

Alkali Hydrogen Peroxide (AHP) Pretreatment to Increase The Cellulose Content In Durian Peel Waste

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Article Information	ABSTRACT
Article History Received : April 24, 2026 Revised : May 11, 2026 Published : July 02, 2026	Indonesia is one of the largest producers of durian, generating substantial quantities of durian peel waste. Due to its high cellulose content, durian peel has strong potential as a lignocellulosic feedstock for reducing sugar and biofuel production. However, the presence of lignin and hemicellulose limits cellulose accessibility and inhibits hydrolysis. This study investigated Alkali Hydrogen Peroxide (AHP) pretreatment to enhance cellulose purity in durian peel waste. Pretreatment was carried out using H₂O₂ concentrations of 0.5–8.5% (w/v) with NaOH adjustment to pH 11–12 at 70°C for 3 h. The optimum condition was obtained at 8.5% H₂O₂, which increased cellulose content from 63.02% to 75.05%, reduced hemicellulose by 24.4%, and removed 99.5% of lignin. Scanning Electron Microscopy (SEM) analysis confirmed the formation of a rougher and more porous surface after pretreatment, indicating disruption of the lignocellulosic structure. Statistical analysis using ANOVA showed that H₂O₂ concentration significantly affected cellulose, hemicellulose, and lignin responses ($p < 0.05$). These results demonstrate that AHP pretreatment is highly effective in improving cellulose accessibility and provides a promising approach for converting durian peel waste into reducing sugars and other bio-based products.
Keywords: <i>Alkali Hydrogen Peroxide (AHP); Durian Peel; Cellulose.</i>	

INTRODUCTION

Indonesia is the world's largest producer of durian, generating a massive amount of durian peel waste each year. According to data from the Central Statistics Agency (BPS), durian production in Indonesia throughout 2023 reached 1,852,045 tons (BPS, 2023). However, in a single durian fruit, the percentage of edible flesh is only 20.52%, while 79.48% consists of durian peel and seeds that have not been fully utilized and become agricultural waste (Dwi Ana et al., 2015). One approach to managing durian peel waste is to utilize the peel as a raw material for the production of reducing sugar. Reducing sugar production can utilize raw materials in the form of cellulose-containing waste (Putra et al., 2024). One type of waste containing cellulose is durian peel, which contains 60.45% cellulose, 13.09% hemicellulose, 15.45% lignin, and 4.35% ash (Husada et al., 2021; Obed et al., 2015). The high cellulose content can serve as a source of reducing sugars upon hydrolysis (Nandini et al., 2021).

Reducing sugars are formed as a result of the conversion of cellulose into sugar monomers (Wesly Harianja & Idiawati, 2015); however, the lignocellulosic structure of durian peel can inhibit degradation, primarily due to the presence of lignin, thus requiring a lignin-removal treatment

(Priatmoko & Rohman, 2023). Therefore, an effective delignification process is required to remove lignin and partially dissolve hemicellulose before hydrolysis. According to a study (Sebran et al., 2018), lignin in empty oil palm fruit bunches can be degraded using 5.5% NaOH at 200°C for 60 minutes by 74.47%. Meanwhile, the delignification process using H₂O₂, as per a study conducted (Dimawarnita et al., 2023) on empty oil palm fruit bunches at a 30% concentration, at 90°C for 1 hour, successfully removed nearly 75% of the lignin content. Based on previous studies, it is known that the use of H₂O₂ and NaOH is highly effective for removing lignin.

