HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

December 2024. 12(6)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 1244-1254

Development of Particle Board Biocomposite From Coffee Skin and Tofu Dregs With Polyethylene Plastic Adhesive As Furniture Interior

Ali Nurdin Hidayat[1*], Edwin Permana[2], Dhian Eka Wijaya[3], Yoga Pratama[1], Fauzi Zufri[1]

[1] Department of Chemistry, Faculty of Science and Technology, Jambi University, Jl. Jambi-Muara Bulian KM 15, Muaro Jambi, Indonesia 36361

[2] Department of Industrial Chemistry, Faculty of Science and Technology, Jambi University, Jl. Jambi-Muara Bulian KM 15, Muaro Jambi, Indonesia 36361

[3] Department of Chemical Analyst, Faculty of Science and Technology, Jambi University, Jl. Jambi-Muara Bulian KM 15, Muaro Jambi, Indonesia 36361

[*] Corresponding Author e-mail: alinurdinhidayat2508@gmail.com

Article History
Received: 05-12-2024
Revised: 21-12-2024
Published: 31-12-2024

Keywords:
biocomposite, coffee husk, particle board, Polyethylent, tofu dregs

Abstract
The need for particle board interiors is still in great demand to be used as wood-sourced interiors. In line with this, currently the problem of waste is still a fairly complex problem, both organic and inorganic waste. Coffee rinds and tofu pulp are organic wastes that have not been optimally utilized. Therefore, research was conducted on the manufacture of particleboard from coffee rinds and tofu pulp with PP plastic adhesive which aims to reduce the rate of deforestation due to tree felling as raw material for interior manufacturing and to control the environment by utilizing waste in the community into functional products. This study aims to determine the best formulation of particleboard made from Polyethylene plastic, coffee bean hulls and tofu pulp. Tofu dregs need to be preserved by soaking the dregs for 48 hours in a 5% glycerol solution and 15% NaCl solution in a 50:50 ratio. Then soaked for 48 hours. soaking 15.121%. To determine a good particleboard formulation, a physical evaluation of the particleboard was carried out including particleboard density test, water absorption test, moisture content test, thickness development test and instrumentation testing using SEM to see the surface structure of the particleboard. Based on the results of physical testing, the best formulation of particleboard biocomposites was obtained, namely the ratio of 70:30 (% w/b) (70% of tofu pulp and coffee bean skin and 30% of PET plastic) which is in accordance with SNI 03-2105-2006 standards. Biocomposite particleboard formulation 70:30 (% w/b) has a density of 0.60186 gr/cm3, water absorption of 95.395%, moisture content of 2.248% and an increase in thickness after soaking of 15.121%.

How to Cite: Hidayat, A., Permana, E., Wijaya, D., Pratama, Y., & Zufri, F. (2024). Development of Particle Board Biocomposite From Coffee Skin and Tofu Dregs With Polyethylene Plastic Adhesive As Furniture Interior. Hydrogen: Jurnal Kependidikan Kimia, 12(6), 1244-1254. doi:https://doi.org/10.33394/hjkk.v12i6.13802

https://doi.org/10.33394/hjkk.v12i6.13802

INTRODUCTION

The human need for board materials for interior furniture continues to increase significantly. In general, this board material is obtained from wood from the forest. It is feared that the high demand for wood materials in the future could have an adverse effect on the balance of the forest ecosystem. The high demand for wood will result in high illegal logging (Situmorang & Zarzani, 2023). This is likely to cause unstable timber production figures and be in a state of scarcity in the future, resulting in deforestation which can cause disasters such as flooding and erosion (Jarlis, 2022; Pratama Nanda et al., 2016). Therefore, innovation is needed in the field of materials engineering technology to find alternative raw materials to replace wood to be used as furniture interior boards.

One of these alternatives is a biocomposite board of particleboard type by utilizing environmental waste in the form of natural fibers or natural fibers that contain lignocellulose compounds (Maulida et al., 2021). In general, composite boards are produced from wood fibers, plastics, cement and various adhesives such as synthetic resins and other adhesives that are combined under pressure and temperature (Odusote et al., 2016; Ohijeagbon et al., 2020). To become a particleboard, the material must be bonded with an adhesive and compressed with heat (Kusumah et al., 2017). Particle board can be made of different types of layers and each layer used will add to the functionality of the particle board (Krumins et al., 2024). The advantages of particleboard compared to wood are that it is free of knots, not easily broken, not easily cracked, size and density can be adjusted according to needs (Nasution & Mora, 2018). The materials that can be used as composite fillers are coffee skin waste and tofu pulp waste. This is supported by a study which states that there is a high fiber content in both wastes, as well as their abundant quantity in the environment.

