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| RESEARCH ARTICLE

Comparison Moisture of Biopellet from Sugarcane Bagasse and Coconut Dregs as Raw Materials for Co-Firing Power Plant

Joko Triatmoko[1], Fatahul Arifin[2] ✉ and Yohandri Bow[3]
[1]Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, 30139, Indonesia
[2]Mechanical Engineering Department, Politeknik Negeri Sriwijaya, 30139, Indonesia; Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, 30139, Indonesia
[3]Chemical Engineering Department, Politeknik Negeri Sriwijaya, 30139, Indonesia; Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, 30139, Indonesia
Corresponding Author: Fatahul Arifin, **E-mail**: farifinus@polsri.ac.id

| ABSTRACT

This study investigated the use of locally-grown sugarcane bagasse and coconut dregs as raw materials for producing biomass pellets, which can be burned in the coarse form to generate heat energy. The proximate properties, such as moisture content, of the fuel pellets produced from sugarcane bagasse and coconut dregs were analyzed to determine the performance of the pelletizer equipment used in producing the biomass pellets. Moisture content was measured to evaluate the fuel pellet properties of the bagasse and coconut biomass and to, determine their durability and optimize the performance of the pelletizer equipment. The ideal pelleting moisture values for sugarcane bagasse and coconut dregs were found to be under 10%. In general, the physical and chemical properties of coconut biomass pellets were within the recommended limits. However, the pellets exhibited a relatively high ash level compared to wood biomass.

| KEYWORDS

Coconut Dregs, Moisture Content, Pelletizer, Sugarcane Bagasse

| ARTICLE INFORMATION

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1. Introduction

The increasing population growth in Indonesia greatly affects the amount of fuel energy used. In 2019, based on an inter-census population survey, Indonesia's population was projected to reach 266.91 million people (Wahyono et al., 2021).

This becomes a problem for the government in meeting the need for gas fuel (Bow et al., 2022). The community expects an alternative gas fuel that can help the community in meeting their fuel needs (Putri et al., 2020). Fossil energy has a limitation and needs diversification of resources energy in order to make sure the availability of renewable energy sources (Rusdianasari et al., 2023).

One of the energy sources that can be developed is the use of biomass energy. Biomass is one of the biological resources that can be converted into renewable fuel energy sources (Carneiro & Gomes, 2019). Biomass energy sources have several advantages, including being a renewable energy source that can provide a sustainable energy source (Bazargan et al., 2015). Renewable energy planning is a continuous improvement process in which urban planning activities of individuals and organizations (Pava, 2023).

Indonesia is one of the largest coconut and sugar cane producing countries in the world(Nielsen et al., 2020). Indonesia is even able to export coconut and sugar cane to several neighboring countries. In 2010 Indonesia could export 800 tons of coconuts, and in 2015, there was an increase to 1.8 million tons of coconuts(Acda, 2015). Meanwhile, sugar cane plantations in 2018 recorded the total area of sugar cane plantations in Indonesia reaching 420 hectares (Albashabsheh & Heier Stamm, 2019). However, various uses can be made, such as making coconut milk, coconut oil, and sugarcane ice, which leaves the dregs and, if thrown away, will have a negative impact on the environment (Damayanti et al., 2021) (Rusdianasari et al. 2023).

Therefore, the author makes a breakthrough in the optimal utilization of coconut pulp and bagasse, one of the effective ways that have been used to increase the value of agricultural and biological materials using pelletizing (Rusdianasari et al., 2022).

After the pellets were produced, they were allowed to cool on the dry concrete floor for a few hours to ensure physical stability(Frodeson et al., 2019). During the experiments, ambient conditions were in the range of 23–28°C temperature and 50–60% relative humidity for 24 hours a day (Rusdianasari et al., 2020). The production capacity during the pelleting process was calculated as kg/h by weighing the pellets deposited in the vessel for 60 seconds (Budiastuti et al., 2022). Particles and powders less than 1-2 mm were excluded from the pellets produced.