Therefore, this study employs an updated method, namely AHP (Alkali Hydrogen Peroxide), which utilizes a mixture of NaOH and H₂O₂ for the delignification and bleaching of durian fruit peel. According to a study (Afifah et al., 2022), the delignification and bleaching of cassava peel were performed using NaOH and H₂O₂. During the delignification process, the pH of the H₂O₂ solution was adjusted using NaOH. A 6% H₂O₂ concentration, pH 11, and a temperature of 70–90°C for 3 hours were able to remove 84.05% of the lignin. The AHP method has proven effective for removing lignin from biomass; therefore, this study employed the AHP method. Cellulose structure can be broken down through the delignification process to increase material porosity, thereby facilitating the conversion of cellulose into glucose (Mardina et al., 2013)(Alaa, A et al., 2025). The novelty of this study lies in the application of AHP pretreatment to durian peel waste using a wide range of H₂O₂ concentrations (0.5–8.5% w/v), combined with comprehensive analysis of lignocellulosic composition, statistical significance using ANOVA, and morphological characterization using Scanning Electron Microscopy (SEM). This study aims to determine the optimum pretreatment condition to maximize cellulose content and improve the suitability of durian peel as a feedstock for reducing sugar and biofuel production. Therefore, this study was conducted to test the effectiveness of the Alkali Hydrogen Peroxide (AHP) method in improving the purity of durian peel cellulose through the delignification process by analyzing the structure using SEM.

RESEARCH METHODS

This study employed an experimental method using durian peel waste obtained from Jl. Bhakti Alam, Kemang, Ngembal, Tukur District, Pasuruan, East Java, as the raw material. The durian peel waste was first processed through a physical pretreatment stage to separate the fruit and extract the peel. The soft, white inner peel was then separated from the spiny outer peel. A delignification process was then carried out to remove lignin in order to produce the best delignification variables using the alkaline hydrogen peroxide (AHP) method as raw material for the production of reducing sugar.

This study employed a single-factor experimental design to evaluate the effect of H₂O₂ concentration on delignification regarding residual lignin content. The H₂O₂ concentration variations were 0.5%, 2.5%, 4.5%, 6.5%, and 8.5%; the delignification temperature was 70°C; and the delignification time was 3 hours (Mun, J., S et al, 2024). The experimental data obtained were analyzed descriptively by examining the remaining lignin concentration after the delignification process against the H₂O₂ concentration to determine the conditions that produced the best results.

The materials used in this study included durian peel, 50% (w/v) H₂O₂, 48% (w/v) liquid NaOH, and distilled water. The main equipment used in the experiment included glass beakers, a thermometer, grinder, a magnetic bar, a hotplate and magnetic stirrer, stirring rods, a measuring flask, pH paper, a stand and clamps, plastic wrap, and aluminum foil. The parameter observed in this study was the residual lignin concentration resulting from the delignification process, which was analyzed using scanning electron microscopy (SEM). Morphological analysis was carried out using a HITACHI FLEXSEM 1000 (Hitachi High-Tech Corporation, Japan) equipped with an Energy Dispersive X-ray Spectroscopy (EDS) detector. The dried samples were analyzed to observe surface morphological changes before and after Alkali Hydrogen Peroxide (AHP) pretreatment at magnifications of 5,000× and 10,000×.

Physical Pre-treatment of Durian Peel

The first step is to separate the durian peel from the fruit and remove the peel. Then, separate the soft, white inner peel from the spiny outer peel. After that, the inner skin is washed under running water and cut into small pieces, then dried in an oven at 110°C until dry (constant mass) and ground in a blender. The durian skin flour is then sifted to a 100-mesh size. Durian skin flour that is finer than 100 mesh is blended again and sifted until a 100-mesh size is achieved.

Preparation of 0.5%, 2.5%, 4.5%, 6.5%, and 8.5% (w/v) H_2O_2 solutions (250 mL)

42.5 ml of 50% liquid H_2O_2 was taken for the 8.5% solution; 32.5 ml for the 6.5% solution; 22.5 ml for the 4.5% solution; and 12.5 ml for the 2.5% solution, while 50 ml was taken with a pipette and measured in a measuring cylinder for the 0.5% concentration. It was then diluted with distilled water to a volume of 250 ml in a volumetric flask. The solution was shaken until homogeneous and ready for use.

Preparation of a 1.5% (w/v) NaOH Solution (100 mL)

Using a pipette, measure 3.125 mL of 48% liquid NaOH into a measuring cylinder. Then, dilute with distilled water to a final volume of 100 mL in a volumetric flask. Shake the solution until homogeneous; it is now ready for use.

