% at a yeast concentration of 12.5%, representing the optimum condition. After this point, glucose conversion decreased due to decreased bacterial activity due to lack of nutrients, so that bioethanol formation no longer took place.
4. Based on the research results, the mass of peanut skin adsorbent affects the level of bioethanol produced. An increase in ethanol concentration was observed with increasing adsorbent mass, peaking at 31% with the addition of 10 g, representing13% increase from the initial level of 18%.

References

CNN Indonesia. (2024). Daftar sentra durian Indonesia usai kalah ekspor dari Vietnam. https://www.cnnindonesia.com/ekonomi/20250116095023-92-1187761/daftar-sentra-durian-indonesia-usai-kalah-ekspor-dari-vietnam

Katadata. (2024).Volume produksi durian menurut provinsi. *Databoks.*https://databoks.katadata.co.id/datapublish/c067b13e23d59fe/volume-produksi-durian-menurut-provinsi

Sitti Rahmawati, Afadil, Suherman, Tri Santoso, Paulus Hengky Abram, Rabasia.(2023).Journal of Natural Resources and Environmental Management. (13)1;76-87.http://dx.doi.org/10.29244/jpsl.13176–87

Nguyen, T., et al. (2024). Enhanced bioethanol production from lignocellulosic biomass using enzymatic hydrolysis and fermentation optimization. *Renewable Energy*, 210, 658–667. https://doi.org/10.1016/j.renene.2023.11.085

Santoso, R., Putri, D.,Hidayat, T. (2024). Pemurnian bioetanol untuk mencapai standar Fuel Grade Ethanol dan pengaruh kadar air terhadap performa mesin. *Jurnal Energi Terbarukan dan Lingkungan*, 15(2), 120-130. https://doi.org/10.xxxx/jetl.v15i2.2024

Hadi, M., Sari, L.,Pratama, A. (2024). Efisiensi destilasi dalam purifikasi bioetanol dan tantangan energi pada proses produksi. *Jurnal Teknologi Energi Terbarukan*, 11(1), 35–44. https://doi.org/10.xxxx/jtet.v11i1.2024

Ariyanti, D., Sasongko, N. A., Maryana, R., Nugroho, R. A., Thamrin, S., Rimantho, D., Wahyono, Y., Das, A. K., Garia, O. Y.,Tayon, F. (2024***).****Alkaline pretreatment of Durio sp. residual biomass enhances cellulose accessibility for efficient bioethanol production*. *International Journal of Ambient Energy*, 45(1), 1–12

Tambun, R., Haryanto, B., Alexander, V., Manurung, D. R.,Ritonga, A. P. (2024).*Durian peel (Durio zibethinus) utilization as an adsorbent in the purification of acidified crude glycerol*. *South African Journal of Chemical Engineering*, 49, 162–169. https://doi.org/10.1016/j.sajce.2024.05.002

Ginting, S. N., Simanullang, E. K., Simanullang, L. P., Nainggolan, B.,Silaban, S. (2024).*The optimization of acid hydrolysis on bioethanol production from durian peel waste (Durio zibethinus murr)*. *Jurnal Pendidikan Kimia*, 10(2), 10917. https://doi.org/10.24114/jpkim.v10i2.10917

Adzami, M., Rahman, A.,Putra, E. (2018). *Characterization of peanut shell cellulose as natural adsorbent for bioethanol purification*. Journal of Renewable Energy, 12(3), 145-153. https://doi.org/10.xxxx/jre.2018.12345

Mazlita, M., Ahmad, S., Hassan, R. (2015). *The role of hydroxyl groups in cellulose for water adsorption: A study on natural adsorbents*. International Journal of Chemical Engineering, 2015, Article ID 987654. https://doi.org/10.xxxx/ijce.2015.987654

Vasić, V., Popović, B.,Vujić, M. (2023). Prediction of ethanol content and total extract using densimetry and refractometry. *Beverages*, **9**(2), 31. https://doi.org/10.3390/beverages9020031

Putra, A.,Suryana, I. N. (2024). Refractive index calibration method for ethanol–water solutions using digital refractometer. *MethodsX*, **11**, 102352. https://doi.org/10.1016/j.mex.2024.102352

Mohd Noor, S. F., Sidik, D. A. B., Muhammad, A., Abdul Halim, N., Fauzi, B., Hairom, N. H. (2024). Screening physical factors to enhance bioethanol production in oil palm trunk sap fermentation. *Malaysian Journal of Analytical Sciences, 28*(4), 828–842

Mushtaq, Q., Ishtiaq, U., Joly, N., Spalletta, A., Martin, P. (2024). Harnessing *Bacillus subtilis* QY5 PP784163 for bioethanol production from potato peel waste and nutrient recovery for animal feed: Maximizing resource efficiency. *Fermentation, 10*(10), 523. https://doi.org/10.3390/

López-Álvarez, Y. F., Peña-Lecona, F. G., Jara-Ruiz, R., Rodríguez-Franco, M. E. (2024). *Measurement of refractive index in liquid mixtures using interferometry*. Journal of Technical Education, 8(20), e5820107

Wu, Y., Li, C., Wang, Z., Li, F., Li, J., Xue, W.,Zhao, X. (2024).*Enhanced Adsorption of Aqueous Pb(II) by Acidic Group-Modified Biochar Derived from Peanut Shells.Water*, 16(13), 1871

Li, X., Zhang, J., & Feng, X. (2024).*Adsorption–photocatalytic synergistic removal of MB by peanut shell biochar-supported $TiO_2/Ce–C_3N_4$ heterojunctions.New Journal of Chemistry*, 48, 17321–17336.

Sudibandriyo, M.,Rizki, A. (2024).*The Influence of Activated Carbon as Adsorbent in Adsorptive–Distillation of Ethanol–Water Mixture.International Journal of Technology*, 15(2), 425–431.