2. Literature Review

The main process of pelletization is the softening of the lignin (contained in the sawdust) during compression and parallel heating, as this grants a high elastic modulus and good bonding properties of pellets (Bartocci et al., 2018). (Bartocci et al., 2018) got the conclusion that moisture is a fundamental parameter in biochar pelletization (Moreira et al., 2021). The optimal value of 20%w/w of moisture is 10%w/w binder (Oguntunde et al., 2018). The best binder was found to be lignin (Nielsen et al., 2020). So it can be inferred that the moisture of the material is maybe less important for torrefied biomass, but it is fundamental for biochar obtained from pyrolysis (Demirbas & Tel, 2003). Another study analyzes the influence on the pelletization process of the pyrolysis temperature. An accurate Scanning Electron Microscope analyzed the mechanism that regulates biochar pellet densification quality (Abubakre et al., 2014). It was found that with pyrolysis temperatures equal to 650°C, the optimal quantity of water is about 35%w/w, while the binder (mainly lignin) can be about 10%w/w (Woern & Pearce, 2018). Dealing with the main processes occurring during biochar pelletization, it must be considered that water and lignin can promote pelletization of carbonized brittle and fine biochar particles derived from pyrolysis at 650°C, acting as binders (Colley et al., n.d.). Lignin which is a randomly cross-linked polymer of phenylpropane units has a glass transition behaviour in the temperature range of 137-157°C (Oduntan & Koya, 2015). The presence of water during the compacting process decreases the glass transition temperature of lignin, so with 35%w/w of water in the raw material and the pressure of 128 MPa, lignin forms solid bridges between the biochar particles, which enhance the compressive strength of the biochar pellet (García et al., 2018).

While several laboratory tests have analysed the pelletising process using single channel press machines, continuous production of biocarbon pellets has never been analysed (Gao et al., 2016). To fill this gap, the authors have focused their attention on a continuous pelletizing machine with a mass flow of 40 kg/h(Okolie et al., 2019). Achieving satisfactory durability of the biocarbon pellet was proven to be quite hard (Cardozo & Malmquist, 2019). It is almost impossible to produce it without additives (for example, sawdust) and proper optimization of the moisture content (Kaliyan et al., 2009). The aim of the work has been to identify the optimal quantity of water and additives in a continuous biocarbon pelletizing process (Agbetoye et al., 2010). This was achieved using a Response Surface Methodology (RSM) to identify the pelletizing parameters that provide the highest durability (Hardiansyah et al., n.d.).

3. Methodology

3.1 Material

The bagasse waste used in this study was collected from PT. Sweet Indolampung, Lampung, Indonesia, and is a byproduct of sugar production. The coconut dregs were obtained from solid waste generated by coconut milk traders in Plaju Modern Market. To process the solid waste materials, each material was chopped into pieces no larger than 5mm using grass scissors and then fed into the pelletizer. All biomass feed materials were dried in an oven at 110°C. All other chemicals used in the study were obtained from the Energy Engineering Laboratory at Politeknik Negeri Sriwijaya.

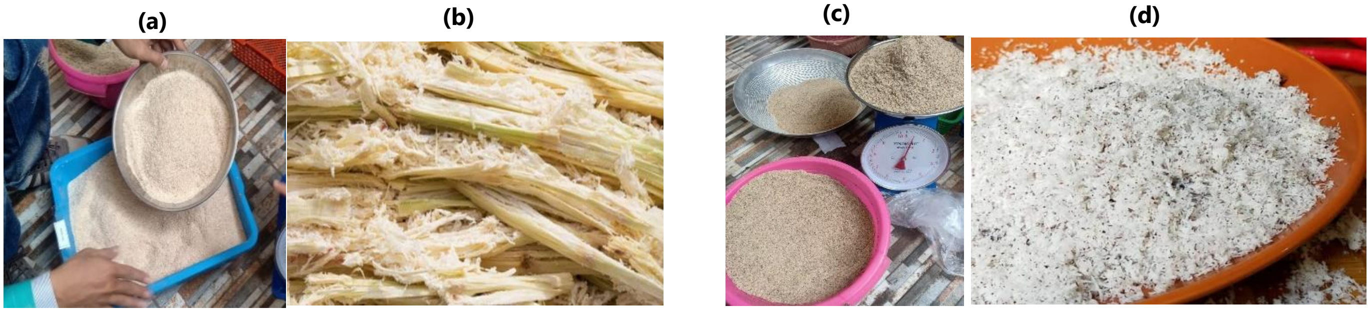

Fig 1. (a) Sugarcane bagassed after drying and chopping ; (b) Sugarcane bagasse before drying and chopping ; (c) Coconut dregs after drying ; (d) Coconut dregs before drying.