Delignification

25 grams of durian peel flour was then mixed with 250 mL of 0.5%, 2.5%, 4.5%, 6.5%, and 8.5% H_2O_2 solutions, and 1.5% NaOH was added until the solution's pH reached 11–12 in a beaker. The pH was then checked with pH paper until the desired pH was reached; NaOH solution was added if the pH was not yet appropriate. Next, the beaker was covered with plastic wrap and aluminum foil, then heated and maintained at a constant temperature of 70°C for 3 hours; during the heating process, the mixture was stirred with a magnetic stirrer at 300 rpm. After the delignification process is complete, the durian peel flour residue is separated from the filtrate. The durian peel residue is washed with distilled water until the pH is neutral (6–7) and dried in an oven at a constant temperature of 105°C for 2 hours.

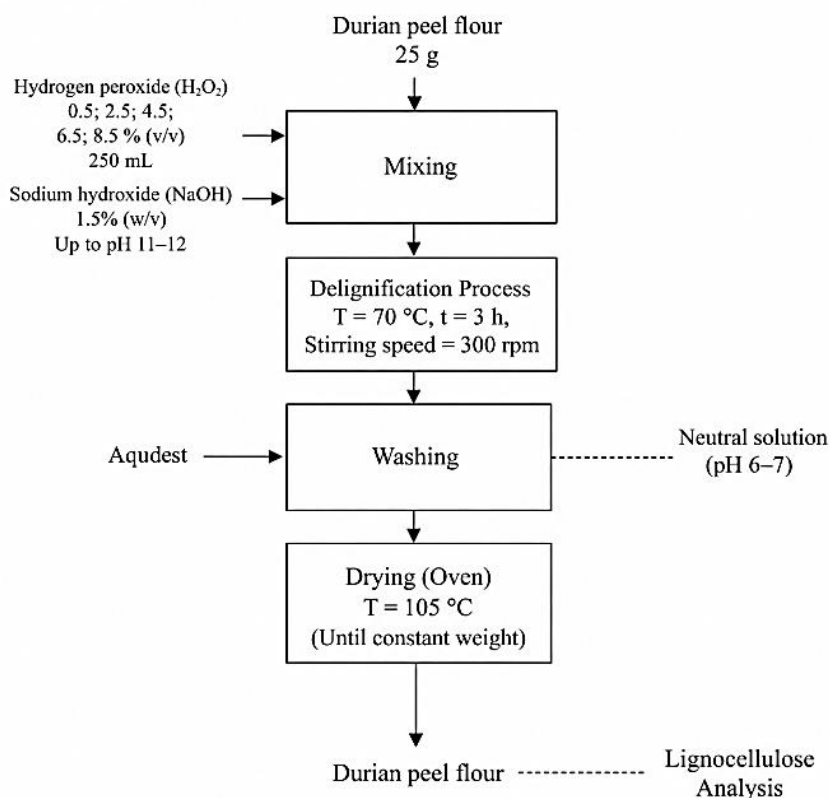


Figure 1. Delignification process flowchart

RESULTS AND DISCUSSION

Pretreatment Delignification

The delignification process influences the AHP method, which has a significant impact on increasing the cellulose content. This is evidenced by the results of the lignocellulose content tests before and after pretreatment, which are summarized in Table 1. The percentage changes in cellulose, hemicellulose, and lignin content were calculated using the following equation (1) (Al-Rajabi, M. M., et al, 2024) :

$$\text{Remove}\% = \frac{M_d - M_o}{M_o} \times 100\% \quad (1)$$

Notes:

Md: content after delignification pretreatment (%)

Mo: content before delignification pretreatment (%)

Table 1. Lignocellulose Content in Durian Peel Samples

H ₂ O ₂ (%)	Compounds in durian peel samples (%)		
	Lignin	Hemicellulose	Cellulose
0	4,02	32,96	63,02
0,5	3,11	31,79	65,10
2,5	2,31	29,64	68,05
4,5	1,13	27,99	70,88
6,5	0,05	25,85	74,10
8,5	0,02	24,93	75,05

