ISOLASI DAN KARAKTERISASI NANOSELULOSA DARI AMPAS KOPI ARABIKA MANDAILING: OPTIMASI KONSENTRASI ASAM

SKRIPSI

Sebagai Salah Satu Syarat Memperoleh Gelar Sarjana Sains

Diajukan Oleh:

Salwa Latisha Xyla Risnandar

2101274

PROGRAM STUDI KIMIA

FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM

UNIVERSITAS PENDIDIKAN INDONESIA

2025

LEMBAR PENGESAHAN

ISOLASI DAN KARAKTERISASI NANOSELULOSA DARI AMPAS KOPI ARABIKA MANDAILING: OPTIMASI KONSENTRASI ASAM

Disetujui dan disahkan oleh pembimbing:

Pembimbing I

Dr. Budiman Anwar, M.Si.
NIP. 197003131997031004

Pembimbing II

Acc sidang,

Galuh Yuliani, M.Si., Ph.D.
NIP. 198007252001122001

Mengetahui,

Ketua Prodi Kimia FPMIPA UPI

Prof. Dr. Fitri Khoerunnisa, M.Si., Ph.D.
NIP. 197806282001122001

HAK CIPTA

Salwa Latisha Xyla Risnandar

ISOLASI DAN KARAKTERISASI NANOSELULOSA DARI AMPAS KOPI ARABIKA MANDAILING: OPTIMASI KONSENTRASI ASAM

Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar Sarjana Sains Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

PERNYATAAN KEASLIAN SKRIPSI

Dengan ini saya menyatakan bahwa skripsi yang berjudul "**Isolasi dan Karakterisasi Nanoselulosa dari Ampas Kopi Arabika Mandailing: Optimasi Konsentrasi Asam**" beserta seluruh isinya merupakan benar-benar karya Saya sendiri. Saya tidak melakukan pengutipan atau penjiplakan dengan cara-cara yang tidak sesuai dengan etika keilmuan yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, saya siap menerima resiko atau sanksi apabila kemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya saya.

Bandung, 22 Agustus 2025

Salwa Latisha Xyla Risnandar
2101274

ABSTRAK

Kopi merupakan tanaman perkebunan bernilai ekonomi tinggi yang banyak dibudidayakan di Indonesia. Pada tahun 2021, konsumsi kopi mencapai 5 juta kantong (60 kg/kantong) dan produksi terus meningkat, yaitu 786,2 ribu ton pada dan 794,8 ton pada tahun 2022. Seiring dengan meningkatnya konsumsi kopi di Indonesia, jumlah limbah ampas kopi yang dihasilkan semakin bertambah. Salah satu upaya pemanfaatannya, yaitu dengan mengisolasi selulosa dan nanoselulosa sebagai bahan ramah lingkungan untuk aplikasi industri seperti biomedis, komposit, dan kemasan. Penelitian ini bertujuan untuk mengisolasi dan mengkarakterisasi selulosa AKAM menggunakan metode delignifikasi-pemutihan serta mengisolasi nanoselulosa AKAM melalui hidrolisis asam dengan variasi konsentrasi H_2SO_4 25%, 30%, 35%, 40%, dan 45%. Karakterisasi dilakukan menggunakan FTIR, XRD, PSA, TEM, dan TGA. Rendemen selulosa diperoleh sebesar 48,96%. Rendemen nanoselulosa tertinggi pada konsentrasi H_2SO_4 35% sebesar 27,59%. Hasil analisis FTIR menunjukkan hilangnya lignin dan hemiselulosa dengan struktur polimorf selulosa I. Hasil analisis XRD menunjukkan indeks kristalinitas nanoselulosa lebih tinggi sebesar 52,66% dibandingkan selulosa dengan indeks kristalinitas sebesar 47,94%. Hasil analisis PSA menunjukkan ukuran partikel nanoselulosa sebesar 64,0±17,8 nm dengan nilai PDI 0,370 yang tergolong ke dalam polidspersi lebar. Hasil analisis TEM menunjukkan morfologi serat panjang dengan struktur fibilar acak yang merupakan selulosa nanofibril. Hasil TGA menunjukkan nanoselulosa AKAM memiliki kestabilan termal lebih rendah dibandingkan dengan selulosa AKAM.

Kata Kunci: Isolasi, ampas kopi, arabika, karakterisasi, nanoselulosa, selulosa

ABSTRACT

Coffee is a high-value cash crop widely cultivated in Indonesia. In 2021, coffee consumption reached 5 million bags (60 kg/bag), and production continued to rise, reaching 786,200 tons in 2021 and 794,800 tons in 2022. As coffee consumption in Indonesia increases, the amount of coffee grounds waste generated also grows. One effort to utilize this waste involves isolating cellulose and nanocellulose as environmentally friendly materials for industrial applications such as biomedicine, composites, and packaging. This study aims to isolate and characterize AKAM cellulose using the delignification-bleaching method and to isolate AKAM nanocellulose through acid hydrolysis with varying concentrations of H_2SO_4 at 25%, 30%, 35%, 40%, and 45%. Characterization was performed using FTIR, XRD, PSA, TEM, and TGA. The cellulose yield was 48.96%. The highest nanocellulose yield was obtained at an H_2SO_4 concentration of 35%, amounting to 27.59%. FTIR analysis results indicated the removal of lignin and hemicellulose with a cellulose I polymorphic structure. XRD analysis results showed that the crystallinity index of nanocellulose was higher at 52.66% compared to cellulose with a crystallinity index of 47.94%. PSA analysis results showed that the particle size of nanocellulose was 64.0±17.8 nm with a PDI value of 0.370, which is classified as broad polydispersity. TEM analysis results showed a long fiber morphology with a random fibrillar structure, which is cellulose nanofiber. TGA results showed that AKAM nanocellulose has lower thermal stability compared to AKAM cellulose.

