Homepage Journal http://jurnal.polsri.ac.id/index.php/austenit

AUSTENIT VOL. 15 NO.2, OKTOBER 2023 ISSN : 2085-1286 E-ISSN : 2622-7649

PERFORMANCE ANALYSIS OF BIO-BRIQUETTING MACHINE WITH SCREW EXTRUDER TYPE BASED ON QUALITY OF BIO-BRIQUETTES

Dilia Puspa[1)*], Muhammad Yerizam[2)], Ahmad Zamheri[3)], Agum Try Wardhana[4)]

[1)] Department of Chemical Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara, Bukit Besar, Palembang - Indonesia

[2)] Department of Chemical Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara, Bukit Besar, Palembang - Indonesia

[3)]Department of Mechanical Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara, Bukit Besar, Palembang - Indonesia

[3)]Department of Electrical Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara, Bukit Besar, Palembang - Indonesia

*Corresponding email: dilia.puspa@polsri.ac.id

ARTICLE INFORMATION

Revised
03/08/2023

Accepted
21/09/2023

Online Publication
31/10/2023

doi:

doi.org/10.5281/zenodo.10060547

ABSTRACT

The purpose of this study is to design a bio-briquetting machine with screw extruder type to convert biomass into higher density based on quality standard of charcoal briquette SNI 01-6235-2000 and SNI 19-4791-1998. The machine had production capacity of 30 kg/hour, equipped with the motor of 1 HP which transmitted to the machine through pulley and belt, and also has cutter which rotates continuously. The raw materials of the bio-briquette were using bagasse and coconut shells. There are 6 parameters that are used to test the quality of bio-briquette such as calorific value, inherent moisture, ash content, dependability pressure, volatile matter content, and fixed carbon content. The bio-briquette was made from the raw materials using amylum adhesives with ratio 30:70:30. With feed as 5 kg, the machine produced 50 pieces of bio-briquette. The machine could produce good bio-briquettes such as calorific value of 6,511.3 cal/g, inherent moisture of 1.97%, ash content of 5.88%, volatile matter of 27.71%, fixed carbon content of 64.99% and compressive strength was 16.98 kg/cm^2.

***Keywords**: briquetting machine, screw extruder, bio-briquette.*

1 INTRODUCTION

The consumption of fossil fuel was increasing in the last decade while the supply of fossil fuel such as oil or natural gas is limited. Due to its limitation, the alternative energy source is required to overcome this problem. (Saputro, 2020) (Papuangan et al., 2019) Biomass is one of the renewable energy sources with a potential to contribute to the energy needs, low-cost production, high calorific value compared to other solid fuel sources, higher boiling efficiency, and less harm to the environment. (Tursi, 2019) (Tan et al., 2017) The biomass can be produced by using the agricultural waste or from the processing of agricultural products such as bagasse and coconut shell. Bagasse is the residue after crushing and extracting the sugarcane. (Veranika, 2022) The technology used for the utilization of the agricultural wastes is biomass briquetting. (Brunerova, 2018)

Production of bio-briquette is divided into several process, starting from the preparation of raw materials, production of carbon, size reduction, mixing of materials, densification, and drying. (Yuliah et al., 2017) (La Ifa, 2020) From the process mentioned before, densification or bio-briquetting is one of the key factors to achieve higher energy per volume of the material. (Tenu, 2021)

During the densification process, the parameters that need to take attention is the compaction pressure of the bio-briquetting machine, the capacity of the machine, and type of presses used. (Kpalo et al., 2020) The bio-briquetting machines that have been developed and commonly have many types of presses such as piston, screw, roller, pelletizing, manual, and low-pressure briquetting. The use of bio-briquetting machine with different types of presses during the densification process produces the bio-briquette with various shape and quality. (Tumuluru, 2011) (Sanchez et al., 2022)

The parameters used to measure the quality of the bio-briquette based on SNI 01-6235-2000 and SNI 19-4791-1998 were inherent moisture, ash content, volatile matter, calorific value, and compressive strength. (Badan Standar Nasional, 2000) (Badan Standar Nasional, 1998) The bio-briquetting machine comprises five primary parts such as a screw extruder responsible for pressing the mixed bio-briquette materials into the desired shape, a motor to drive and rotate the screw, a pulley and belt to transmit power from the motor to the screw extruder, a cutter for cutting the bio-briquettes as they emerge from the output, and finally, a controller to manage the system's on/off functions and to control the rotation of the cutter. (Krisna, 2020) (Wardhana, 2023)

2. MATERIALS AND METHODS

This project consists of five phases. The first phase was the carbonization process for the raw materials used (coconut shell and bagasse). After that, the carbon produced was ground and sieved. Then, mixed it with the amylum adhesive. The mixed materials were molded by screw extruder. Lastly, analyzed the quality of the bio-briquette produced.

