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Characteristic Tests of Bio-pellets Made of Calliandra Wood as a Renewable Alternative Fuel

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Abstract*—Calliandra wood is a kind of forest biomass located in Baturaden Adventure Forest (BAF). The availability of which is quite abundant, so it has such an outsized potential to be processed into biopellets. This study was aimed at creating biopellets made of Calliandra wood and assessing their calorific value and their proximate value, and doing the mechanical and the combustion tests. This wood was converted into bio-pellets by employing several processes such as the drying, crushing, and milling processes, as well as the process of a 60-mesh sifting and the process of printing the bio-pellets with a starch adhesive of 16% Calliandra wood powder mass. Based on the results of this study, it was found out that the characteristics of the Calliandra wood biopellets taken from BAF had met the standards recommended by SNI 8021:2014, namely that of an over 4000 cal/gr calorific value, 3.6 % maximum moisture content, 69.4% maximum volatile matter content, 0.95% maximum ash content and 26% minimum fixed carbon content. The tests found out that the maximum stress value was 2.5MPa. and 66gram Calliandra wood bio-pellet could boil 500 ml of water in 6.5 minutes. Therefore, the biopellets can highly effectively be used as an alternative fuel.

***Keywords*—Biopellet, Calliandra Wood, Combustion Test, Calorific Value, Mechanical Test, Proximate Value.**

I. INTRODUCTION (*HEADING 1*)

This Nowadays, many global energy experts have begun to consider the use of biomass as a kind of an environmentally-friendly and sustainably renewable energy especially those based on forest biomass. Indonesia has such abundant biomass fuel amounting to 50,000MW from various sources of biomass. However, the energy potential of the biomass has never optimally been utilized yet; by 2013, less than 5% or only 865.73MW new biomass has been utilized in Indonesia [1] [2].

Biopellets are biomass-based alternative sources of fuel having the same density, shape, size, humidity and energy content. When biomass is converted into biopellets, the conversion will create several advantages such as an increased calorific value, a lowered water content and a lowered ash content of the combustion residues [3] [4] [5] [6]. Bio-pellet technology has been such a breakthrough employed to solve a problem of the dependence on various non-renewable sources of energy. Quality bio-pellets are bio-pellets whose characteristic values meet the requirements stipulated by Indonesian National Standard (SNI) Number 8021:2014 as follows. The maximum value of the water content is 12%, the maximum value of the ash content is 1.5%, the maximum value of the volatile matter is 80%, the minimum value of the carbon content is 14%, and the minimum heating value is 4000 Cal/g [3] [7] [8] [9] [10].

In this study, Calliandra wood from Baturaden Adventure Forest (BAF) served as the source of the bio-pellets. This plant is often used in as a source of biomass since it has some fast-growing properties; it is easily cultivated, has abundant seeds, is able to grow on common soils, and has a relatively high calorific value [11] [12].

This study was aimed at making a bio-pellet made of Calliandra wood. Moreover, it was also aimed at analyzing the calorific value and the proximate value of the water content, ash content, carbon content, and volatile matter content, which would then be compared to the standard quality of wood pellets recommended by SNI 8021:2014 and compared to the value of their mechanical and firing tests. In this study, the limit of the problem was that Calliandra wood serving as the raw materials came from the Baturaden Adventure Forest and that the size of the biomass was 20 mm long with a 6mm diameter; moreover, the adhesive used in this study was starch with 16% Calliandra wood mass powder.

II. METHODOLOGY

To simplify the processes in the study, it necessary to design several flow diagrams since the design processes could be carried out in a sequence as shown in Fig. 1.

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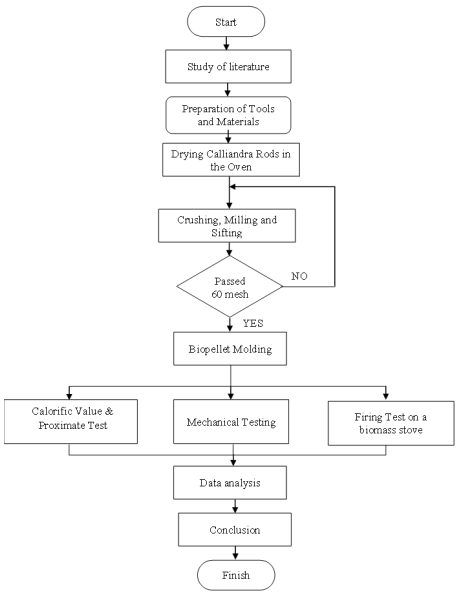

Fig. 1. Flowchart of Research Method

III. Experimental Procedure

Prepare to enhance the density level of the biopellet, so it would result in a higher calorific value and a higher carbon value [11]. Fig. 2 – 7 show the conversion of the Calliandra wood into powder.