3.2 Pelletizer Machine

A laboratory-scale pelletizing machine (Figure 1) was used to produce the pellets for this study, with a production capacity of 250-300 kg/h depending on the type of raw material and moisture content.

The design view of the pelletizer is shown in Figures 1 and 2, with each component designed following standard engineering principles (Lisowski et al., 2017). The pelleting process was carried out with a constant flow by feeding the sugarcane bagasse and coconut dregs using a shovel. During the pelleting of sugarcane bagasse, 40 ml of waste lubricants and 60 ml of water were added to the raw material before it was added to the funnel. On the other hand, 60 ml of waste lubricants and 90 ml of water were added to the coconut dregs before they were added to the funnel.

After the pellets were produced, they were allowed to cool on the dry concrete floor for a few hours to ensure physical stability(Frodeson et al., 2019). The experiments were conducted under ambient conditions of 23–28°C temperature and 50–60% relative humidity for 24 hours a day. The production capacity during the pelleting process was calculated as kg/h by weighing the pellets deposited in the vessel for 60 seconds. Any particles or powders less than 1-2 mm were excluded from the pellets produced.

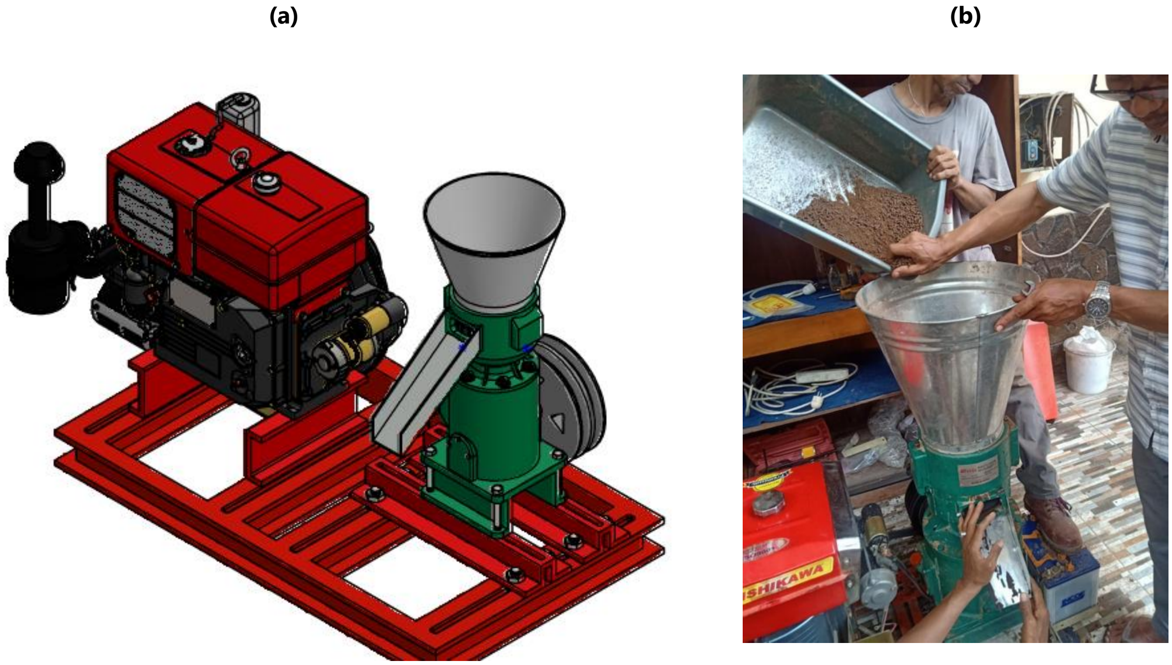

Fig 2. Pelletizer Machine, (a) as a 3D drawing ; (b) actual pelletizer machine.