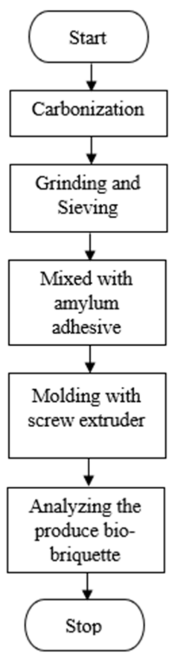

Figure 1 . Flowchart

2.1 Materials

The raw materials used were bagasse and coconut shell which obtained from the waste of agricultural production. The composition of the raw materials was 30:70 which 30% for bagasse and 70% for coconut shell. The raw materials were mixed with amylum as an adhesive.

2.2 System Design

The designed system was a screw extruder type of bio-briquetting machine with a production capacity of 30 kg/hour with pulley and belt as its transmission, and a motor with a power capacity of 1 hp. The raw materials were pushed through the hopper which located on the top of the machine. The materials were processed in the barrel which located on the bottom of the machine. The barrel consists of screw extruder that rotated simultaneously and push the materials to grinding plate. The produced bio-briquette was coming out from the holes of the grinding plate with a diameter of 1 inch or 26 mm which located in front of the machine. The shape of the bio-briquette produced was cylindrical.

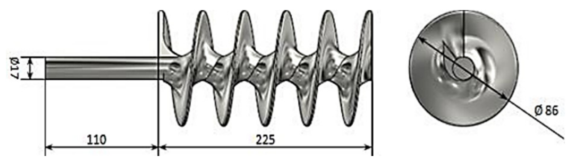

Figure 2 . The Dimension of the Screw

In order to optimize the efficiency of the designed bio-briquetting machine, it was equipped with a cutter, with a length of 25 cm. It moved continuously at a certain speed adjusted to the linear speed of the bio-briquette produced from the output or the die.

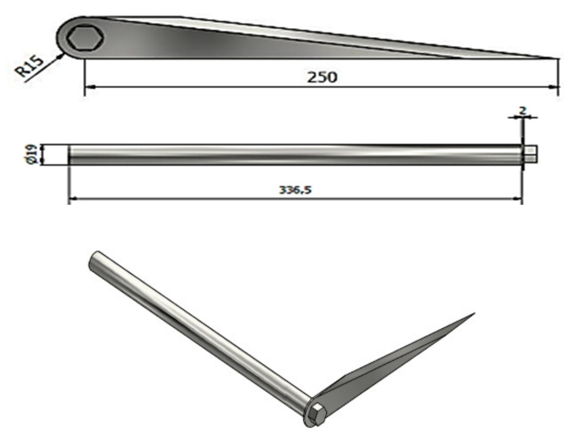

Figure 3 . The Dimension of the Cutter

The support frame for placing the main parts was constructed using square-shaped iron bars and L-shaped iron bars. These bars had dimensions of 35 mm in length, 35 mm in width, and 5 mm in thickness. The height for the support frame leg was 130 mm. The total dimension size for the support frame was 69 cm x 30 cm x 40 cm as shown in Figure 3 below.

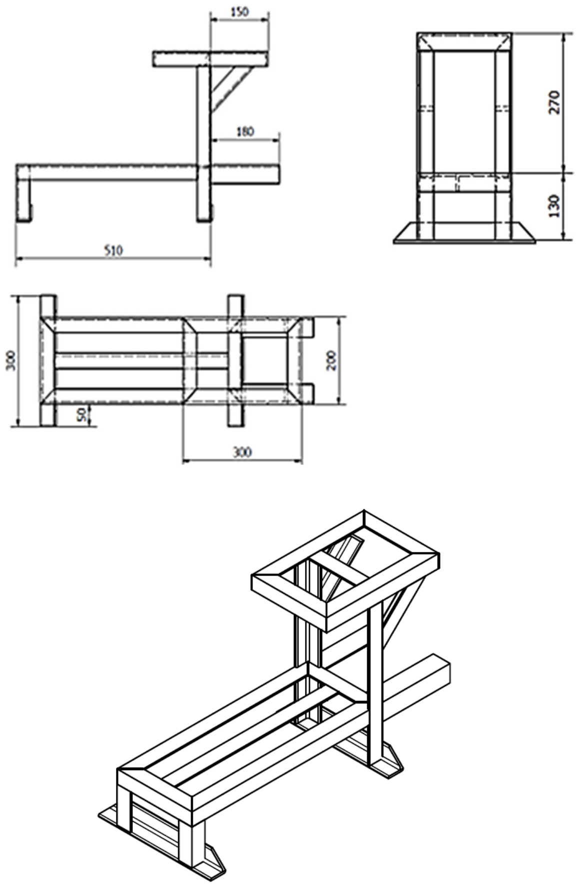

Figure 4 . The Dimension of the Support Frame

The controller for the bio-briquetting machine consists of three component such as two push buttons to run and stop the driving motor, a potentiometer to control the rotation of the cutter, and a switch to start and stop the cutter.