A bio-pellet was made of Calliandra wood powder with the help of a starch adhesive amounting to 16% of Calliandra wood powder. The adhesive used in the process was a mixture of starch and water with a ratio of 1:3. Starch was selected to serve as an adhesive since starch could easily be found. Moreover, its price was relatively low, too. The bio-pellet molding process was carried out by employing a pellet mill machine at the Headquarters of *Gerakan Ciliwung Bersih*. The process taking place in the pellet mill machine resulted in a 20mm long biopellet mold with a 6mm diameter, so the mold was still within the range of a standard biopellet size; the standard diameter ranged from 3mm to 12mm, and the standard length ranged from 6mm to 25mm [1].

After molded, the biopellets had to be dried by drying it in the daylight for 4-5hours. Then, they were sorted out and stored in an airtight storage plastic to prevent them from getting moldy. Fig. 8 – 11 show a series of processes employed to make a bio-pellet from Calliandra wood.

After the adhesive dough made of a mixture of starch and water with a ratio of 1:3 was made, it was mixed with the Calliandra wood powder. After well mixed, the biopellet mixture was entered into the pellet mill machine to be printed. Fig. 12 and Fig. 13 show the molding process and the results of the biopellet molding.

In this study, a series of experiments on the formulation of the biopellet dough were carried out to obtain a perfect biopellet mold. Table I shows the experiments on the molding formulation of the biopellet.

Based on the results of the study, it was found out that the best formulation of biopellet printing is by mixing it with an adhesive amounting to 16% of Calliandra wood powder. That composition produced prints with a perfect texture.

Fig. 1. Calliandra Wood

Fig. 2. Sample Drying with Oven

Fig. 3. Crusher Machine

Fig. 4. Crusher Machine Yield

Fig. 5. Disc Mill Machine

Fig. 6. Calliandra Sawdust

Fig. 8. Calliandra Wood Powder

Fig. 7. Starch As An Adhesive

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Fig. 8. Adhesive Manufacturing Process

Fig. 9. Glue Dough

Fig. 10. Calliandra Wood Printing Process with A Pellet Mill Machine

Fig. 11. The Results of Biopellet Molding Calliandra Wood Biopellets With 16% Adhesive

TABLE I. EXPERIMENTS ON THE MOLDING FORMULATION OF THE CALLIANDRA WOOD BIO-PELLET

No	Biopellet Formulation	Adhesive Content	Mold Result	Description
1	500 gr of Calliandra sawdust	No Adhesive	Fail	No molded bio-pellets
2	500 gr of Calliandra sawdust + 25 gr of starch + 75 ml of water	5%	Fail	The molded bio-pellets only constituted 5% of the dough
3	500 gr of Calliandra sawdust + 50 gr of starch + 150 ml of water	10%	Fail	The molded bio-pellet only constituted 30% of the dough and the printed bio-pellet texture was not perfect.
4	500 gr of Calliandra sawdust + 80 gr of starch + 240 ml of water	16%	Success	100% of the bio-pellets could be molded

IV. Conclusion

After Tests on the biopellets went through 4 stages such as testing the calorific value, testing the proximate value, the mechanical testing and the combustion testing taking place on a biomass stove to see the effectiveness of a bio-pellet made of Calliandra wood as an alternative fuel.

Biopellets made of Calliandra wood manufactured with a starch adhesive amounting to 16% of Calliandra wood powder has met Indonesia's standard recommended by SNI 8021:2014 in regard to wood pellets [11]. Table II shows the results of the biopellet tests [13].

A. Calorific Value Test

Referring to the standard quality of a wood bio-pellet pursuant to SNI 8021:2014, the minimum standard of the calorific value is 4,000 cal/gr [7]. Based on the results of the study, it was found out that the bio-pellet samples made of Calliandra wood had a calorific value amounting to 58,572 kJ/gr; thus, it was equivalent to 13,993.02 cal/gr.

Therefore, it was concluded that the bio-pellets made of Calliandra wood met the standard calorific value recommended by SNI 8021:2014. The calorific value serves as a main parameter used to determine the quality of a bio-pellet, so it could be used to determine the value of the produced combustion heat. The higher the calorific value is, the higher the high combustion rate and the better the bio-pellet quality will be [14] . Furthermore, the calorific value is affected by water content and ash content. The lower the water content and the ash content are, the higher the calorific value will be [15] [16].

B. Proximate value

A proximate test measures several parameters such as the moisture content, the ash content, the volatile matter and the fixed carbon. Those parameters provide such technical properties of a bio-pellet to be used as an alternative fuel that can replace a fossil fuel.