Keywords: Isolation, coffee grounds, arabica, characterization, nanocellulose, cellulose

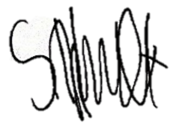
KATA PENGANTAR

Puji syukur kami panjatkan ke hadirat Tuhan Yang Maha Esa atas segala limpahan rahmat dan karunia-Nya sehingga skripsi ini dapat diselesaikan dengan baik yang berjudul "Isolasi dan Karakterisasi Nanoselulosa dari Ampas Kopi Arabika Mandailing: Optimasi Konsentrasi Asam" yang diajukan sebagai persyaratan untuk memperoleh gelar Sarjana di Prodi Kimia Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia. Keberhasilan skripsi ini berlangsung tidak lepas dari dukungan, bimbingan, dan bantuan dari berbagai pihak. Oleh karena itu, penulis ingin menyampaikan rasa terima kasih yang mendalam kepada:

1. Dosen pembimbing, yang telah dengan penuh kesabaran memberikan arahan, bimbingan, serta motivasi berharga sepanjang proses penyusunan skripsi. Dukungan serta ilmu yang diberikan menjadi bekal berharga bagi penulis dalam menyelesaikan penelitian ini.
2. Dosen penguji, yang telah meluangkan waktu, tenaga, serta pikiran untuk memberikan masukan, kritik, dan saran yang sangat membangun demi kesempurnaan skripsi ini.

Penulis menyadari bahwa skripsi ini masih memiliki kekurangan dan keterbatasan. Oleh karena itu, penulis sangat terbuka terhadap kritik dan saran yang membangun guna perbaikan di masa mendatang. Semoga skripsi ini dapat memberikan manfaat, baik bagi penulis, institusi, maupun pembaca yang mempelajarinya. Akhir kata, semoga skripsi ini dapat menjadi kontribusi yang bermanfaat dalam pengembangan ilmu pengetahuan.

Bandung, 22 Agustus 2025



Salwa Latisha Xyla Risnandar

UCAPAN TERIMA KASIH

Penulis skripsi ini tidak terlepas dari bantuan, bimbingan, serta dukungan dari berbagai pihak. Oleh karena itu, pada kesempatan ini penulis ingin menyampaikan ucapan terima kasih yang setulus-tulusnya kepada semua pihak yang telah memberikan dukungan baik secara langsung maupun tidak langsung dalam proses penyusunan hingga penyelesaian skripsi ini, izinkan saya menyampaikan rasa syukur serta terima kasih yang setulus-tulusnya kepada:

1. Allah SWT yang telah memberikan rahmat dan inayah-Nya sehingga penulis dapat menjalani perkuliahan hingga penyusunan skripsi ini dengan baik.
2. Bapak Dr. Budiman Anwar, M.Si. selaku Dosen Pembimbing I yang telah bersedia membimbing, meluangkan waktu, ilmu, dan memberi dukungan moral selama penyusunan skripsi ini.
3. Ibu Dr. Galuh Yuliani, M.Si., Ph.D. selaku Dosen Pembimbing II yang telah meluangkan waktu, enaga, dan ilmu selama penyusunan skripsi ini.
4. Ibu Prof. Fitri Khoerunnisa, M.Si. Ph.D. selaku Ketua Program Studi Kimia FPMIPA UPI yang telah memberi dukungan.
5. Ibu Prof. Ratnaningsih Eko Sardjono, M.Si. selaku Dosen Pembimbing Akademik yang telah memberikan dukungan.
6. Kepada Ibu Marlina sebagai orang tua tercinta yang selalu hadir dalam setiap langkah kehidupan penulis dengan memberikan dukungan dan doa. Tanpa kehadirannya penulis tidak dapat berhasil hingga saat ini.
7. Kepada Ayah Rian Risnandar sebagai orang tua tercinta yang selalu mengorbankan waktunya untuk penulis dengan memberikan dukungan moral dan materil. Tanpa kehadirannya penulis tidak dapat berhasil hingga saat ini.
8. Kepada Nenek Maemunah serta keluarga penulis yang selalu memberikan doa, semangat serta dukungan baik selama perkuliahan dan penyusunan skripsi ini.

9. Laras Adistya, Karhesma Cinta, Karina Nur, dan Salsa Rahmita selaku sahabat penulis yang selalu hadir dalam suka dan duka dengan memberikan dukungan serta bantuan selama perkuliahan hingga penyusunan skripsi ini.
10. Reka Salwa dan Vera Aulia selaku rekan penelitian dan sebimbingan penulis yang telah membantu dan memberikan dukungan selama penyusunan skripsi ini.
11. Shaula Davina Aulia selaku sahabat penulis yang telah memberikan dukungan dan selalu hadir dalam keadaan suka dan duka penulis selama perjalanan kehidupan penulis.
12. Debora Keisha, Azzahrah Aulia, Cinta Auly, Ananda Lestari, Naila Inayah, Dzakiyah Assyafiqah, dan Sri Rahma Ayu selaku sahabat penulis yang telah memberikan dukungan dan menemani selama penyusunan skripsi ini.
13. Rekan-rekan Kelas Kimia 21C yang telah memberikan dukungan dan bantuan selama penyusunan skripsi ini.

DAFTAR ISI

DAFTAR GAMBAR

DAFTAR TABEL

DAFTAR ISTILAH

AKAM : Ampas Kopi Arabika Mandailing

CNC : *Cellulose Nanocrystal*

CNF : *Cellulose Nanofiber*

FTIR : *Fourier Transform Infrared Spectrophotometry*

PSA : *Particle Size Analysis*

TGA : *Thermogravimetric Analysis*

TEM : *Transmission Electron Microscope*

XRD : *X-Ray Diffraction*

DAFTAR PUSTAKA

A, A. G., Farid, M., Ardhyananta, H., Kosong, T., & Sawit, K. (2017). Gian 2017, *6*(2), 228–231.