The potential waste obtained from the coffee processing stage is the coffee bean skin. Based on research by (Barbu et al., 2020), walnut shells can be used as particle board manufacturing material which can produce particle boards with higher dimensional and Brinell stability compared to soft wood particles. Coffee fruit consists of wet fruit skins, liquid waste containing mucus, and dry and dry shells. By-product waste in the form of coffee skin ranges from 50-60% of the harvest (Effendi, Z & Hatta, 2013). Dry coffee skin consisting of outer skin and fruit skin is known to have a fiber content of 65.2% (Siswati et al., 2012). Meanwhile, tofu pulp waste contains protein levels ranging from 23-29%, crude fiber 22.65% and fat 4.93% (Suryani, 2024). Currently, the utilization of coffee skin waste is used as aroma therapy in candles, soaps and tea bags (Kencanawati et al., 2023; Permana et al., 2023; Widyasanti & Muharram, 2023)

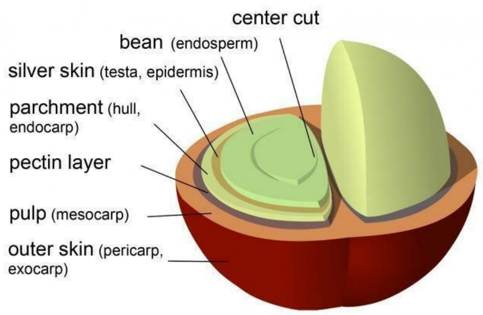


Figure 1. Structure of the Coffee Bean (Ogunjirin et al., 2021)

In addition, human growth is always increasing, resulting in an increase in the amount of plastic waste in the environment. In general, plastic waste is only disposed of in the trash, recycled and even burned. However, burning plastic waste has a serious impact on human health and the environment (Tiago et al., 2023). Currently only about 18% of plastics in the world have been recycled (Chamas et al., 2020). Polyethylene (PE) is the most widely circulated type of plastic in the community. Polyethylene (PE) is the most widely produced polymer in the world at least 27% of the world's plastic production. Polyethylene (PE) material is most widely used because it has a high molecular weight, semi-crystalline structure and strong hydrophobicity and very low biodegradability (Issac & Kandasubramanian, 2021).

In this particle board biocomposite innovation, the composition of coffee skin waste and tofu pulp as filler and Polyethylene (PE) plastic as a matrix (adhesive) is used. The addition of plastic waste aims to increase the adhesion/bond between the fibers and the matrix in the natural fiber composite. Supported by the characteristics of Polyethylene (PE) plastic which is resistant to load but still elastic, thermoplastic and hydrophibic (Chamas et al., 2020). In addition, the particle board also has the ability not to be easily eaten by termites, free of formaldehyde emissions and environmentally friendly (Rahmawati, 2015). So that it can make the resulting composite more resistant to water and low humidity. However, Polyethylene is not biodegradable and can last a long time in water and soil (El-Sherif et al., 2022). This has an impact on increasing the amount of Polyethylene in the environment, therefore Polyethylene must be maximally processed to reduce and reduce Polyethylene plastic in the environment which will have an impact on public health. In addition, Polyethylene must be processed wisely so that it can be useful and has a selling value among the community. Particleboard innovation contributes to the development of particleboard because this innovation utilizes waste materials of tofu pulp and coffee rinds that have not been utilized and is unique because usually particleboard comes from wood powder.

METHOD

Preparation of filler material

Coffee skin waste was cleaned and split into small pieces. Each piece is chopped using a chopper so that it becomes small particles, then dried using sunlight to dry (Meldayanoor et al., 2020). The tofu pulp that has been prepared is then washed using clean water. After that, the tofu pulp was soaked using 5% glycerol solution and 15% NaCl solution in a ratio of 50:50. Then soaked for 48 hours. After that, it was filtered using a cloth. Next, the first stage of drying (aerated for one day) and the second stage of drying (in the oven at 100 ℃ for 3 hours). After drying, it is then crushed using a blender (Sari et al., 2018).