Based on the standard quality of a wood bio-pellet pursuant to SNI 8021:2014, the standard value of the moisture content is 12%. Based on the results of the study, it was found out that the bio-pellet made of Calliandra wood had the moisture content amounting to 3.64%. Therefore, it was concluded that the bio-pellet made of Calliandra wood met the standard water content recommended by SNI 8021:2014. Moisture content greatly affects the quality of bio-pellets. Therefore, the lower the moisture content is, the higher the quality of the bio-pellets will be. High moisture content will reduce the calorific value, make the ignition process more difficult, and cause a lot of smoke during the combustion [15].

Referring to the standard quality of a wood bio-pellet pursuant to SNI 8021:2014, the standard value of the ash content is 1.5%. Based on the results of the study, it was found out that the bio-pellet made of Calliandra wood had the ash content amounting to 0.95%. Therefore, it was concluded that the bio-pellet made of Calliandra wood met the standard ash content recommended by SNI 8021:2014. Ash is a waste material resulting from the combustion process that has no calorific values and no carbon elements. The lower the ash content is, the higher the calorific value and the value of bound carbon will be. Therefore, it can improve the quality of a bio-pellet. High ash content will result in ash during the combustion, thus resulting in a decreased production of heat [15].

Referring to the standard quality of a wood bio-pellet pursuant to SNI 8021:2014, the standard value of volatile

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matter content is 80%. Based on the results of study, it was found out that the level of the volatile matter of a bio-pellet made of Calliandra wood was 69.43 %, so it was concluded that the bio-pellets made of Calliandra wood meet the standard volatile substance recommended by SNI 8021:2014. Volatile matter content is an index of the fuel content for the gas contained in the biomass. The lower the level of the volatile matter is, the higher the quality of the bio-pellet will be since it will produce a higher calorific value and produce less smoke during the combustion [14].

Referring to the standard quality of a wood bio-pellet pursuant to SNI 8021:2014, the standard value of the bound carbon content is 14%. Based on the results of the study, it was found out that the fixed carbon content of the Calliandra wood bio-pellet was 26.10%. Therefore, it was concluded that the bio-pellet made of Calliandra met the standard bound carbon content recommended by SNI 8021:2014. A Bonded carbon is the elemental carbon present in the sample together with the water content, ash content and volatile matter. A bound carbon content greatly affects the quality of a bio-pellets since the higher the level of the bound carbon, the higher the calorific value and the higher the quality of the bio-pellet will be [15] [17].

C. *Mechanical Test*

The mechanical properties of the bio-pellet compressive strength were measured to determine the material's ability to withstand any external pressure which could cause the material to be crushed or broken [18].

Table II shows biopellet samples made of Calliandra wood has a maximum stress value amounting to 2.59 MPa. Referring to the standard bio-pellets recommended by SNI 8021:2014, the value does not require a minimum or maximum standard compressive strength value of the bio-pellet. However, the higher the value in the mechanical test of the bio-pellet compressive strength is, the higher the quality of the bio-pellet will be since it will not easily be damaged [15].

TABLE II. TEST RESULTS OF THE BIOPELLET

Test	Standard SNI 8021:2014	Results	Description
Calorific Value	≥ 4000 cal/gr	13993.02 cal/gr	Meet the standards
Proximate Value	Moisture content ≤ 12%	3.64%	Meet the standards
	Volatile matter ≤ 80%	69.43%	Meet the standards
	Ash ≤ 1,5%	0.95%	Meet the standards
	Fixed Carbon ≥ 14%	26.10%	Meet the standards
Mechanical	No standard	2.59 MPa	-
Firing Test	No standard	It takes 66 grams of biopellet made of Calliandra wood to boil 500 ml of water in 6.5 minutes	

D. *Firing Test*

Burning tests on bio-pellets on a biomass stove were carried out to observe how long it would take to boil 500 ml of water and to compare the duration to that of other fuels such as LPG. Fig. 14 and Fig. 15 show the firing test.

Fig. 12 Firing Test with Biomass Stove

Fig. 13 Soot from Burning Bio-Pellets

It took 6 minutes 34 seconds to boil 500 ml of water by burning the biopellets made of Calliandra wood. Before they were burned, the biopellets put into the biomass stove weighed 350 gr. After they were burned, the biopellets weighed 284 gr. Therefore, it took 66 grams of biopellets to heat the water. The color of the flame produced during the burning process of the biopellets was orange; moreover, the process created soot. Meanwhile, it took 3 minutes 39 seconds faster if burned with an LPG, and the color of the flame was blue. Moreover, it did not create any soot.

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REFERENCES

[1] R. Effendi, N. Roffandi, T. Puspitodjati, and I. Bangsawan, "Menggagas energi biomassa hutan sebagai sumber energi terbarukan," *Penelit. dan Pengemb. Sos. Ekon. Kebijak. Dan Perubahan Iklim*, vol. 11, no. 02, pp. 1–5, 2018.

[2] A. Bunyamin and D. Purnomo, "Potential impact of beekeeping activity on bioenergy supply in West Java, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 460 012023, no. 1, pp. 1–5, Mar. 2020.