Abdul Khalil, H. P. S., Bhat, A. H., & Ireana Yusra, A. F. (2012). Green composites from sustainable cellulose nanofibrils: A review. *Carbohydrate Polymers*, *87*(2), 963–979. https://doi.org/10.1016/j.carbpol.2011.08.078

Abdul Khalil, H. P. S., Bhat, I. U. H., Jawaid, M., Zaidon, A., Hermawan, D., & Hadi, Y. S. (2012). Bamboo fibre reinforced biocomposites: A review. *Materials and Design*, *42*, 353–368. https://doi.org/10.1016/j.matdes.2012.06.015

Abdulmajid, A. M. (2014). Sensory Evaluation of beverage characteristics and biochemical components of Coffee Genotypes. *Advances in Food Science and Technology*, *2*(12), 281–288. Retrieved from www.internationalscholarsjournals.org

Abitbol, T., Rivkin, A., Cao, Y., Nevo, Y., Abraham, E., Ben-Shalom, T., … Shoseyov, O. (2016). Nanocellulose, a tiny fiber with huge applications. *Current Opinion in Biotechnology*, *39*(I), 76–88. https://doi.org/10.1016/j.copbio.2016.01.002

Abouzeid, R. E., Khiari, R., El-Wakil, N., & Dufresne, A. (2019). Current State and New Trends in the Use of Cellulose Nanomaterials for Wastewater Treatment. *Biomacromolecules*, *20*(2), 573–597. https://doi.org/10.1021/acs.biomac.8b00839

Abraham, A., Mathew, A. K., Park, H., Choi, O., Sindhu, R., Parameswaran, B., … Sang, B. I. (2020). Pretreatment strategies for enhanced biogas production from lignocellulosic biomass. *Bioresource Technology*, *301*, 122725. https://doi.org/10.1016/j.biortech.2019.122725

Abraham, E., Deepa, B., Pothan, L. A., Jacob, M., Thomas, S., Cvelbar, U., & Anandjiwala, R. (2011). Extraction of nanocellulose fibrils from lignocellulosic fibres: A novel approach. *Carbohydrate Polymers*, *86*(4), 1468–1475. https://doi.org/10.1016/j.carbpol.2011.06.034

Amirudin, S., Rejeki, S., & Ilmu dan Teknologi Pangan Fakultas Pertanian Universitas Halu Oleo, J. (2024). METODE SINTESIS NANOSELULOSA: KAJIAN PUSTAKA [Study of Nanocellulose Synthesis Method: A Review], *2*(1), 89–96.

Amrillah, Z., Hanum, F. F., & Rahayu, A. (2022). Studi Efektivitas Metode Ekstraksi Selulosa dari Agricultural Waste. *Seminar Nasional Penelitian*

LPPM UMJ, 8. Retrieved from http://jurnal.umj.ac.id/index.php/semnaslit%0AE-ISSN:2745-6080

Anwar, B., Bundjali, B., Sunarya, Y., & Arcana, I. M. (2021). Properties of Bacterial Cellulose and Its Nanocrystalline Obtained from Pineapple Peel Waste Juice. *Fibers and Polymers*, *22*(5), 1228–1236. https://doi.org/10.1007/s12221-021-0765-8

Azeredo, H. M. C., Rosa, M. F., & Mattoso, L. H. C. (2017). Nanocellulose in bio-based food packaging applications. *Industrial Crops and Products*, *97*(July 2016), 664–671. https://doi.org/10.1016/j.indcrop.2016.03.013

Bacha, E. G., & Demsash, H. D. (2021). Extraction and Characterization of Nanocellulose from Eragrostis Teff Straw. *Journal of Cellulose*. Retrieved from https://www.researchsquare.com/article/rs-296990/latest.pdf

Beyler, C. L., & Hirschler, M. M. (2011). Thermal Decomposition of Polymers. *Chemistry of Materials*, *23*(15), 3495–3508.

Bondeson, D., Mathew, A., & Oksman, K. (2006). Optimization of the isolation of nanocrystals from microcrystalline cellulose by acid hydrolysis. *Cellulose*, *13*(2), 171–180. https://doi.org/10.1007/s10570-006-9061-4

Brinchi, L., Cotana, F., Fortunati, E., & Kenny, J. M. (2013). Production of nanocrystalline cellulose from lignocellulosic biomass: Technology and applications. *Carbohydrate Polymers*, *94*(1), 154–169. https://doi.org/10.1016/j.carbpol.2013.01.033

Brown, R. M. (2004). Cellulose Structure and Biosynthesis: What is in Store for the 21st Century? *Journal of Polymer Science, Part A: Polymer Chemistry*, *42*(3), 487–495. https://doi.org/10.1002/pola.10877

Bunaciu, A. A., Udriştioiu, E. gabriela, & Aboul-Enein, H. Y. (2015). X-Ray Diffraction: Instrumentation and Applications. *Critical Reviews in Analytical Chemistry*, *45*(4), 289–299. https://doi.org/10.1080/10408347.2014.949616

Cataldi, A., Rigotti, D., Nguyen, V. D. H., & Pegoretti, A. (2018). Polyvinyl alcohol reinforced with crystalline nanocellulose for 3D printing application. *Materials Today Communications*, *15*(April 2017), 236–244. https://doi.org/10.1016/j.mtcomm.2018.02.007

Cizmarova, B., Hubkova, B., Bolerazska, B., Marekova, M., & Birkova, A. (2020). Caffeic acid: A brief overview of its presence, metabolism, and bioactivity. *Bioactive Compounds in Health and Disease*, *3*(4), 74–81. https://doi.org/10.31989/bchd.v3i4.692

Collazo-Bigliardi, S., Ortega-Toro, R., & Chiralt Boix, A. (2018). Isolation and characterisation of microcrystalline cellulose and cellulose nanocrystals from coffee husk and comparative study with rice husk. *Carbohydrate Polymers*, *191*, 205–215. https://doi.org/10.1016/j.carbpol.2018.03.022

Dalmis, R. (2023). Description of a new cellulosic natural fiber extracted from Helianthus tuberosus L. as a composite reinforcement material. *Physiologia Plantarum*, *175*(4), 1–13. https://doi.org/10.1111/ppl.13960

Das, K., Ray, D., Bandyopadhyay, N. R., Ghosh, T., Mohanty, A. K., & Misra, M. (2009). A study of the mechanical, thermal and morphological properties of microcrystalline cellulose particles prepared from cotton slivers using different acid concentrations. *Cellulose*, *16*(5), 783–793. https://doi.org/10.1007/s10570-009-9280-6

Deb Dutta, S., Patel, D. K., Ganguly, K., & Lim, K. T. (2021). Isolation and characterization of cellulose nanocrystals from coffee grounds for tissue engineering. *Materials Letters*, *287*, 129311. https://doi.org/10.1016/j.matlet.2021.129311