The delignification process using the Alkali Hydrogen Peroxide (AHP) method significantly altered the lignocellulosic composition of durian peel, as presented in Table 1. The cellulose content increased from 63.02% in untreated biomass to 75.05% after pretreatment with 8.5% H₂O₂. At the same time, hemicellulose decreased from 32.96% to 24.93%, while lignin content was reduced from 4.02% to 0.02%, corresponding to 99.5% lignin removal. These results demonstrate that AHP pretreatment effectively removes structural barriers and enhances cellulose purity. The lignin removal efficiency obtained in this study is considerably higher than those reported in previous studies. Sebran et al. (2018) reported that pretreatment of oil palm empty fruit bunches using 5.5% NaOH at 200°C for 60 min removed 74.47% of lignin. Dimawarnita et al. (2023) found that 30% H₂O₂ at 90°C for 1 h removed approximately 75% of lignin from the same biomass. In addition, Afifah et al. (2022) reported that the combination of NaOH and H₂O₂ under alkaline conditions (6% H₂O₂, pH 11, 70–90°C, 3 h) removed 84.05% of lignin from cassava peel. Compared with these studies, the 99.5% lignin removal achieved in this study indicates that the selected AHP conditions were highly effective for durian peel waste. This study concludes that delignification pretreatment using the AHP method is highly effective in opening the lignocellulose structure, making the cellulose in the biomass easier to convert into reducing sugars. The result can be seen in the figure below:

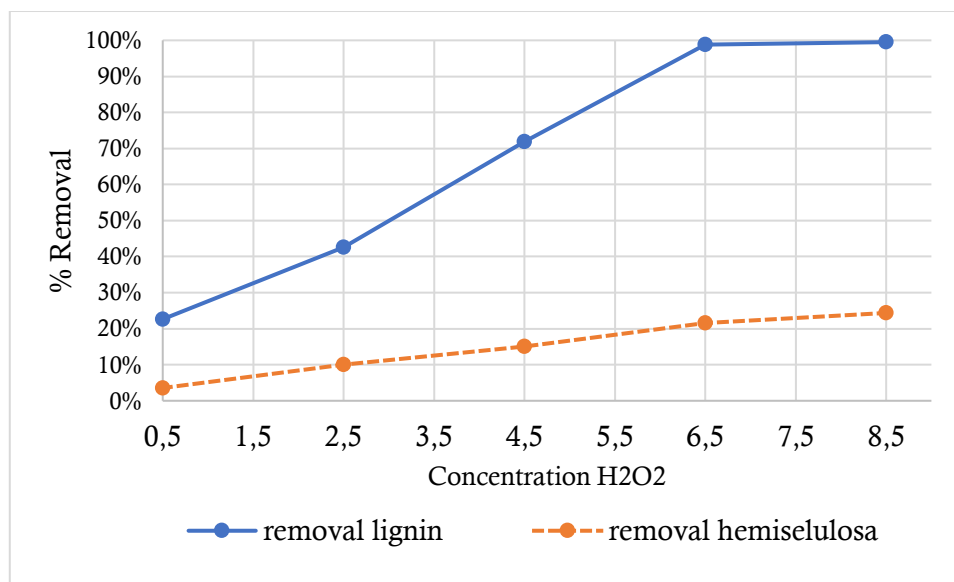


Figure 2. Effect of Concentration H₂O₂ (N) and % Removal removal of lignin and hemicellulose in the delignification process