3.3 Moisture Content

The moisture content of sugarcane bagasse, coconut dregs, and pellets was measured using the gravimetric method ASTM E871-82 (ASTM 2014) (Huang et al., 2017). After the pelletizing process, the moisture content of each raw material was measured on a wet basis (W1). The following equation was used to calculate the moisture content:

$$\text{Moisture (MC)} = \frac{W_1 - W_2}{W_1} \times 100\% \qquad (1)$$

The equation variables are MC, which is the amount of water to be added (%); W1, which is the initial weight of the sample before heating (g); and W2, which is the initial weight of the sample after heating (g) (Mani et al., 2006). For proximate analysis, pellets were randomly selected from each batch. The dimensions of individual pellets were determined by measuring their length and diameter randomly. The average values of diameter, length, weight, and the ratio of length/diameter were calculated from these samples (Bow et al., 2022). Particle density was calculated from the average weight and volume of these measurements (Ciolkosz et al., 2015). The density of samples was determined using the weight and volume of a predetermined amount of pellets in a graduated cylinder (Nemchinova et al., 2019).

4. Results and Discussion

The pellet samples were stored in a room at 28-30°C and 55-60% relative humidity for 7 days to ensure their stabilization. The moisture content of the pellets was measured immediately after the pelletizing process and at the end of the 7-day period to determine the effects of ambient conditions on the pellets, as shown in Figure 4 and Figure 3, respectively, representing actual biopellets.

Fig 3. Biopellet, (a) Coconut Dregs Biopellets ;(b) Sugarcane Bagassed Biopellets.

During the pelletizing process of the raw materials, sugarcane bagasse lost more moisture, resulting in pellets with lower moisture content. Although SP1 and CP1 showed the highest decrease in moisture content, the minimum decrease was observed in SP2 when considering the pelletizing moisture. The addition of water and waste-lubricant to the raw material shortens the residence time of the raw material in the die holes, resulting in high-moisture pellets because the raw material is less exposed to the temperature of the pressure die (Serrano et al., 2011). Furthermore, the use of adhesive during the pelletizing of coconut dregs allowed them to pass easily through the die holes. The statement that increasing the moisture content in raw material increases the moisture content of the pellets was confirmed by research results obtained by other researchers. After storage for 7 days at ambient conditions with 29°C temperature and 60% relative humidity, SP1, SP2, SP3, and CP2 pellets lost moisture, while CP1 and CP3 pellets absorbed moisture. The pellets most affected by ambient conditions were SP2 and SP3 pellets with the lowest moisture content. Pellets with low moisture content are more suitable for absorbing moisture from the environment. The results were compared with SNI 89651:2020, and the moisture content of pellets was acceptable except for CP1 and CP3 pellets because they had a moisture content of more than 10%. The phenomenon is because the retention time can make raw materials throughout steam (Rivai Suhendra F & Iskandar, 2021).

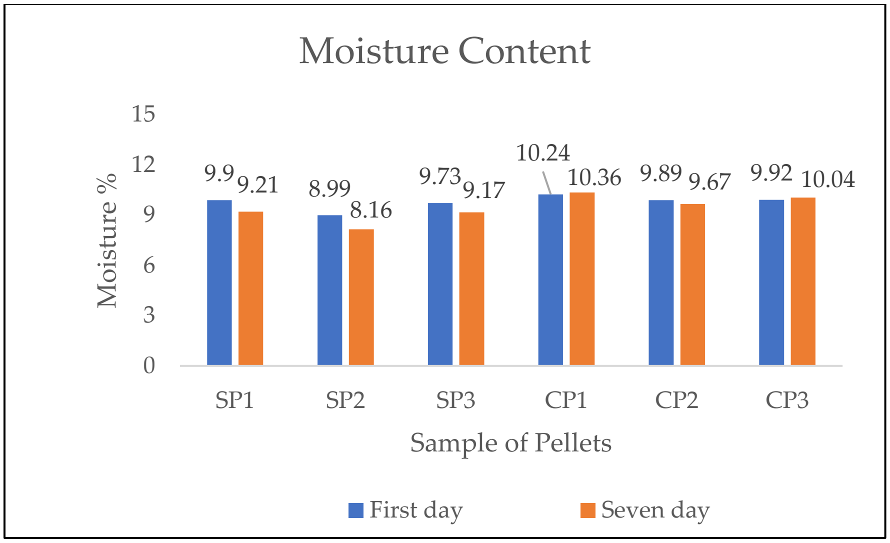

Fig 4. Pellet Moisture Per Each Sample.