Deepa, B., Abraham, E., Cordeiro, N., Mozetic, M., Mathew, A. P., Oksman, K., … Pothan, L. A. (2015). Utilization of various lignocellulosic biomass for the production of nanocellulose: a comparative study. *Cellulose*, *22*(2), 1075–1090. https://doi.org/10.1007/s10570-015-0554-x

Diah JuliantariD, N. P., Wrasiati, L. P., & Wartini, N. M. (2018). KARAKTERISTIK EKSTRAK AMPAS KOPI BUBUK ROBUSTA (Coffea canephora) PADA PERLAKUAN KONSENTRASI PELARUT ETANOL DAN SUHU MASERASI. *Jurnal Rekayasa Dan Manajemen Agroindustri*, *6*(3), 243. https://doi.org/10.24843/jrma.2018.v06.i03.p08

Directorate General of Plantations, M. of A. of the R. of I. (2021). Statistical of National Leading Estate CRops Commodity 2019-2021. *Secretariate of Directorate General of Estate Crops, Directorate General of Estate Crops, Ministry of Agriculture, Indonesia*, 1–788. Retrieved from https://ditjenbun.pertanian.go.id/template/uploads/2021/04/BUKU-STATISTIK-PERKEBUNAN-2019-2021-OK.pdf

Dong, X. M., Revol, J. F., & Gray, D. G. (1998). Effect of microcrystallite preparation conditions on the formation of colloid crystals of cellulose. *Cellulose*, *5*(1), 19–32. https://doi.org/10.1023/A:1009260511939

Dufresne, A. (2012). *CHAPTER 1. Nanocellulose: Potential Reinforcement in Composites* (Vol. 2). https://doi.org/10.1039/9781849735315-00001

Dufresne, A. (2013). Nanocellulose: A new ageless bionanomaterial. *Materials Today*, *16*(6), 220–227. https://doi.org/10.1016/j.mattod.2013.06.004

Entegris. (2019). Particle Size Analysis Overview.

Fahma, F., Sugiarto, Sunarti, T. C., Indriyani, S. M., & Lisdayana, N. (2017). Thermoplastic Cassava Starch-PVA Composite Films with Cellulose Nanofibers from Oil Palm Empty Fruit Bunches as Reinforcement Agent. *International Journal of Polymer Science*, *2017*, 1–6. https://doi.org/10.1155/2017/2745721

Feng, S., Yuan, Z., Leitch, M., Shui, H., & Xu, C. C. (2016). Effects of bark extraction before liquefaction and liquid oil fractionation after liquefaction on bark-based phenol formaldehyde resoles. *Industrial Crops and Products*, *84*, 330–336. https://doi.org/10.1016/j.indcrop.2016.02.022

Ferrer, A., Pal, L., & Hubbe, M. (2017). Nanocellulose in packaging: Advances in barrier layer technologies. *Industrial Crops and Products*, *95*, 574–582. https://doi.org/10.1016/j.indcrop.2016.11.012

Gallardo-Sánchez, M. A., Diaz-Vidal, T., Navarro-Hermosillo, A. B., Figueroa-Ochoa, E. B., Casillas, R. R., Hernández, J. A., … Macías-Balleza, E. R. (2021). Optimization of the obtaining of cellulose nanocrystals from agave tequilana weber var. Azul Bagasse by acid hydrolysis. *Nanomaterials*, *11*(2), 1–21. https://doi.org/10.3390/nano11020520

Gamage, J., Lam, H., & Zhang, Z. (2010). Bioethanol production from lignocellulosic biomass, a review. *Journal of Biobased Materials and Bioenergy*, *4*(1), 3–11. https://doi.org/10.1166/jbmb.2010.1071

Gautam, S. P., Bundela, P. S., Pandey, A. K., Jamaluddin, J., Awasthi, M. K., & Sarsaiya, S. (2010). A review on systematic study of cellulose. *Journal of Applied and Natural Science*, *2*(2), 330–343. https://doi.org/10.31018/jans.v2i2.143

Ginting, A. B., Indaryati, S., & Setiawan, J. (2005). Penentuan Parameter Uji dan Ketidakpastian Pengukuran Kapasitas Panas pada Differential Scanning Calorimeter. *Jurnal Teknologi Bahan Nuklir*, *1*(1), 34–45.

Gouws, S., & Muller, M. (2021). Valorization of products from grounded-coffee beans. *Scientific Reports*, *11*(1), 1–8. https://doi.org/10.1038/s41598-021-99938-x

Gupta, V. K., & Tuohy, M. G. (2014). *Biofuel technologies: Recent developments*. *Biofuel Technologies: Recent Developments*. https://doi.org/10.1007/978-3-642-34519-7

Hailu, H. (2011). Growth and Physiological Response of Two Coffea arabica L. Populations under High and Low Irradiance. *School of Graduate Studies, Faculty of Science*, (January), 1–86. Retrieved from http://etd.aau.edu.et/bitstream/handle/123456789/5537/Hiwot Hailu.pdf?

Harmsen P F H dkk. (2010) Literature Review of Physical and Chemical Pretreatment Processes for Lignocellulosic Biomass. Food & Biobased Research.Energy Research Centre of the Netherlands. p. 8-12

Hazwan Hussin, M., Trache, D., Hui Chuin, C. T., Nurul Fazita, M. R., Mohamad Haafiz, M. K., & Sohrab Hossain, M. (2019). *Extraction of cellulose nanofibers and their eco-friendly polymer composites*. *Sustainable Polymer Composites and Nanocomposites*. https://doi.org/10.1007/978-3-030-05399-4_23

Horiba. (2022). *A Guidebook to Particle Size Analysis*. Paris.

Horiba. (2014). *A Guide To Particle Size Analysis*. USA: Horiba Instruments, Inc.

Husen, Edi & Pratiwi, Etty & Surono, & Widowati, Ladiyani. (2022). Metode Analisis Biologi Tanah.

ICO. (2013). ICO Annual Review 2012/13 – 1, 1–36.