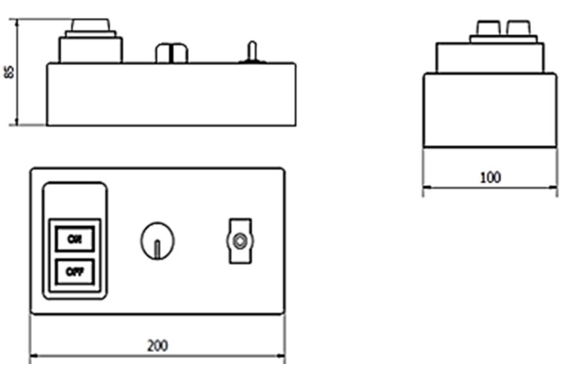

Figure 5 . The Dimension of The Controller Box

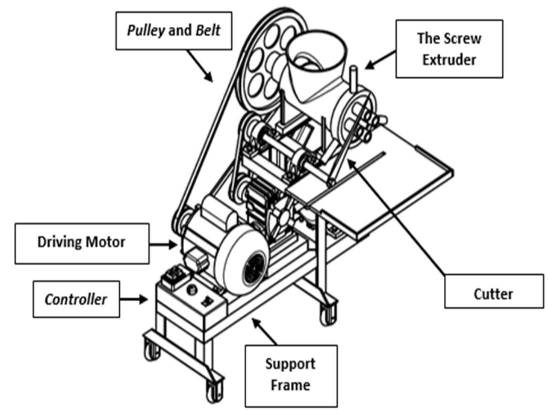

Figure 6 . The Bio-briquetting Machine

2.3 The Calculation of The Designed System

2.3.1 The Rotation of The Screw Extruder

Before calculating the rotational speed of the screw extruder, first the mass density (ρ), debit (Q), and velocity (v). The value of the mass density used was from the mass density of the mixed materials used. The mass density of the mixed materials used was 0.765 g/cm^3 or 7.65 x 10^{-7} kg/mm^3. The production capacity was 30 kg/hour. The debit value (Q) was computed using the following equation.

$$Q = \frac{q}{\rho} \qquad (1)$$

$$Q = \frac{30\ kg/hour}{7.65 \text{ x } 10^{-7} \text{ kg}/mm^3}$$

$$Q = 3.922 \text{ x } 10^7 mm^3/hour$$

The holes of the grinding plate in the screw extruder have a circular cross-sectional area with a diameter of 1 inch or 26 mm (d) and a depth (h) of 14,9 mm. The diameter and the depth were used to calculate the cross-sectional area of the hole in the shape of cylinder as show in equation below.

$$A = 2\pi r\ (r + h) \qquad (2)$$

After obtaining the cross-sectional area (A) of the hole, which was measured to be 2,277.76 mm², and the debit value (Q), the linear velocity could be calculated using the following equation.

$$Q = v \ x \ A \qquad (3)$$

The linear velocity based on the formula above was 285.785 mm/minute. The inclination angle of the screw with respect to the vertical axis was 16.7°. The value of the radial velocity (v_{radial}) and the rotational speed of the screw (n) was calculated based on the equation below.

$$\tan \alpha = \frac{v_{linier}}{v_{radial}} \qquad (4)$$

$$v_{radial} = 2\pi \times r_{ulir} \times n \qquad (5)$$

Based on the equation above, the rotational speed of the screw was 3.524 rpm.