Polythylene (PE) Matrix Preparation

Plastic waste was reduced in size using scissors. Then blended and filtered with an 18 mesh size sieve to separate the particles (Meldayanoor et al, 2020).

Preparation of Particleboard Biocomposites

The manufacture of particleboard biocomposites was carried out using the formulations listed in the research of (Dotun et al., 2018). The manufacture of particle board biocomposites was carried out with the ratio of coffee skin waste (CSW): tofu pulp waste (TPW): Polythylene plastic (PE) adhesive presented with the following formulation:

Table 1. Particleboard Biocomposite Manufacturing Formulation

Treatment	Ration (NF : PE)	Formulation		
		Natural Fibers (NF)		Adhesive (PE)
		CSW (%)	TPW (%)	PE (%)
F1	90:10	45	45	10
F2	80:20	40	40	20
F3	70:30	35	35	30

Compressing and Conditioning of Mixed Results

Weighed the coffee husk and tofu waste powder, and PE plastic powder for each formulation. Each material was mixed into a basin and then stirred manually until evenly distributed. Then put into a 25 cm × 25 cm × 5 cm mold. The press was heated for 10 minutes with a temperature of 150℃-165℃. The composite board was pressed for 15 minutes. The composite board is left for 30 minutes with the aim that the sheet hardens. After the composite board has hardened.

The composite board is conditioned for 1 week, then cut according to the size of each test sample, about (5 × 5) cm^2.

Evaluation of Particleboard Composite Formulation

This evaluation is carried out to determine whether the particleboard biocomposite that has been made is in accordance with the desired criteria and achieves maximum results of SNI 03-2105-2006 standards.

Density Test

The density or compactness of a particle within a sheet is influenced by the fiber density and the pressure applied during the production of particleboard. Density is determined by the weight and dry volume of the air sample. The test sample, measuring 10 cm x 10 cm in accordance with SNI 03-2105-2006 (Badan Standarisasi Nasional., 2006) , allows for the calculation of density using the following equation (1)

$$\rho = \frac{m}{v} \qquad (1)$$

Water Absorption Test

The water absorption test aims to assess the maximum capacity of the composite to absorb water. To evaluate the water absorption of the board, the weight difference is measured before and after soaking for 24 hours. The test sample is sized at 5 cm x 5 cm x 2 cm, in accordance with SNI 03-2105-2006 (Badan Standarisasi Nasional., 2006). The water absorption value is calculated using the following equation (2).

$$\text{DSA (\%)} = [(B_2 - B_1)/B_1] \times 100\% \qquad (2)$$

Water Content Test

The purpose of the water content test is to assess the amount of water present in the particle board, expressed as a percentage (%) of its dry weight. To evaluate the moisture content of the board, the weight is measured before and after it has been placed in an oven. The test sample dimensions are 10 cm x 10 cm x 2 cm, in accordance with SNI 03-2105-2006 (Badan Standarisasi Nasional., 2006). The water absorption value is determined using a specific equation (3).

$$KA = \frac{m_a - m_k}{m_k} \times 100\% \qquad (3)$$

Termite Resistance Test

To evaluate the effectiveness of the research on anti-termite particleboard, it is necessary to calculate the impact of the particleboard on termites. This involves measuring the weight loss of the test samples at the end of the exposure period after observation. The assessment of termite attack follows the SNI 01-2707-2006 (Badan Standarisasi Nasional., 2006) standard and utilizes a specific equation (4).

$$PT = \frac{T_a - T_k}{T_k} \times 100\% \qquad (4)$$

RESULTS AND DISCUSSION

The fillerization process is carried out by cleaning coffee skin waste and chopping it using a chopper so that it becomes small particles. The coffee bean skin is chopped to give texture to the particle board and expand the surface of the coffee bean epidermis which is then dried at 105˚C so that the coffee bean epidermis becomes dry. The tofu pulp obtained is washed thoroughly to remove the remaining impurities in the tofu pulp. The addition of glycerol and NaCl serves as a nurse and prevents the growth of microorganisms in tofu pulp. In addition, it also serves to reduce the pungent odor on the tofu pulp.