Indah Wahyuni, Syarifuddin Yusuf, & Erna Magga. (2020). Pengaruh Konsumsi Kopi Terhadap Tekanan Darah Dan Insomnia Pada Mahasiswa Universitas Muhammadiyah Parepare. *Jurnal Ilmiah Manusia Dan Kesehatan*, *3*(3), 395–402. https://doi.org/10.31850/makes.v3i3.368

Ioelovich, M. (2012). Optimal Conditions for Isolation of Nanocrystalline Cellulose Particles. *Nanoscience and Nanotechnology*, *2*(2), 9–13. https://doi.org/10.5923/j.nn.20120202.03

Iranmahboob, J., Nadim, F., & Monemi, S. (2002). Optimizing acid-hydrolysis: A critical step for production of ethanol from mixed wood chips. *Biomass and Bioenergy*, *22*(5), 401–404. https://doi.org/10.1016/S0961-9534(02)00016-8

Johar, N., Ahmad, I., & Dufresne, A. (2012). Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. *Industrial Crops and Products*, *37*(1), 93–99. https://doi.org/10.1016/j.indcrop.2011.12.016

Jonoobi, M., Oladi, R., Davoudpour, Y., Oksman, K., Dufresne, A., Hamzeh, Y., & Davoodi, R. (2015). Different preparation methods and properties of nanostructured cellulose from various natural resources and residues: a review. *Cellulose*, *22*(2), 935–969. https://doi.org/10.1007/s10570-015-0551-0

Jozala, A. F., de Lencastre-Novaes, L. C., Lopes, A. M., de Carvalho Santos-Ebinuma, V., Mazzola, P. G., Pessoa-Jr, A., … Chaud, M. V. (2016). Bacterial nanocellulose production and application: a 10-year overview. *Applied Microbiology and Biotechnology*, *100*(5), 2063–2072. https://doi.org/10.1007/s00253-015-7243-4

Julianto, H., Farid, M., & Rasyida, A. (2017). Ekstraksi Nanoselulosa dengan Metode Hidrolisis Asam sebagai Penguat Komposit Absorpsi Suara. *Jurnal Teknik ITS*, *6*(2), 242–245. https://doi.org/10.12962/j23373539.v6i2.24259

Kaboorani, A., & Riedl, B. (2015). Surface modification of cellulose nanocrystals (CNC) by a cationic surfactant. *Industrial Crops and Products*, *65*, 45–55. https://doi.org/10.1016/j.indcrop.2014.11.027

Kannan, M. (2018). Transmission Electron Microscope-Principle, Components and Applications. *A Textbook on Fundamentals and Applications of Nanotechnology*, 93–102.

Karlinasari, L., Nawawi, D., & Widyani, M. (2010). Study of Anatomic and Mechanical Properties of Wood Relation With Acoustical Properties. *Bionatura Jurnal Ilmu-Ilmu Hayati Dan Fisik*, *12*(3), 110–116.

Klemm, D., Philipp, B., Heinze, T., Heinze, U., & Wagenknecht, W. (1998). Comprehensive cellulose chemistry: Functionalization of cellulose. Weinheim: Wiley-VCH.

Kumar, A., Singh Negi, Y., Choudhary, V., & Kant Bhardwaj, N. (2020). Characterization of Cellulose Nanocrystals Produced by Acid-Hydrolysis from Sugarcane Bagasse as Agro-Waste. *Journal of Materials Physics and Chemistry*, *2*(1), 1–8. https://doi.org/10.12691/jmpc-2-1-1

Kurniaty, I. (2017). Proses Delignifikasi Menggunakan Naoh Dan Amonia (Nh3) Pada Tempurung Kelapa. *Jurnal Integrasi Proses, 6*(4), 197. https://doi.org/10.36055/jip.v6i4.2546

Lamsal, B., Yoo, J., Brijwani, K., & Alavi, S. (2010). Extrusion as a thermo-mechanical pre-treatment for lignocellulosic ethanol. *Biomass and Bioenergy*, *34*(12), 1703–1710. https://doi.org/10.1016/j.biombioe.2010.06.009

Lavoine, N., Desloges, I., Dufresne, A., & Bras, J. (2012). Microfibrillated cellulose - Its barrier properties and applications in cellulosic materials: A review. *Carbohydrate Polymers*, *90*(2), 735–764. https://doi.org/10.1016/j.carbpol.2012.05.026

Lee, H. V., Hamid, S. B. A., & Zain, S. K. (2014). Conversion of lignocellulosic biomass to nanocellulose: Structure and chemical process. *Scientific World Journal*, *2014*. https://doi.org/10.1155/2014/631013

Lempang, M. (2016). Pemanfaatan Lignin sebagai Bahan Perekat Kayu. *Jurnal Buletin Eboni*, *13*(2), 139–150.

Lestari, M. D., Sudarmin, & Harjono. (2018). Ekstraksi Selulosa dari Limbah Pengolahan Agar Menggunakan Larutan NaOH sebagai Prekursor Bioetanol. *Indonesian Journal of Chemical Science*, *7*(3), 236–241. Retrieved from http://journal.unnes.ac.id/sju/index.php/ijcs

Leung, A. C. W., Hrapovic, S., Lam, E., Liu, Y., Male, K. B., Mahmoud, K. A., & Luong, J. H. T. (2011). Characteristics and properties of carboxylated cellulose nanocrystals prepared from a novel one-step procedure. *Small*, *7*(3), 302–305. https://doi.org/10.1002/smll.201001715

Li, W., Yue, J., & Liu, S. (2012). Preparation of nanocrystalline cellulose via ultrasound and its reinforcement capability for poly(vinyl alcohol) composites. *Ultrasonics Sonochemistry*, *19*(3), 479–485. https://doi.org/10.1016/j.ultsonch.2011.11.007

Liu, Q., Zhong, Z., Wang, S., & Luo, Z. (2011). Interactions of biomass components during pyrolysis: A TG-FTIR study. *Journal of Analytical and Applied Pyrolysis*, *90*(2), 213–218. https://doi.org/10.1016/j.jaap.2010.12.009

Lo Vecchio, A., & Zacur, G. M. (2012). Clostridium difficile infection: An update on epidemiology, risk factors, and therapeutic options. *Current Opinion in Gastroenterology*, *28*(1), 1–9. https://doi.org/10.1097/MOG.0b013e32834bc9a9