[3] S. Mustamu, D. Hermawan, and G. Pari, "Karakteristik Biopelet Dari Limbah Padat Kayu Putih Dan Gondorukem," *J. Penelit. Has. Hutan*, vol. 36, no. 3, pp. 191–204, 2018.

[4] Maemuna, M. Jaya, and M. N. A. Sofyan, "Pemanfaatan Biomassa Tumbuhan Menjadi Biopellet sebagai Alternatif Energi Terbarukan," *Hasanuddin Student J.*, vol. 2, no. 1, pp. 180–188, 2018.

[5] S. Sylviani and E. Yosefi Suryandari, "Potensi Pengembangan Industri Pelet Kayu Ssbagai Bahan Bakar Terbarukan Studi Kasus Di

Kabupaten Wonosobo," *J. Penelit. Sos. dan Ekon. Kehutan.*, vol. 10, no. 4, pp. 235–246, Dec. 2013.

[6] I. Pradnyaswari, J. N. Pongrekun, P. Ridhana, and I. Budiman, "Barriers and Opportunities of Bio pellets Fuel Development in Indonesia: Market Demand and Policy," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 997 012003, no. 1, pp. 1–15, Feb. 2022.

[7] SNI 8021:2014 BSN, "SNI Pelet Kayu," 2014.

[8] C. P. Artemio, N. H. Maginot, C.-U. Serafín, F. P. Rahim, R. Q. José Guadalupe, and C.-M. Fermín, "Physical, mechanical and energy characterization of wood pellets obtained from three common tropical species," *PeerJ*, vol. 6, Sep. 2018.

[9] P. Science, N. Resources, and L. Banos, "Physico – Chemical Properties Of Wood Pellets From Forest Residues," vol. 26, no. 4, pp. 589–595, 2014.

[10] R. J. Silmi Yusri Rahmadani, Alponsin Alponsina,Tesri Maidelizaa, "Karakteristik Anatomi Dan Energi Kayu Dari Tiga Tumbuhan Invasif," *J. Ris. Ind. Has. Hutan*, vol. 13, no. 1, pp. 1–14, 2021.

[11] N. Hendrati,R.L dan Hidayati, *Budidaya Kaliandra (Calliandra calothyrsus) Untuk Bahan Baku Sumber Energi*, Cetakan Pe. PT Penerbit IPB Press, 2014.

[12] E. Prasetyo *et al.*, "Penanaman Kaliandra Sebagai Kayu Energi dan Hijauan Makanan Ternak Pada Pertanaman Agroforestri Masyarakat Desa Gerbosari, Samigaluh Kulon Progo," *J. Pengabdi. dan Pengemb. Masy.*, vol. 1, no. 1, pp. 1–10, May 2018.

[13] M. A. Susi Rahayu, Sitti Hilyana, Embun Suryani, Nazmi Herlina Sari, "Analysis of Wood Pellet Quality from Calliandra Callothyrsus, Gliricida Sepium, and Sawdust as New and Renewable Energy," in *Proceedings International Conference on Science and Technology (ICST)*, pp. 110-115, 2020.

[14] S. Y. Adaganti, V. S. Yaliwal, B. M. Kulkarni, G. P. Desai, and N. R. Banapurmath, "Factors Affecting Bioethanol Production from Lignocellulosic Biomass (Calliandra calothyrsus)," *Waste and Biomass Valorization*, vol. 5, no. 6, pp. 963–971, Dec. 2014.

[15] R. Lies Indrayanti, Alpian Wahyu Supriyati, Renhart Jemi,Theresia Anggreini Sirait, "Kualitas Pelet Tiga Jenis Kayu: Bangkirai (Shorea laevis Rdl), Sungkai (Peronema canescens Jack) Dan Meranti Merah (Shorea leprosula Mig)," *Agrenvi*, vol. 14, no. 1, pp. 13–23, 2014.

[16] K. N. M. Faisal Mahdie, Noor Mirad Sari, "Sifat-sifat penyalaan dari pembakaran biopellet dari limbah serbuk kayu ulin dan limbah serbuk kayu campuran (balsa dan meranti) sebagai energi terbarukan," *Pros. Semin. Nas. Lingkung*, vol. 3, no. April, pp. 429–432, 2018.

[17] E. Arsad, "Sifat Fisik Dan Kimia Wood PelletT Dari Limbah Industri Perkayuan Sebagai Sumber Energi Alternatif (Carakteristic Physical and Chemistry of Wood pellet from Industrial Disposal of Wood as Sources Energy Alternatif)," *J. Ris. Ind. Has. Hutan*, vol. 6, no. 1, pp. 1–8, 2014.

[18] W. J. Cichy, A. Panek, and D. Radoński, "Assessment of mechanical properties of pellets made from wood raw materials," vol. 9, pp. 35–39, 2014.

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