Figure 1. Coffee Bean Husk

Manufacture of Polythylene (PE) Adhesive Material (Matrix)

Polythylene (PE) is used from shopping plasmas that are cut into small pieces as Polythylene (PE) adhesive material. Polythylene (PE) will be used to glue the coffee beans with tofu pulp. The cutting of Polythylene (PE) plastic is done so that Polythylene (PE) so that the Polythylene (PE) melting process can be evenly distributed throughout the particle board and expand the surface so that Polythylene (PE) so that Polythylene (PE) will spread evenly into and throughout the particle board.

Density Test

The density test is a test of the physical properties of particleboard by comparing the mass of the sample to the volume, meaning that the physical property of density is the amount of particle mass per volume (Said et al., 2021). The density test is an important test in evaluating particleboard because a standardized density will indicate the potential strength and durability of the particleboard.

Table 2. Density Test Results

Formulation	Repetition	Density (ρ) (gr/cm^3)	Average (gr/cm^3)
(90 : 10)	1	0,4091	0,40914
	2	0,4093	
	3	0,4091	
(80 : 20)	1	0,3822	0,38224
	2	0,3822	
	3	0,3823	
(70 : 30)	1	0,6019	0,60186
	2	0,6018	
	3	0,6019	

Based on **table 2**, it can be seen that the particleboard with the highest density is in the 70:30 (% w/b) formulation of 0.60186 gr/cm3. This is due to the composition of plastic as a binder or adhesive component in the filler of tofu pulp and coffee epidermis which increases, causing the board density value to be higher. The effect of this plastic adhesive will physically interact with the coffee grounds and coffee grounds through the cavities it fills. The lowest density value was obtained in the 80:20 (% w/b) composition of 0.38224 gr/cm^3 and for the 90:10 (% w/b) composition, the density was 0.40914 gr/cm^3. The low density test results are due to the minimal adhesive composition and the cavities in the particleboard are filled with filler, so the board has a small weight compared to the volume of the board itself (Hasan et al., 2020). There are factors that affect the density value such as the type of wood, the amount of felt pressure, the number of wood particles, the adhesive content and other additives (Iswanto et al., 2008) . The results of the particleboard density test for formulations 1 and 3 have met the density standards required by SNI 03-2105-2006 which ranges from 0.40 - 0.90 gr/cm^3 (Badan Standarisasi Nasional., 2006).

Water Absorption Test

This absorption test is conducted to see the particle board is able to absorb water or is hydroscopic. The results obtained show the largest to smallest water absorption in order, namely formulations 2, 3 and 1. This is because the composition of tofu pulp particles and coffee rinds is more than the amount of plastic adhesive given. The water absorption of a particleboard will tend to decrease with increasing amounts of adhesive. This is in accordance with research conducted by (Aminah et al., 2018) that the concentration of adhesive used affects the value of water absorption, the higher the concentration of adhesive used, the lower the water absorption value of the resulting particle board.

Table 3. Water Absorption Test Results

Formulation	Repetition	% Absorbability	SD	Average (%)
	1	105,968		
(90 : 10)	2	105,835	0,0628	105,879
	3	105,835		
	1	129,906		
(80 : 20)	2	129,903	0,0278	129,924
	3	129,963		
	1	95,311		
(70 : 30)	2	95,445	0,0596	95,395
	3	95,428		

Based on this, it can be seen that the amount of adhesive given will affect the ability of particleboard to absorb water. The high water absorption of particleboard is due to its hygroscopic nature, mostly due to the presence of lignin and cellulose. These components are known to easily absorb and release water, so materials containing these components are very susceptible to changes in moisture levels (Iswanto et al., 2008). The decrease in water absorption is due to the adhesive entering the particle cell cavities more and more so that the contact between particles is tighter and water vapor will be difficult to enter the particle board.

Water Content Test

Water content shows the content contained in particleboard when it is in a state of equilibrium with the surrounding environment (Indrayanti et al., 2023). The moisture content in particleboard is influenced by the water content contained in the raw materials used**.** Increasing the amount of adhesive has a positive effect on the value of water content. This is because more adhesive will cover the cavity of the tofu pulp and coffee epidermis so that the particle board structure will be perfectly covered and not easily hydrolyzed. The moisture content of particleboard with minimal adhesive composition has a much higher value than with more adhesive composition. This shows that the particles used as the base material have a high ability to absorb water.