Lopez-Sanchez, R. D. C., Lara-Diaz, V. J., Aranda-Gutierrez, A., Martinez-Cardona, J. A., & Hernandez, J. A. (2018). HPLC Method for Quantification of Caffeine and Its Three Major Metabolites in Human Plasma Using Fetal Bovine Serum Matrix to Evaluate Prenatal Drug Exposure. *Journal of Analytical Methods in Chemistry*, *2018*. https://doi.org/10.1155/2018/2085059

Luo, W., Cheng, L., Yuan, C., Wu, Z., Yuan, G., Hou, M., … Li, W. (2019). Preparation, characterization and evaluation of cellulose nanocrystal/poly(lactic acid) in situ nanocomposite scaffolds for tissue engineering. *International Journal of Biological Macromolecules*, *134*, 469–479. https://doi.org/10.1016/j.ijbiomac.2019.05.052

Luzi, F., Fortunati, E., Puglia, D., Lavorgna, M., Santulli, C., Kenny, J. M., & Torre, L. (2014). Optimized extraction of cellulose nanocrystals from pristine and carded hemp fibres. *Industrial Crops and Products*, *56*, 175–186. https://doi.org/10.1016/j.indcrop.2014.03.006

Mabuto, B., & Hlangothi, S. P. (2024). Wood fibre alkalization effect on the thermal stability of meranti wood flour: a modification of the conventional method. *Wood Science and Technology*, *58*(1), 87–107. https://doi.org/10.1007/s00226-023-01524-z

Macías-Almazán, A., Lois-Correa, J. A., Domínguez-Crespo, M. A., López-Oyama, A. B., Torres-Huerta, A. M., Brachetti-Sibaja, S. B., & Rodríguez-Salazar, A. E. (2020). Influence of operating conditions on proton conductivity of nanocellulose films using two agroindustrial wastes: Sugarcane bagasse and pinewood sawdust. *Carbohydrate Polymers*, *238*(February), 116171. https://doi.org/10.1016/j.carbpol.2020.116171

Malarat, S., Khongpun, D., Limtong, K., Sinthuwong, N., Soontornapaluk, P., Sakdaronnarong, C., & Posoknistakul, P. (2023). Preparation of Nanocellulose from Coffee Pulp and Its Potential as a Polymer Reinforcement. *ACS Omega*, *8*(28), 25122–25133. https://doi.org/10.1021/acsomega.3c02016

Malarat, S., Khongpun, D., Limtong, K., Sinthuwong, N., Soontornapaluk, P., Sakdaronnarong, C., & Posoknistakul, P. (2023). Preparation of Nanocellulose from Coffee Pulp and Its Potential as a Polymer Reinforcement. *ACS Omega*, *8*(28), 25122–25133. https://doi.org/10.1021/acsomega.3c02016

Manan, S., Ullah, M.W., Ul-Islam, M., Shi, Z., Gauthier, M. and Yang, G., 2022. Bacterial cellulose: Molecular regulation of biosynthesis, supramolecular assembly, and tailored structural and functional properties. Progress in Materials Science, 129, p.100972.

Matsutani, A., Harada, T., Ozaki, S., & Takaoka, T. (1993). *Inhibitory effects of combination of CDDP and cepharanthin on the cultured cells from rat ascites hepatoma*. *Journal of Japan Society for Cancer Therapy* (Vol. 28).

Metungku, N. A., Darwis, D., & Sesa, E. (2017). Pemurnian Dan Karakterisasi Senyawa SiO2 Berbasis Pasir Kuarsa Dari Desa Pendolo Kecamatan Pamona Selatan Kabupaten Poso. *Gravitasi*, *16*(1), 39–43.

Moon, R. J., Martini, A., Nairn, J., Simonsen, J., & Youngblood, J. (2011). *Cellulose nanomaterials review: Structure, properties and nanocomposites*. *Chemical Society Reviews* (Vol. 40). https://doi.org/10.1039/c0cs00108b

Moon, R. J., Martini, A., Nairn, J., Simonsen, J., & Youngblood, J. (2011). *Cellulose nanomaterials review: Structure, properties and nanocomposites*. *Chemical Society Reviews* (Vol. 40). https://doi.org/10.1039/c0cs00108b

Moon, R. J., Schueneman, G. T., & Simonsen, J. (2016). Overview of Cellulose Nanomaterials, Their Capabilities and Applications. *Jom*, *68*(9), 2383–2394. https://doi.org/10.1007/s11837-016-2018-7

Munasir, Triwikantoro, Zainuri, & Darminto. (2012). (BATUAN DAN PASIR) SEBAGAI SUMBER MATERIAL CERDAS (CaCO3 DAN SiO2). *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA) ISSN: 2087-9946*, *2*(1), 20–29.

Muryanto, M., Sudiyani, Y., & Abimanyu, H. (2016). Optimasi Proses Perlakuan Awal NaOH Tandan Kosong Kelapa Sawit untuk menjadi Bioetanol. *Jurnal Kimia Terapan Indonesia*, *18*(01), 27–35. https://doi.org/10.14203/jkti.v18i01.37

Mussatto, S. I., Machado, E. M. S., Martins, S., & Teixeira, J. A. (2011). Production, Composition, and Application of Coffee and Its Industrial Residues. *Food and Bioprocess Technology*, *4*(5), 661–672. https://doi.org/10.1007/s11947-011-0565-z

Nada, A. A. M. A., Kamel, S., & El-Sakhawy, M. (2000). Thermal behaviour and infrared spectroscopy of cellulose carbamates. *Polymer Degradation and Stability*, *70*(3), 347–355. https://doi.org/10.1016/S0141-3910(00)00119-1

Newman, R. H. (1999). Estimation of the lateral dimensions of cellulose crystallites using 13C NMR signal strengths. *Solid State Nuclear Magnetic Resonance*, *15*(1), 21–29. https://doi.org/10.1016/S0926-2040(99)00043-0

Nowicki, L., & Markowski, M. (2012). Kinetic analysis of thermogravimetric data collected from bigger samples. *Chemical and Process Engineering - Inzynieria Chemiczna i Procesowa*, *33*(1), 85–94. https://doi.org/10.2478/v10176-012-0008-z

Palonen, H. (2004). Role of lignin in the enzymatic hydrolysis of lignocellulose. *VTT Publications*, (520), 3–80.