5. Conclusion

The research conducted focused on the pelleting process of raw materials such as sugarcane bagasse and coconut dregs, with the addition of waste lubricant and water as a side material. Based on the research background, sugarcane bagasse and coconut dregs need to convert into pellets to improve the quality of biomass and decrease waste. It was observed that the appropriate moisture content of the pellet samples, depending on the type of material, is necessary in order to achieve a solid pellet during the pelleting process. The best reduction in moisture content and absorption ability was achieved with sugarcane bagasse, which can reach a moisture content of under 10%. While coconut dregs had the highest moisture content absorption of over 10%, they were able to pass easily through the die holes during the pelleting process in the pelletizer machine. High moisture content in the product can cause deformation and insufficient durability of the pellets. However, in their current form, sugarcane bagasse and coconut dreg pellets can be used in large-scale industrial co-firing systems. But fortunately, sugarcane bagasse and coconut dregs pellets can be used in low-scale industries such as homemade food industries.

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ORCID iD: https://orcid.org/0000-0002-8973-0709

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References

[1] Abubakre, O. K., Garba, A. B., & Tukur, H. (2014). Design and fabrication of model feed pelletizer. *Applied Mechanics and Materials*, *533*, 64–67. https://doi.org/10.4028/www.scientific.net/AMM.533.64

[2] Acda, M. N. (2015). Fuel pellets from downed coconut (Cocos nucifera) in super typhoon Haiyan. *Biomass and Bioenergy*, *83*, 539–542. https://doi.org/10.1016/j.biombioe.2015.11.005

[3] Agbetoye, L., shankar Tumuluru, J., O, O. A., A S, A. L., & O, O. F. (2010). *Ojomo Agbetoye Ologunagba Related papers Performance Evaluation of a Fish Feed Pellet sizing Machine Leo Agbet oye A Review on Biomass Densificat ion for Energy Applications Jaya Shankar Tumuluru A Technical Review on Biomass Processing: Densificat ion, Preprocessing, Modeling, and Optimization Performance Evaluation of A Fish Feed Pelletizing Machine* (Vol. 5, Issue 9). www.arpnjournals.com

[4] Albashabsheh, N. T., & Heier Stamm, J. L. (2019). Optimization of lignocellulosic biomass-to-biofuel supply chains with mobile pelleting. *Transportation Research Part E: Logistics and Transportation Review*, *122*, 545–562. https://doi.org/10.1016/j.tre.2018.12.015

[5] Bartocci, P., Barbanera, M., Skreiberg, O., Wang, L., Bidini, G., & Fantozzi, F. (2018). Biocarbon pellet production: Optimization of pelletizing process. *Chemical Engineering Transactions*, *65*, 355–360. https://doi.org/10.3303/CET1865060

[6] Bazargan, A., Bazargan, M., & McKay, G. (2015). Optimization of rice husk pretreatment for energy production. *Renewable Energy*, *77*, 512–520. https://doi.org/10.1016/j.renene.2014.11.072

[7] Bow, Y., Hasan, A., Rusdianasari, R., Zakaria, Z., Irawan, B., & Sandika, N. (2022). Biodiesel from Pyrolysis Fatty Acid Methyl Ester (FAME) using Fly Ash as a Catalyst. Proceedings of the 5th FIRST T1 T2 2021 International Conference (FIRST-T1-T2 2021), 9, 175–181. https://doi.org/10.2991/ahe.k.220205.030

[8] Budiastuti, H., Hanifah, N. A., Mardiani, D. U., Haryadi, H., Rusdianasari, R., & Fudholi, A. (2022). Biodiesel Production from Rubber Seed Oil as An Alternative Energy Source – A Review. Current Journal: *International Journal Applied Technology Research, 3(*2), 120–134. https://doi.org/10.35313/ijatr.v3i2.92

[9] Cardozo, E., & Malmquist, A. (2019). Performance comparison between the use of wood and sugarcane bagasse pellets in a Stirling engine micro-CHP system. *Applied Thermal Engineering*, *159*. https://doi.org/10.1016/j.applthermaleng.2019.113945

[10] Carneiro, M. L. N. M., & Gomes, M. S. P. (2019). Energy, exergy, environmental and economic analysis of hybrid waste-to-energy plants. *Energy Conversion and Management*, *179*, 397–417. https://doi.org/10.1016/j.enconman.2018.10.007

[11] Ciolkosz, D., Hilton, R., Swackhamer, C., Yi, H., Puri, V. M., Swomley, D., & Roth, G. (2015). Farm-Scale biomass pelletizer performance for switchgrass pellet production. *Applied Engineering in Agriculture*, *31*(4), 559–567. https://doi.org/10.13031/aea.31.10803

[12] Colley, Z., Fasina, O. O., Bransby, D., & Lee, Y. Y. (n.d.). Moisture Effect on the Physical Characteristics of Switchgrass Pellets. *Transactions of the ASABE*, *49*(6), 1845–1851.