Table 4. Water Content Test Results

Formulation	Repetition	% Water Content	SD	Average (%)
	1	17,474		
(90 : 10)	2	17,465	0,219	17,315
	3	17,005		
	1	5,574		
(80 : 20)	2	5,586	0,023	5,564
	3	5,532		
	1	2,236		
(70 : 30)	2	2,272	0,017	2,248
	3	2,236		

Too high water content can cause the adhesive bond in the board to become weak, so the smaller the water content in the particleboard, the better the board. The decrease in moisture content is in line with the decrease in the percentage of use of tofu pulp and coffee grounds. This is in accordance with research which states that the less raw material used, the smaller the water content, but the results of this study show that the value of water content is getting bigger. The high value of water content is due to the hygroscopic nature of particleboard because it contains lignin and cellulose (Fauziah et al., 2014).

The optimum moisture content occurs at the 70:30 (% w/b) particleboard formulation concentration, which is 2.248% and 80:20 (% w/b) formulation, which is 5.564%. The moisture content of the particleboard produced has met the required standard of SNI 03-2105-2006, namely, moisture content < 14% (Badan Standarisasi Nasional., 2006).

Thickness Development Test

Thickness development is a test of physico-chemical properties that will show the dimensional stability of a particle board and can be used as a reference in the use of particle boards (Anggraini et al., 2021). The purpose of testing thickness development is to find out how much water absorbs on the particle board.

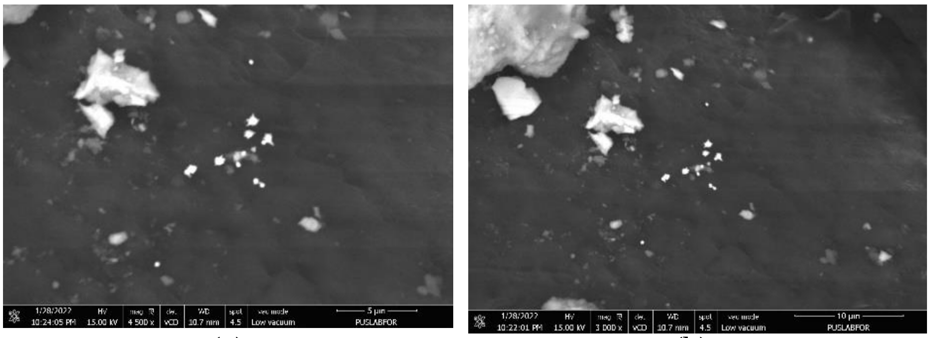
Table 5. Thickness Development Test Results

Formulation	Repetition	% Increase	SD	Average (%)
	1	2,857		
(90 : 10)	2	9,827	2,845	6,347
	3	6,358		
	1	12,313		
(80 : 20)	2	14,829	6,559	18,152
	3	27,313		
	1	16,889		
(70 : 30)	2	15,284	1,514	15,121
	3	13,191		

The results of the particle thickness development test using PET adhesive after soaking for 2 hours. The table shows that the water absorption tends to increase with the increase of adhesive amount. The value of particle board thickness development produced by PET adhesive ranged from 6.374%-18.152%. The lowest value of 6.374% occurred in the 90:10 (% w/b) particleboard formulation concentration, while the highest was 18.152% in the 80:20 (% w/b) particleboard formulation. In this study, the three particleboard formulations met the standards set by the Indonesian National Standardization Agency SNI 03-2105-2006 which tolerates the development of particleboard thickness after soaking in water by 20-25% (Badan Standarisasi Nasional., 2006). According to (Said et al., 2021), the higher the water absorption in a particleboard, the more particles of material can absorb water so that this will weaken the bond between particles which has an impact on the expansion of the particleboard.