Pengkajian, B., & Pertanian, T. (2012). Pasca panen dan pengolahan pisang, (September).

Pennells, J., Godwin, I. D., Amiralian, N., & Martin, D. J. (2020). Trends in the production of cellulose nanofibers from non-wood sources. *Cellulose*, *27*(2), 575–593. https://doi.org/10.1007/s10570-019-02828-9

Perdoch, W., Cao, Z., Florczak, P., Markiewicz, R., Jarek, M., Olejnik, K., & Mazela, B. (2022). Influence of Nanocellulose Structure on Paper Reinforcement. *Molecules*, *27*(15). https://doi.org/10.3390/molecules27154696

Poletto, M., Dettenborn, J., Pistor, V., Zeni, M., & Zattera, A. J. (2010). Materials produced from plant biomass.Part I: Evaluation of thermal stability and pyrolysis of wood. *Materials Research*, *13*(3), 375–379. https://doi.org/10.1590/S1516-14392010000300016

Popescu, M. C., Popescu, C. M., Lisa, G., & Sakata, Y. (2011). Evaluation of morphological and chemical aspects of different wood species by spectroscopy and thermal methods. *Journal of Molecular Structure*, *988*(1–3), 65–72. https://doi.org/10.1016/j.molstruc.2010.12.004

Popescu, C. M., P. T. Larsson, N. Olaru, and C. Vasile. 2012. "Spectroscopic Study of Acetylated Kraft Pulp Fibers." *Carbohydrate Polymers*, 88 (2): 530–536. https://doi.org/10.1016/j.carbpol.2011.12.046.

Portal, G. (1981). Preparation and properties of principal TL products. *Applied Thermoluminescence Dosimetry*, *852745443*, 97–122.

Pratama, J. H., Rohmah, R. L., Amalia, A., & Saraswati, T. E. (2019). Isolasi Mikroselulosa dari Limbah Eceng Gondok (Eichornia crassipes) dengan Metode Bleaching-Alkalinasi. *ALCHEMY Jurnal Penelitian Kimia*, *15*(2), 239. https://doi.org/10.20961/alchemy.15.2.30862.239-250

Raju, V., Revathiswaran, R., Subramanian, K. S., Parthiban, K. T., Chandrakumar, K., Anoop, E. V., & Chirayil, C. J. (2023). Isolation and characterization of nanocellulose from selected hardwoods, viz., Eucalyptus tereticornis Sm. and Casuarina equisetifolia L., by steam explosion method. *Scientific Reports*, *13*(1), 1–15. https://doi.org/10.1038/s41598-022-26600-5

Rehman, N., Alam, S., Mian, I., & Ullah, H. (2019). Environmental friendly method for the extraction of cellulose from Triflolium resopinatum and its characterization. *Bulletin of the Chemical Society of Ethiopia*, *33*(1), 61–68. https://doi.org/10.4314/bcse.v33i1.6

Ronie, A. S. (2011). Studi Proses Bleaching Serat Kelapa Sebagai Reinforced Fiber. *Seminar Rekayasa Kimia Dan Proses*, *4*(2005), 4–5.

Rosa, M. F., Medeiros, E. S., Malmonge, J. A., Gregorski, K. S., Wood, D. F., Mattoso, L. H. C., … Imam, S. H. (2010). Cellulose nanowhiskers from coconut husk fibers: Effect of preparation conditions on their thermal and morphological behavior. *Carbohydrate Polymers*, *81*(1), 83–92. https://doi.org/10.1016/j.carbpol.2010.01.059

Safitri, R., Dwi Anggita, I., Safitri, F. M., Agung, D. A., & Ratnadewi, I. (2020). Pengaruh Konsentrasi Asam Sulfat dalam Proses Hidrolisis Selulosa dari Kulit

Buah Naga Merah (Hylocereus costaricensis) untuk Produksi Bioetanol. *Industrial Research Workshop and National Seminar*, 1–5.

Sahlin, K., Forsgren, L., Moberg, T., Bernin, D., Rigdahl, M., & Westman, G. (2018). Surface treatment of cellulose nanocrystals (CNC): effects on dispersion rheology. *Cellulose*, *25*(1), 331–345. https://doi.org/10.1007/s10570-017-1582-5

Sanjay, M. R., Madhu, P., Jawaid, M., Senthamaraikannan, P., Senthil, S., & Pradeep, S. (2018). *Characterization and properties of natural fiber polymer composites: A comprehensive review*. *Journal of Cleaner Production* (Vol. 172). Elsevier B.V. https://doi.org/10.1016/j.jclepro.2017.10.101

Santosa, B. A. S., Sudaryono, & Widowati, S. (2006). Characteristics of extrudates of several corn varieties with the addition of distilled water. *Jurnal Penelitian Pascapanen Pertanian*.

Saurabh, C. K., Dungani, R., Owolabi, A. F., Atiqah, N. S., Zaidon, A., Aprilia, N. A. S., … Abdul Khalil, H. P. S. (2016). Effect of hydrolysis treatment on cellulose nanowhiskers from oil palm (Elaeis guineesis) fronds: Morphology, chemical, crystallinity, and thermal characteristics. *BioResources*, *11*(3), 6742–6755. https://doi.org/10.15376/biores.11.3.6742-6755

Segal, L., Creely, J. J., Martin, A. E., & Conrad, C. M. (1959). An Empirical Method for Estimating the Degree of Crystallinity of Native Cellulose Using the X-Ray Diffractometer. *Textile Research Journal*, *29*(10), 786–794. https://doi.org/10.1177/004051755902901003

Seidl, P. R., & Goulart, A. K. (2016). Pretreatment processes for lignocellulosic biomass conversion to biofuels and bioproducts. *Current Opinion in Green and Sustainable Chemistry*, *2*, 48–53. https://doi.org/10.1016/j.cogsc.2016.09.003

SEKİ, Y. (2025). Isolation and characterization of cellulose from spent ground coffee (Coffea Arabica L.): A comparative study. *Waste Management*, *193*(November 2024), 54–61. https://doi.org/10.1016/j.wasman.2024.11.048