The effectiveness of lignin and hemicellulose removal in this study aligns with several previous studies stating that lignin and hemicellulose tightly bound to cellulose microfibrils can inhibit hydrolysis, resulting in suboptimal conversion of cellulose into reducing sugars (Moron, 2025). The significant reduction in lignin up to 99.5% in this study indicates that the AHP method is capable of producing a substrate with a high and relatively pure cellulose content. This is crucial for enhancing reducing sugar yields during the hydrolysis stage. The 24.4% reduction in hemicellulose opens up the cell wall structure. Although hemicellulose is not completely removed, this compound can function as a pentose sugar. Under these conditions, the delignified substrate has the potential to produce mixed sugars (glucose and xylose) during the hydrolysis stage (Melati, R.B et al, 2023) (Dyshlyuk, L et al, 2024). Figure 2 shows that increasing H₂O₂ concentration progressively improved lignin and hemicellulose removal. This trend can be explained by the formation of perhydroxyl ions (HOO⁻) under alkaline conditions. These reactive species oxidatively cleave β-O-4 ether linkages and aromatic structures in lignin, converting them into smaller water-soluble compounds. Simultaneously, NaOH causes fiber swelling and partially dissolves hemicellulose, which opens the compact lignocellulosic matrix and exposes cellulose microfibrils. As a result, higher H₂O₂ concentrations produce greater delignification efficiency and increase cellulose accessibility. The decrease in hemicellulose also contributes to improved biomass porosity. Although only 24.4% of hemicellulose was removed, this reduction is sufficient to loosen the cell wall structure and facilitate subsequent hydrolysis. The combined removal of lignin and hemicellulose is particularly important because both components form a protective matrix around cellulose that limits contact between cellulose and hydrolyzing agents. To confirm that these compositional changes were significantly influenced by the pretreatment, a statistical analysis using the Analysis of Variance (ANOVA) method was conducted, as presented in Table 2.

Table 2. Analysis of Variance (ANOVA) of Cellulose, Hemicellulose, and Lignin Responses

Parameters	Cellulose	Hemicellulose	Lignin
F-Value	134,39	201,81	66,36
P-Value	0,0003	0,0001	0,0012
R ²	0,9711	0,9806	0,9431
Adj R ²	0,9639	0,9757	0,9289
Model	Linear	Linear	Linear
Description	Significant	Significant	Significant

Based on Table 2, the results of the ANOVA analysis indicate that the models obtained for cellulose, hemicellulose, and lignin responses are statistically significant. This is evidenced by p-values less than 0.05, specifically 0.0003 for cellulose, 0.0001 for hemicellulose, and 0.0012 for lignin. These very small p-values indicate that variations in pretreatment conditions have a significant effect on changes in the lignocellulose composition of durian peel.

The high F-values for each response 134.39 for cellulose, 201.81 for hemicellulose, and 66.36 for lignin indicate that the resulting models have a strong ability to explain the effects of treatment on the observed responses. Additionally, the high coefficient of determination (R^2) values 0.9711, 0.9806, and 0.9431 indicate that over 94% of the variation in the experimental data can be explained by the models used. The Adjusted R^2 values, which are close to the R^2 values, also indicate that the models fit the experimental data well.

The models obtained for the three responses are linear models, indicating that an increase in pretreatment treatment yields a linear relationship with an increase in cellulose content and a decrease in hemicellulose and lignin content.

Morphological Changes in Durian Skin Before and After Initial Treatment as Observed by Scanning Electron Microscopy (SEM)