SEM (Scanning Electron Microscopy) Testing

Analysis using SEM instrument is used to see the pore or surface of a particle with an electron microscope (Fitria et al., 2017). Based on the physical test analysis, the best formulation of particle board biocomposite was obtained with a ratio of 70: 30 (%b/b). After that, SEM factography analysis was carried out on the formulation. The results of SEM testing in this study show that the adhesive covers all the particles, the adhesive that covers the particles binds each other so that the particles can unite to form a bond, namely the board. The bonding strength of the preservative is very dependent on the amount used. In the SEM results for particle board biocomposites formulation 70:30 (%b / b) with 1000x magnification has a level of homogeneity that is not good when mixing the particles with the adhesive causing certain parts to look imperfect particles covered by the adhesive (there is porosity). SEM results obtained on this biocomposite particle board are obtained as follows:



(a) (b)

Figure 2. SEM analysis (a) 3000x; (b) 4500x

Figure 2 is the result of SEM analysis showing the surface structure of the particleboard samples. Figure 7a shows the surface morphology of the particleboard at 1500x magnification. The image shows tofu pulp and coffee bean skin bound by Polyethylene plastic. Figures 2a and 2b clearly illustrate the small particles bound to the polyethylene at 3000x and 4500x magnification. Polyethylene samples that are not treated or not bound with a particle will show a smooth surface (Gupta & Devi, 2019). It can be seen in the picture that the black surface shows the specifics of Polyethylene plastic.

CONCLUSION

Particle board innovation contributes to the utilization and processing of tofu pulp waste and coffee epidermis and particle board development, with this innovation it is hoped that the cutting of trees as furniture can be controlled so that the manufacture and use of furnicture is more environmentally friendly. In this particle board biocomposite innovation, the composition of coffee skin waste and tofu pulp as filler and Polyethylene (PE) plastic as matrix (adhesive) is used. The addition of plastic waste aims to increase the adhesion/bond between the fibers and the matrix in natural fiber composites. Three particle board biocomposite formulations have been made. Based on the results of physical testing, the best formulation of particleboard biocomposites was obtained, namely in the ratio of 70:30 (% w/b) (70% tofu pulp and coffee bean skin and 30% PET plastic) which is in accordance with SNI 03-2105-2006 standards. Biocomposite particleboard formulation 70:30 (% w/b) has a density of 0.60186 gr/cm3, water absorption of 95.395%, moisture content of 2.248% and an increase in thickness after soaking of 15.121%.

RECOMMENDATIONS

It is necessary to add variations in the mixture of natural fibers with Polyethylene (PE) adhesive and pay attention to the effect of pressure and temperature used during pressing so that a sturdier and stronger particle board will be obtained and a printing tool is needed that can provide pressure and temperature during the particle board printing process.

ACKNOWLEDGEMENTS

I would like to thank you for funding this research. This work was supported by Program Kreativitas Mahasiswa (PKM) of Jambi University.

BIBLIOGRAPHY

Aminah, Setyawati, D., & Yani, A. (2018). Sifat Fisik dan Mekanik Papan Partikel Dari Limbah Kayu Acacia crassicarpa Pada Beberapa Ukuran Partikel dan Konsentrasi Urea Formaldehida. *Jurnal Hutan Lestari*, *6*(3), 557–568.

Anggraini, R., Khabibi, J., & Adelka, Y. F. (2021). Karakteristik Papan Partikel dari Campuran Limbah Akasia (*Acacia mangium* Willd.) DAN KULIT KELAPA MUDA (Cocos nucifera L.). *Jurnal Silva Tropika*, *5*(1), 366–381. https://doi.org/10.22437/jsilvtrop.v5i1.12170

Badan Standarisasi Nasional. (2006). *SNI 03-2105-2006 : Mutu Papan partikel*. Badan Standarisasi Nasional.

Barbu, M. C., Sepperer, T., Tudor, E. M., & Petutschnigg, A. (2020). Walnut and hazelnut shells: Untapped industrial resources and their suitability in lignocellulosic composites. *Applied Sciences (Switzerland)*, *10*(18). https://doi.org/10.3390/APP10186340

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., Abu-Omar, M., Scott, S. L., & Suh, S. (2020). Degradation Rates of Plastics in the Environment. *ACS Sustainable Chemistry and Engineering*, *8*(9), 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635

Dotun, A. O., Adesoji, A. A., & Oluwatimilehin, A. C. (2018). Physical and mechanical properties evaluation of particle board produced from saw dust and plastic waste. *International Journal of Engineering Research in Africa*, *40*, 1–7. https://doi.org/10.4028/www.scientific.net/JERA.40.1

Effendi, Z & Hatta, L. (2013). Kandungan Nutrisi Hasil Fermentasi Kulit Kopi (Studi Kasus Desa Air Meles Bawah Kecamatan Curup Timur). *BPTP Bengkulu*, *1 (1)*(2005), 1–5.