2.3.2 The Power of The Screw Extruder (P_{screw})

To calculate the power required to rotate the screw, the tangential force, normal force and torque were calculated. The normal force was calculate using the equation below.

$$F_n = A_{total} \text{ x kt x g} \quad (6)$$

$$A_{total} = 6\left(\frac{1}{4}\pi\ (D_r^2 - D_o^2)\right) \quad (7)$$

The diameter of the screw (D_r) was 86 mm and the diameter of the screw shaft (D_o) was 17 mm, then the length of the shaft was 300 mm. The surface area of the screw (A_{total}) was 33,473.97 mm^2 or 0.033 m^2. The bio-briquette compressive strength (kt) was 16.9 kg/cm^2 or 169,000 kg/m^2 and the acceleration of gravity (g) was 9.81 m/s^2. The normal force (F_n) was 54,710.37 kg m/s^2. The tangential force was calculate as shown in equation below.

$$F_t = F_n \cos\ (90°\text{-}\alpha) \quad (8)$$

The tangential force obtained by using the equation above was 15,721.6 N. The power required to rotate the screw was calculated using the equation below.

$$P = F_t \times r \times \frac{2\pi n}{60} \quad (9)$$

From the calculation, the power required to rotate the screw was 249.35 Watt.

2.3.3 The Power of The Cutter (P_{cutter})

The bio-briquette emerged from the holes or the output of the screw extruder and was subsequently cut by the cutter. The force required to cropped the mixed materials by the cutter was equal to the average value of the force required to press the mixed materials. An experiment was carried out to find the force required to press the mixed materials as shown in Table 2 below.

Table 2 . The Experiment to Calculate the Force

Number of Experiment	Force (kgf)
1	4.3
2	4.2
3	4.1
4	4.5
5	3.9
6	4.3
7	4.4
8	4.0
9	4.3
10	4.0

From the experiments above, the average value of the force required to press the mixed materials was 4.2 kgf or 41.202 N and the length of the cutter was 250 mm or 0.25 m. The power required to rotate the cutter was calculated based on the equation below.

$$P = F \times L_p \times \frac{2\pi n}{60} \quad (10)$$

Based on the equation above, the power needed to rotate the cutter was determined to be 9.798 Watt.

2.3.4 The Power of Driving Motor

The power required to move the bio-briquetting machine was calculated from the sum of the power required to rotate the screw and the power required to rotate the cutter and then divided by 80%. The equation of the power required to move the bio-briquetting machine was shown in equation (11) below.

$$P_{total} = \frac{P_{screw} + P_{cutter}}{80\%} \quad (11)$$

The bio-briquetting machine necessitated a power of 323.94 Watts or approximately 0.434 horsepower to operate efficiently. To meet this power requirement, a 1 horsepower driving motor was deemed necessary to run the system properly.

2.3.4 The Power of Driving Motor

The distance (C) between the pulley attached on the motor and the pulley attached on the gearbox was 500 mm. The diameter of each pulley used was 304.8 mm and 182.88 mm. The bigger size of pulley was labeled as Dp and the smaller one was labeled as dp. The length of the belt used was shown in the equation below.

$$L = 2C + \frac{\pi}{2}\ (Dp + dp) + \frac{1}{4C}\ (Dp - dp)^2 \quad (12)$$

The length of the belt required to connect from one pulley to another pulley was 1,773.22 mm based on the equation above.

3. RESULTS AND DISCUSSION

Based on Table 3 below, the bio-briquette produced had 3 parameters that met the national quality standard of Indonesia, SNI 01-6235-2000 such as the inherent moisture, ash content, and calorific value. The compressive strength of the bio-briquette produce had met the national quality standard of Indonesia, SNI 19-4791-1998. These data were taken three times and were calculated to find the average value. The average values were shown on Table 3.

Table 3 . Analysis Result of the Bio-briquette Produced

No	Parameters	Unit	Quality Standard	Results
1	Inherent moisture	%	≤ 8	1.97
2	Ash content	%	≤ 8	5.88
3	Volatile matter	%	≤ 15	27.01
4	Fixed carbon content	%	≥ 79	64.94
5	Calorific value	cal/g	≥ 5,00	6,51
6	Compressive strength	kg/cm^2	≥ 3	16.98

Inherent moisture of the bio-briquette produced was 2.04%. The inherent moisture greatly affects the quality of the bio-briquette. The lower the value of inherent moisture, the higher the calorific value and burning rate of the bio-briquette. If the inherent moisture is high, it will make it hard to ignite, and produce smoke. The inherent moisture in the bio-briquette can be affected by the hygroscopic nature of the raw materials. The greater the ability of a material to absorb water, the greater the inherent moisture value of the bio-briquette produced. Bio-briquettes that contain high inherent moisture value also tend to affect the compressive strength because they will be more easily crushed.