[13] Damayanti, A., Musfiroh, R., & Andayani, N. (2021). The Effect of Tapioca Flour Adhesives on the Biopellet Characteristics of Rice Husk Waste as Renewable Energy. *IOP Conference Series: Earth and Environmental Science*, *700*(1). https://doi.org/10.1088/1755-1315/700/1/012028

[14] Demirbas, A., & Tel, *. (2003). Relationships between lignin contents and fixed carbon contents of biomass samples. In *Energy Conversion and Management* (Vol. 44). www.elsevier.com/locate/enconman

[15] Frodeson, S., Henriksson, G., & Berghel, J. (2019). Effects of moisture content during densification of biomass pellets, focusing on polysaccharide substances. *Biomass and Bioenergy*, *122*, 322–330. https://doi.org/10.1016/j.biombioe.2019.01.048

[16] Gao, W., Tabil, L. G., Zhao, R. F., & Liu, D. J. (2016). Optimized design and experiment on ring mold pelletizer for producing biomass fuel pellets. *International Journal of Agricultural and Biological Engineering*, *9*(3), 57–66. https://doi.org/10.3965/j.ijabe.20160903.2074

[17] García, R., González-Vázquez, M. P., Pevida, C., & Rubiera, F. (2018). Pelletization properties of raw and torrefied pine sawdust: Effect of co-pelletization, temperature, moisture content and glycerol addition. *Fuel*, *215*, 290–297. https://doi.org/10.1016/j.fuel.2017.11.027

[18] Huang, Y., Finell, M., Larsson, S., Wang, X., Zhang, J., Wei, R., & Liu, L. (2017). Biofuel pellets made at low moisture content – Influence of water in the binding mechanism of densified biomass. *Biomass and Bioenergy*, *98*, 8–14. https://doi.org/10.1016/j.biombioe.2017.01.002

[19] Kaliyan, N., Morey, R. v, & Morey, R. V. (2009). Densification Characteristics of Corn Stover and Switchgrass. *Transactions of the ASABE*, *52*(3), 907–920.

[20] Lisowski, A., Dąbrowska-Salwin, M., Ostrowska-Ligęza, E., Nawrocka, A., Stasiak, M., Świętochowski, A., Klonowski, J., Sypuła, M., & Lisowska, B. (2017). Effects of the biomass moisture content and pelleting temperature on the pressure-induced agglomeration process. *Biomass and Bioenergy*, *107*, 376–383. https://doi.org/10.1016/j.biombioe.2017.10.029

[21] Mani, S., Tabil, L. G., & Sokhansanj, S. (2006). Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses. *Biomass and Bioenergy*, *30*(7), 648–654. https://doi.org/10.1016/j.biombioe.2005.01.004

[22] Moreira, B. R. de A., Cruz, V. H., Oliveira, M. L. C., & Viana, R. da S. (2021). Full-scale production of high-quality wood pellets assisted by multivariate statistical process control. *Biomass and Bioenergy*, *151*. https://doi.org/10.1016/j.biombioe.2021.106159

[23] Nemchinova, N. v., Leonova, M. S., Tyutrin, A. A., & Bel'skii, S. S. (2019). Optimizing the Charge Pelletizing Parameters for Silicon Smelting Based on Technogenic Materials. *Metallurgist*, *63*(1–2), 115–122. https://doi.org/10.1007/s11015-019-00800-3

[24] Nielsen, S. K., Mandø, M., & Rosenørn, A. B. (2020). Review of die design and process parameters in the biomass pelleting process. In *Powder Technology* (971–985). Elsevier B.V. https://doi.org/10.1016/j.powtec.2019.10.051