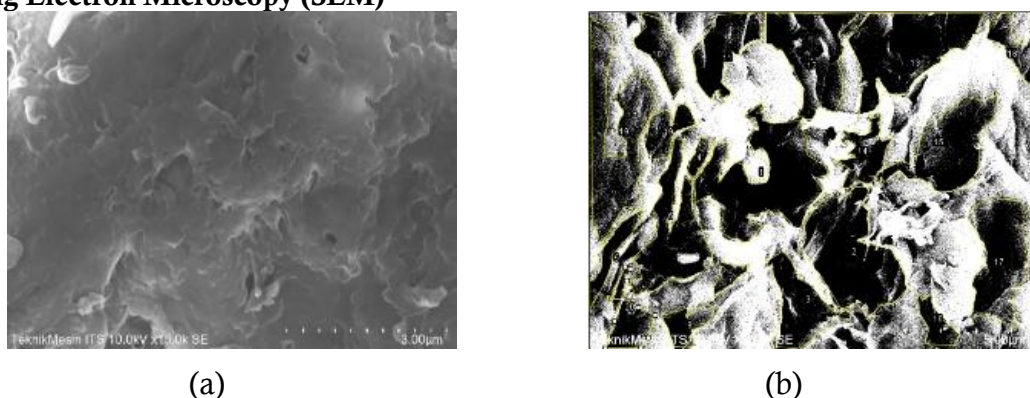


Figure 3. SEM images of durian peel with (a) no pretreatment, (b) alkaline hydrogen peroxide (AHP) pretreatment

The results of the Scanning Electron Microscopy (SEM) analysis in **Figure 2** show significant morphological changes between the durian peel samples before and after pretreatment using the Alkali Hydrogen Peroxide (AHP) method. In the untreated samples, the biomass surface appears relatively dense, smooth, and uniform. This structure indicates that the cellulose fibers are still enclosed by a lignin and hemicellulose matrix, forming a compact lignocellulosic network.

In contrast, after AHP pretreatment using a combination of NaOH and H_2O_2 , the biomass surface exhibits quite distinct changes. The surface structure becomes rougher, cracked, and shows signs of peeling on the outer layer of the biomass. The formation of cracks and pores on the surface indicates that the delignification process has damaged the structure of the lignocellulosic cell walls. These morphological changes occur due to the oxidative reaction of hydrogen peroxide under basic conditions, which breaks the lignin bonds and partially dissolves the hemicellulose that binds the cellulose fibers (Permata, D.A et al, 2021). The degradation of these components exposes the internal structure of the biomass, thereby increasing the surface area and porosity of the material. This condition is highly advantageous for subsequent conversion stages because cellulose becomes more accessible to reagents or enzymes during the hydrolysis process (Adebayo, A. J and Olanrewaju, A, 2025).

These SEM observations align with the compositional analysis results in Table 1, which show a reduction in lignin of up to 99.5% and an increase in cellulose content following the pretreatment process. Thus, this morphological analysis reinforces that the AHP method is effective in disrupting the lignocellulosic structure of durian peel and enhancing cellulose accessibility.

Table 3. Particle Size Measurements After AHP Pretreatment

Label	Area	Mean	Min	Max
1	7,230	74.318	19.000	230.000
2	6,334	74.622	17.000	235.000
3	2,871	85.163	20.000	255.000
4	0,444	96.616	36.000	212.000
5	1,028	79.280	24.000	197.000
6	4,510	82.394	22.000	242.000
7	0,466	95.511	41.000	184.000
8	1,032	96.005	24.000	255.000
9	1,212	90.040	29.000	188.000
10	1,458	90.351	28.000	203.000
11	2,696	83.660	23.000	216.000
12	4,566	85.739	21.000	221.000
13	6,130	75.029	18.000	255.000
14	1,606	80.355	16.000	195.000
15	4,425	84.548	22.000	189.000
16	0,811	83.174	31.000	255.000
17	4,385	87.959	28.000	214.000
18	1,553	95.024	24.000	215.000
19	5,849	96.324	36.000	188.000
20	1,490	96.607	19.000	255.000
mean	3,005	86.636	24.900	220.200
SD	2,214	7.703	6.882	25.979
MIN	0,444	74.318	16.000	184.000
MAX	7,230	96.616	41.000	255.000

In addition, particle size measurements taken at 20 points using ImageJ showed a mean value of 3.005 with a standard deviation (SD) of 2.214, indicating that the particle size distribution was quite variable. The minimum value of 0.444 and the maximum value of 7.230 indicate significant structural fragmentation in the sample. This variation in particle size indicates that the pretreatment caused part of the material's structure to degrade and break into smaller particles. Based on the analysis of SEM image intensity, a mean intensity value of 86.636 with a standard deviation of 7.703 was obtained, along with a minimum value of 74.318 and a maximum of 96.616. This variation in intensity indicates differences in the material's surface topography.