El-Sherif, D. M., Eloffy, M. G., Elmesery, A., Abouzid, M., Gad, M., El-Seedi, H. R., Brinkmann, M., Wang, K., & Al Naggar, Y. (2022). Environmental risk, toxicity, and biodegradation of polyethylene: a review. *Environmental Science and Pollution Research*, *29*(54), 81166–81182. https://doi.org/10.1007/s11356-022-23382-1

Fauziah, ., Wahyuni, D., & Lapanporo, B. P. (2014). Analisis Sifat Fisik dan Mekanik Papan Partikel Berbahan Dasar Sekam Padi. *Positron*, *4*(2), 60–63. https://doi.org/10.26418/positron.v4i2.8728

Fitria, L. N., Susanto, H., & Istirokhatun, T. (2017). Penyisihan Karbosulfan Dalam Air Dengan Menggunakan Membran Nanofiltrasi. *Jurnal Teknik Lingkungan*, *6*(1), 1–17.

Hasan, A., Yerizam, M., & Kusuma, M. N. (2020). Bagasse (Saccharum officinarum) Particle board with high density polyethylene adhesive. *Jurnal Kinetika*, *11*(03), 8–13.

Indrayanti, L., Siska, G., & Sijabat, F. (2023). Uji Pendahuluan Sifat Fisika Mekanika Papan Partikel Kayu Kawui (Vernonia Arborea) dengan Tiga Persentase Perekat PVAc (Polyvinyl Acetate). *Juni*, *17*(1), 27–36.

Issac, M. N., & Kandasubramanian, B. (2021). Effect of microplastics in water and aquatic systems. *Environmental Science and Pollution Research*, *28*(16), 19544–19562. https://doi.org/10.1007/s11356-021-13184-2

Iswanto, A. H., Coto, Z., & Effendy, K. (2008). Pengaruh Perendaman Partikel terhadap Sifat Fisis dan Mekanis Papan Partikel dari Ampas Tebu (*Saccharum officinarum*). *Perennial*, *4*(1), 6. https://doi.org/10.24259/perennial.v4i1.176

Jarlis, R. (2022). Mechanical Properties of Coconut Particle Board with Variation of Material Composition. *Asian Journal of Science Education*, *4*(1), 40–50. https://doi.org/10.24815/ajse.v4i1.25325

Kencanawati, I., Saslina, T., Mairisiska, T., & Anzalina, H. (2023). *Pemanfaatan Limbah Kulit Kopi : Strategi Pengolahan*. *03*(02), 47–55.

Krumins, J. A., Vamza, I., Dzalbs, A., & Blumberga, D. (2024). Particle Boards from Forest Residues and Bio-Based Adhesive. *Buildings*, *14*(2). https://doi.org/10.3390/buildings14020462

Kumar Gupta, K., & Devi, D. (2019). Biodegradation of low density polyethylene by selected bacillus sp. *Gazi University Journal of Science*, *32*(3), 802–813. https://doi.org/10.35378/gujs.496392

Kusumah, S. S., Umemura, K., Guswenrivo, I., Yoshimura, T., & Kanayama, K. (2017). Utilization of sweet sorghum bagasse and citric acid for manufacturing of particleboard II: influences of pressing temperature and time on particleboard properties. *Journal of Wood Science*, *63*(2), 161–172. https://doi.org/10.1007/s10086-016-1605-0

Maulida, C. R., Mursal, & Ismail, I. (2021). Studi pemanfaatan ampas kopi untuk papan partikel. *J. Aceh Phys. Soc*, *10*(2), 48–52. https://doi.org/10.24815/jacps.v10vi2.19063

Meldayanoor, Muhammad Indra Darmawan, N. (2020). Pembuatan Papan Komposit dengan Memanfaatkan Limbah Pelepah Kelapa Sawit dan Plastik Polyethylene Terephthalate (PET) Daur Ulang. *Jurnal Teknol.Ogi Agro-Industri*, *7 (1)*, 56–69. https://doi.org/10.34128/jtai.v7i1.116

Nasution, W. M., & Mora, M. (2018). Analisis Pengaruh Komposisi Partikel Ampas Tebu dan Partikel Tempurung Kelapa terhadap Sifat Fisis dan Mekanis Komposit Papan Partikel Perekat Resin Epoksi. *Jurnal Fisika Unand*, *7*(2), 117–123. https://doi.org/10.25077/jfu.7.2.117-123.2018