Sheltami, R. M., Abdullah, I., Ahmad, I., Dufresne, A., & Kargarzadeh, H. (2012). Extraction of cellulose nanocrystals from mengkuang leaves (Pandanus tectorius). *Carbohydrate Polymers*, *88*(2), 772–779. https://doi.org/10.1016/j.carbpol.2012.01.062

Shukla, P. R., Wang, S., Sun, H., Ang, H. M., & Tadé, M. (2010). Activated carbon supported cobalt catalysts for advanced oxidation of organic contaminants in aqueous solution. *Applied Catalysis B: Environmental*, *100*(3–4), 529–534. https://doi.org/10.1016/j.apcatb.2010.09.006

Simanihuruk, K. dan J. S. (2010). Silase Kulit Buah Kopi Sebagai Pakan Dasar Pada Kambing Boerka Sedang Tumbuh (Coffee Pulp Silages as Basal Feed for Boerka Goats on Growth Phase). *Seminar Nasional Teknologi Peternakan Dan Veteriner*, 557–566.

Srebotnik, E., Jensen, K. A., & Hammel, K. E. (1994). Fungal degradation of recalcitrant nonphenolic lignin structures without lignin peroxidase. *Proceedings of the National Academy of Sciences of the United States of America*, *91*(26), 12794–12797. https://doi.org/10.1073/pnas.91.26.12794

Struszczyk, H. (1986). Modification of Lignins. 111. Reaction of Lignosulfonates with Chlorophosphazenes. *Journal of Macromolecular Science: Part A - Chemistry*, *23*(8), 973–992. https://doi.org/10.1080/00222338608081105

Sullivan, E. M., Moon, R. J., & Kalaitzidou, K. (2015). Processing and characterization of cellulose nanocrystals/polylactic acid nanocomposite films. *Materials*, *8*(12), 8106–8116. https://doi.org/10.3390/ma8125447

Tahir, D., Karim, M. R. A., Hu, H., Naseem, S., Rehan, M., Ahmad, M., & Zhang, M. (2022). Sources, Chemical Functionalization, and Commercial Applications of Nanocellulose and Nanocellulose-Based Composites: A Review. *Polymers*, *14*(21). https://doi.org/10.3390/polym14214468

Terinte, N., Ibbett, R., & Schuster, K. C. (2017). Overview on native cellulose and microcrystalline cellulose I structure studied by X-ray diffraction (WAXD): Comparison between measurement techniques. *Overview On Native Cellulose and Microcrystalline Cellulose I Structure Studied By X-Ray Diffraction*. (*89*(January 2011), 118–131.

Thomas, B., Raj, M. C., Athira, B. K., Rubiyah, H. M., Joy, J., Moores, A., … Sanchez, C. (2018). Nanocellulose, a Versatile Green Platform: From Biosources to Materials and Their Applications. *Chemical Reviews*, *118*(24), 11575–11625. https://doi.org/10.1021/acs.chemrev.7b00627

Tiptipakorn, S., Damrongsakkul, S., Ando, S., Hemvichian, K., & Rimdusit, S. (2007). Thermal degradation behaviors of polybenzoxazine and silicon-containing polyimide blends. *Polymer Degradation and Stability*, *92*(7), 1265–1278. https://doi.org/10.1016/j.polymdegradstab.2007.03.021

Trache, D., Hussin, M. H., Haafiz, M. K. M., & Thakur, V. K. (2017). Recent progress in cellulose nanocrystals: Sources and production. *Nanoscale*, *9*(5), 1763–1786. https://doi.org/10.1039/c6nr09494e

Trisanti, P. N., Setiawan H.P, S., Nura'ini, E., & Sumarno. (2018). Gergaji Kayu Sengon Melalui Proses Delignifikasi Alkali Ultrasonik. *Sains Materi Indonesia*, *19*(3), 113–119.

Ummah, M. S. (2019). *Sustainability (Switzerland)*, *11*(1), 1–14. Retrieved from http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Verma, S. R., & Dwivedi, U. N. (2014). Lignin genetic engineering for improvement of wood quality: Applications in paper and textile industries, fodder and bioenergy production. *South African Journal of Botany*, *91*, 107–125. https://doi.org/10.1016/j.sajb.2014.01.002

Verma, S. R., & Dwivedi, U. N. (2014). Lignin genetic engineering for improvement of wood quality: Applications in paper and textile industries, fodder and bioenergy production. *South African Journal of Botany*, *91*, 107–125. https://doi.org/10.1016/j.sajb.2014.01.002

Weimer, P. J., Hackney, J. M., & French, A. D. (1995). Effects of chemical treatments and heating on the crystallinity of celluloses and their implications for evaluating the effect of crystallinity on cellulose biodegradation. *Biotechnology and Bioengineering*, *48*(2), 169–178. https://doi.org/10.1002/bit.260480211

Wohlert, M., Benselfelt, T., Wågberg, L., Furó, I., Berglund, L. A., & Wohlert, J. (2022). Cellulose and the role of hydrogen bonds: not in charge of everything. *Cellulose*, *29*(1), 1–23. https://doi.org/10.1007/s10570-021-04325-4

Xu, K., Liu, C., Kang, K., Zheng, Z., Wang, S., Tang, Z., & Yang, W. (2018). Isolation of nanocrystalline cellulose from rice straw and preparation of its biocomposites with chitosan: Physicochemical characterization and evaluation of interfacial compatibility. *Composites Science and Technology*, *154*, 8–17. https://doi.org/10.1016/j.compscitech.2017.10.022

Yunidar, D., & Hifzhurrahman, A. H. (2024). Pemanfaatan Ampas Kopi Sebagai Material Dasar Untuk Membuat Pot Tanaman. *Narada : Jurnal Desain Dan Seni*, *10*(3), 297. https://doi.org/10.22441/narada.2023/v10.i3.003

Zulnazri, Z., Daniati, R., Hakim, L., & Hasbullah, S. A. (2022). Study of Cellulose Extraction from Robusta Coffee Husk Using NaOH Solution. *International Journal of Engineering, Science and Information Technology*, *2*(2), 73–78. https://doi.org/10.52088/ijesty.v1i1.253