Areas with brighter intensity indicate denser or protruding surface regions, while darker areas indicate regions with pores, voids, or cracks resulting from structural degradation. Overall, the SEM analysis results show that the pretreatment performed was able to alter the surface morphology of the material, making it more open, irregular, and featuring cracks and pores. These structural changes indicate that the pretreatment successfully disrupted the lignocellulosic matrix, thereby enhancing the accessibility of cellulose for subsequent hydrolysis processes.

CONCLUSION

Based on the research results, the Alkali Hydrogen Peroxide (AHP) method was found to be effective in increasing the cellulose purity of durian peel biomass. Treatment with 1.5% NaOH and 8.5% H₂O₂ at 70 °C for 3 hours increased the cellulose content from 63.02% to 75.05%, reduced hemicellulose by 24.4%, and removed lignin by up to 99.5%. Statistical analysis using ANOVA showed that the obtained model was significant with a p-value < 0.05 and an R² value above 0.94, indicating that the model could explain most of the variation in the experimental data. Morphological analysis using SEM also revealed changes in the surface structure of the biomass from a dense state to a rougher and more porous state after pretreatment, indicating the degradation of the lignin and hemicellulose matrix. Scanning Electron Microscopy (SEM) analysis revealed degradation of the cell wall structure and the formation of pores, indicating the release of lignin and hemicellulose. Therefore, the AHP method is an efficient and environmentally friendly delignification process, with the potential for application in the bioconversion of lignocellulosic waste into reducing sugars. Future studies are recommended to investigate the hydrolysis of the pretreated biomass to produce reducing sugars, evaluate its potential for bioethanol production, and optimize the process under pilot-scale and industrial-scale conditions.

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REFERENCES

- Adebayo, A.J. and Olanrewaju, A. (2025) ‘A complete review of lignin’s extraction, analysis, applications, and future outlook’, *Chemistry Africa*, 8(5), pp. 1711–1741. <https://doi.org/10.1007/s42250-025-01323-y>
- Afifah, D.N., Damajanti, N., Mustholidah, M. & Hariyanti (2022) ‘Delignification of cassava peel by using alkaline hydrogen peroxide method: study of peroxide concentration, solid/liquid ratio, and pH’, *Jurnal Teknik Kimia dan Lingkungan*, 6(2), pp.128–137.
- Dwi Ana A, Pampang H, Yunita L. Potensi Limbah Kulit Durian Sebagai Bahan Baku Pembuatan Energi Alternatif. Seminar Nasional Teknologi. 2015;1(1):843–51.
- Al-Rajabi, M.M., Jia En, K., Mahmod, S.S. and Abdullah, M.F. (2023) ‘Impact of alkali concentration in delignification treatment for cellulose extraction from rice straw’, *Jordanian Journal of Chemical Engineering and Industries (JJEI)*, 7(4), pp. 94–102
- Aniriani Gw, Apriliani Nf, Sulistiono E, Program), Lingkungan Sk. Hidrolisis Polisakarida Xilan Jerami Menggunakan Larutan Asam Kuat Untuk Bahan Dasar Produksi Bioetanol. Jurnal Ilmiah Sains. 2018;18(2):114–7.
- Badan Pusat Statistik (2023) *Statistik Indonesia Indonesia 2023* [Internet]. Available at: <https://www.bps.go.id> [Accessed 13 Mar. 2025].
- Dandash, A.A., Abu-Jdayil, B. and Tannous, J.H. (2025) ‘Lignin extraction from various biomass sources: a comprehensive review of characteristics, applications, and future prospects’, *The Chemical Record*, 25(8), e202500045. <https://doi.org/10.1002/tcr.202500045>
- Dimawarnita, F., Faramitha, Y., Prakoso, H.T., Puspitasari, I., Kalbuadi, D.N. & Prasetyo, D. (2023) ‘Characterization of cellulose from oil palm empty fruit bunches by fast delignification process with different solvents’, *E-Journal Menara Perkebunan*, 91(2).
- Dwi Ana, A., Pampang, H. & Yunita, L. (2015) ‘Potensi limbah kulit durian sebagai bahan baku pembuatan energi alternatif’, *Seminar Nasional Teknologi*, 1(1), pp.843–851.
- Dyshlyuk, L., Ulrikh, E., Agafonova, S. and Kazimirchenko, O. (2024) ‘Xylooligosaccharides from biomass lignocellulose: properties, sources and production methods’, *Reviews in Agricultural Science*, 12, pp. 1–12. <https://doi.org/10.7831/ras.12.0.1>