[25] Oduntan, O. B., & Koya, O. A. (2015). Effect of speed, die sizes and moisture contents on the durability of cassava pellet in a pelletizer. *Research in Agricultural Engineering*, *61*(1), 35–39. https://doi.org/10.17221/9/2013-RAE

[26] Oguntunde, P. E., Adejumo, O. A., Odetunmibi, O. A., Okagbue, H. I., & Adejumo, A. O. (2018). Data analysis on physical and mechanical properties of cassava pellets. *Data in Brief*, *16*, 286–302. https://doi.org/10.1016/j.dib.2017.11.044

[27] Okolie, P. C., Chukwujike, I. C., Chukwuneke, J. L., & Dara, J. E. (2019). Design and production of a fish feed pelletizing machine. *Heliyon*, *5*(6). https://doi.org/10.1016/j.heliyon.2019.e02001

[28] Pava, D. S. (2023). *Land Use and Environmental Planning: History & Context*. 1–10. https://doi.org/10.32996/jmcie

[29] Putri, M., Kalsum, L., & Syarif, A. (2020). Waste-Cooking-Oil-Free Fatty Acid Reduction Using Deep Eutectic Solvent as Raw Material of Biodiesel. *Indonesian Journal of Fundamental and Applied Chemistry*, *6*(2), 40–45. https://doi.org/10.24845/ijfac.v6.i2.40

[30] Rezaei, H., Yazdanpanah, F., Lim, C. J., & Sokhansanj, S. (2020). Pelletization properties of refuse-derived fuel - Effects of particle size and moisture content. *Fuel Processing Technology*, *205*. https://doi.org/10.1016/j.fuproc.2020.106437

[31] Rivai Suhendra F, & Iskandar, I. (2021). Analysis of Retention Time and Steam Pressure Variations in the Conditioning Process on the Moisture Content of Feed in the Packaging Process. *Journal of Mechanical, Civil and Industrial Engineering*, *2*(2), 01–16. https://doi.org/10.32996/jmcie.2021.2.2.1

[32] Rusdianasari, R., Arissetyadhi, I., Kalsum, L., Bow, Y., Syarif, A., & Arifin, F. (2023). Characterization of Empty Fruit Bunch of Palm Oil as Co-firing Biomass Feedstock. *AJARCDE (Asian Journal of Applied Research for Community Development and Empowerment)*, *7*(1), 74-78. https://doi.org/10.29165/ajarcde.v7i1.237

[33] Rusdianasari, R., Kalsum, L., Masnila, N., Utarina, L., & Wulandari, D. (2022). Characteristics of Palm Oil Solid Waste and Its Potency for Bio-Oil Raw Material. Proceedings of the 5th FIRST T1 T2 2021 International Conference (FIRST-T1-T2 2021), 9, 415–420. https://doi.org/10.2991/ahe.k.220205.073

[34] Rusdianasari, R., Taufik, M., Bow, Y., & Fitri, M. S. (2020). Application of Nanosilica from Rice Husk Ash as Iron Metal (Fe) Adsorbent in Textile Wastewater. *Indonesian Journal of Fundamental and Applied Chemistry, 5*(1), 7–12. https://doi.org/10.24845/ijfac.v5.i1.7

[35] Serrano, C., Monedero, E., Lapuerta, M., & Portero, H. (2011). Effect of moisture content, particle size and pine addition on quality parameters of barley straw pellets. *Fuel Processing Technology*, *92*(3), 699–706. https://doi.org/10.1016/j.fuproc.2010.11.031

[36] Wahyono, Y., Hadiyanto, H., Zuli Pratiwi, W., & Dianratri, I. (2021). "Biopellet" as One of Future Promising Biomassbased Renewable Energy: a Review. *E3S Web of Conferences*, *317*, 04029. https://doi.org/10.1051/e3sconf/202131704029

[37] Woern, A. L., & Pearce, J. M. (2018). 3-D printable polymer pelletizer chopper for fused granular fabrication-based additive manufacturing. *Inventions*, *3*(4). https://doi.org/10.3390/inventions3040078

[38] Yilmaz, H., Topakci, M., Karayel, D., & Çanakci, M. (2020). Comparison of the physical properties of cotton and sesame stalk pellets produced at different moisture contents and combustion of the finest pellets. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*. https://doi.org/10.1080/15567036.2020.1850931