Odusote, J. K., Onowuma, S. A., & Fodeke, E. A. (2016). Production of paperboard briquette using waste paper and sawdust. *Journal of Engineering Research*, *13*(1), 80–88. https://doi.org/10.24200/tjer.vol13iss1pp80-88

Ogunjirin, O. A., Ola, O., Farounbi, A. J., & Ogini, F. U. (2021). Development of Improved Coffee Bean Depulping Machine. *International Journal of Research in Agricultural Sciences*, *8*(1), 2348–3997.

Ohijeagbon, I. O., Adeleke, A. A., Mustapha, V. T., Olorunmaiye, J. A., Okokpujie, I. P., & Ikubanni, P. P. (2020). Development and characterization of wood-polypropylene plastic-cement composite board. *Case Studies in Construction Materials*, *13*, e00365.

https://doi.org/10.1016/j.cscm.2020.e00365

Permana, E., Nelson, N., Asti Rahayu, M., Arsa, D., Alim, K., Eka Wijaya, D., Nurdin Hidayat, A., & Salsa Rusmana, A. (2023). Pelatihan Pembuatan Lilin Aromaterapi Kulit Kopi Berbasis Minyak Jelantah Di Desa Mukai Pintu Kabupaten Kerinci. *Literasi Jurnal Pengabdian Masyarakat Dan Inovasi*, *3*(2), 620–625. https://doi.org/10.58466/jurnalpengabdianmasyarakatdaninovasi.v3i2.1111

Pratama Nanda, Djamas Djusmaini, & Darvina Yenni. (2016). Pengaruh Variasi Ukuran Partikel TerhadapNilai Konduktivitas Termal Papan Partikel Tongkol Jagung. *Pillar of Physics*, *7*(April), 25–32.

Rahmawati, A. (2015). Pengaruh Penggunaan Plastik Polyethylene (PE) dan High Density Polyethylene (HDPE) Pada Campuran Lataston - WC Terhadap Karakteristik Marshall. *Jurnal Ilmiah Semesta Teknika*, *18*(2), 147–159. https://journal.umy.ac.id/index.php/st/article/view/1816

Said, M., Fuadi, N., & Dzikriansyah, M. F. (2021). Karakterisasi Sifat Fisis Papan Partikel Sabut Kelapa-Serat Pelepah Lontar. *Jurnal Fisika Dan Terapannya*, *8*(2), 1–12. https://doi.org/10.24252/jft.v8i1.24814

Sari, A. M., Ab, S., Yulianti, N. O., & Permana, Y. Y. (2018). Terhadap Yield Tepung Ampas Tahu. *Prosiding Seminar Nasional Sains Dan Teknologi*, 1–5.

Siswati, N. D., Yatim, M., & Hidayanto, R. (2012). Bioetanol Dari Limbah Kulit Kopi Dengan Proses Fermentasi Bioethanol From Coffe Peel Waste With Fermentation Process. *Teknik Kimia*, *1*, 1–4.

Situmorang, J., & Zarzani, T. R. (2023). Aspek Hukum Terhadap Pertanggung Jawaban Pelaku Tindak Pidana Illegal Looging. *Innovative: Journal Of Social Science Research*, *3*(4), 7744–7756. https://j-innovative.org/index.php/Innovative/article/view/4518

Suryani, R. R. (2024). *Pemanfaatan protein ampas tahu sebagai bahan dasar pembuatan Bioplastik (Plastik Biodegradable)*. UIN Sunan Ampel Surabaya.

Tiago, G. A. O., Mariquito, A., Martins-Dias, S., & Marques, A. C. (2023). The problem of polyethylene waste – recent attempts for its mitigation. *Science of the Total Environment*, *892*(June), 164629. https://doi.org/10.1016/j.scitotenv.2023.164629

Widyasanti, A., & Muharram, A. (2023). Pemanfaatan Limbah Kulit Kopi Dan Praktik Pembuatan Sabun Cascara Kopi. *Sawala : Jurnal Pengabdian Masyarakat Pembangunan Sosial, Desa Dan Masyarakat*, *4*(2), 54. https://doi.org/10.24198/sawala.v4i2.46566