- Husada, E.D., Sudiana, I.M., Idris, Indriyani, N.L.P. & Santoso, P.J. (2021) 'Preliminary study of biohydrolysis method of durian rind for reducing sugar determination on bioethanol production', *Jurnal Hortikultura Indonesia*, 12(2), pp.117–125.
- Mardina, P., Talalangi, A.I., Sitinjak, J.F.M., Nugroho, A. & Fahrizal, M.R. (2013) 'Pengaruh proses delignifikasi pada produksi glukosa dari tongkol jagung dengan hidrolisis asam encer', *Konversi*, 2(2).
- Melati, R.B., Sass, D.C., Contiero, J. and Brienzo, M. (2023) 'Xylan solubilization from partially delignified biomass, and residual lignin removal from solubilized xylan', *Polysaccharides*, 4(2), pp. 176–188. doi: <https://doi.org/10.3390/polysaccharides4020013>
- Moron, J.B., van Klink, G.P.M. & Gruter, G.-J.M. (2025) 'Lignocellulose saccharification: historical insights and recent industrial advancements towards 2nd generation sugars', *RSC Sustainability*, 3, pp.1170–1211.
- Mun, J.S. and Mun, S.P. (2024) 'Alkaline hydrogen peroxide delignification of three lignocellulosic biomass under atmospheric pressure', *BioResources*, 19(1), pp. 998–1009. Available at: <https://bioresources.cnr.ncsu.edu/resources/alkaline-hydrogen-peroxide-delignification-of-three-lignocellulosic-biomass-under-atmospheric-pressure/>
- Nandini, A., Nuherdiana, S.D., Nagarajan, D. & Jo, S.-C. (2021) 'Optimasi mikroorganisme (LAB) terhadap pembentukan asam laktat dengan metode batch fermentasi', *Akta Kimia Indonesia*, 6(2), p.127.
- Permata, D.A., Kasim, A., Asben, A. and Yusniwati (2021) 'Delignification of lignocellulosic biomass', *World Journal of Advanced Research and Reviews*, 12(2), pp. 462–469. doi: <https://doi.org/10.30574/wjarr.2021.12.2.0618>
- Priatmoko, S. & Rohman, A.N. (2023) 'Modifikasi selulosa kulit durian menggunakan glutaraldehid sebagai koagulan untuk pemulihan limbah cair tepung pati aren', in *Bookchapter Alam Universitas Negeri Semarang*. Universitas Negeri Semarang, pp.115–144.
- Putra, R., Yerizam, M., Yuliati, S., Studi, P., Kimia, T., Jurusan, I. et al. (2024) 'Pretreatment delignifikasi limbah kulit durian sebagai bahan baku pembuatan bioetanol', *Jurnal Daur Lingkungan*, 1(2), pp.5–10. Available at: <http://journal.daurlingkungan.ac.id>.
- Sebran, N.H., Gaik, L.P. & Hussain, A.S. (2018) 'Structural analysis on the effect of base-catalysed delignification process parameters on palm oil empty fruit bunches fibres using glycome profiling', in *IOP Conference Series: Materials Science and Engineering*. Institute of Physics Publishing.
- Wesly Harianja, J. & Idiawati, N. (2015) 'Optimasi jenis dan konsentrasi asam pada hidrolisis selulosa dalam tongkol jagung', *Jurnal Untan*, 4(4), pp.66–71.