Ash content obtained from the bio-briquette was 6.03% and met the quality standard. The ash content of the bio-briquettes is usually influenced by the level of adhesive used. The higher the level of adhesive used, The higher the value of ash content. It is due to the addition of ash from adhesive used and also the content of inorganic substances such as silica in the adhesive as well as several minerals such as phosphorus and calcium which can turn into ashes when burned. Even though the adhesive has the effect of increasing the ash content, the adhesive must still be added so that the bio-briquettes are not easily crushed. The ash content also affects the calorific value of the bio-briquettes. Higher the value of the ash content will reduce the calorific value of the bio-briquettes and reduce the burning rate of the bio-briquettes.

Volatile matter in bio-briquettes comprises combustible gases like methane, light hydrocarbons, hydrogen, carbon monoxide, and water vapor. When bio-briquettes have a high volatile matter content, the combustion process speeds up the burning of solid carbon. The obtained volatile matter value was 27.01% and did not meet Indonesia's national quality standard, SNI 01-6235-2000, which sets a maximum limit of 15% for volatile matter in bio-briquettes. The addition of adhesives with a high concentration can influence the level of volatile substances, as both the combustible and non-combustible gases in the adhesive and raw materials evaporate during combustion. The volatile matter content is also affected by the temperature and duration of the carbonization process of the raw materials. Higher temperatures and longer carbonization durations result in more volatile matter being wasted during the process. Consequently, a higher volatile matter value leads to increased smoke generation when igniting bio-briquettes.

The fixed carbon content plays a crucial role in determining the burning rate and calorific value of bio-briquettes. A higher fixed carbon content results in a longer burning rate and a higher calorific value. However, the obtained fixed carbon content was below the national quality standard of 64.99%. This lower value is influenced by the volatile matter content in the bio-briquette. When the volatile matter value is higher, it leads to a decrease in the fixed carbon content.

The obtained calorific value was 6,511.3 cal/g, and it complied with the national quality standard. The calorific value of bio-briquettes is influenced by the density of the raw materials. When the density value of the raw materials is higher, it results in a greater fixed carbon content, which leads to an increased calorific value.

The compressive strength of bio-briquettes is a physical parameter that influences their overall quality. To test the compressive strength, a hydraulic press with a maximum pressure of 100 kg/cm2 ± 20 kg/cm2 was used. The test revealed that the compressive strength of the bio-briquettes was 16.9 kg/cm2, met Indonesia's national standard, SNI 19-4791-1998. The compressive strength of a bio-briquette depends on the pressure applied during the bio-briquetting process. Higher pressure values result in a more solid bio-briquette. Additionally, the cellulose content in the raw materials also plays a role in determining the compressive strength. A higher cellulose content leads to increased compressive strength because cellulose possesses elastic properties.

4. CONCLUSION

A screw extruder type of bio-briquetting machine was designed and constructed with a capacity of 30 kg/hour. The machine's overall dimensions measured 77.5 x 61 x 74.9 cm, with a rotational speed of 3.524 rpm. The machine was equipped with a transmission system consisting of a pulley and belt, along with a cutter and a 1 Hp motor.

The bio-briquettes produced using this machine exhibited excellent quality and adhered to Indonesia's national quality standard, SNI 01-6235-

2000, meeting the specified parameters such as a calorific value of 6,511.3 cal/g, inherent moisture of 1.97%, and ash content of 5.3%. Moreover, the compressive strength of the bio-briquettes produced also met the national quality standard, SNI 19-4791-1998, which was 16.98 kg/cm^2.

However, there were two parameters that did not meet the Indonesian national quality standard, SNI 01-6235-2000, namely the fixed carbon content and the volatile matter. These parameters fell short of the specified standards.

REFERENCES

Brunerová, Anna, Roubík, Hynek, and Brožek, Milan. (2018). Bamboo fiber and sugarcane skin as a bio-briquette fuel. Energies, 11(9), 2186. https://doi.org/10.3390/en11092186

Ifa, L., Yani, S., Nurjannah, N., Darnengsih, D., Rusnaenah, A., Mel, M., ... & Kusuma, H. S. (2020). Techno-economic analysis of bio-briquette from cashew nut shell waste. Heliyon, 6(9). https://doi.org/10.1016/j.heliyon.2020.e05009

Ţenu, I., Roman, C., Senila, L., Roşca, R., Cârlescu, P., Băetu, M., ... & Corduneanu, O. R. (2021). Valorization of vine tendrils resulted from pruning as densified solid biomass fuel (Briquettes). *Processes*, *9*(8), 1409. https://doi.org/10.3390/pr9081409

Kpalo, Sunday Yusuf, Zainuddin, M. F., Manaf, Latifah Abd, and Roslan, A. M. (2020). A review of technical and economic aspects of biomass briquetting. Sustainability, 12(11), 4609. https://doi.org/10.3390/su12114609

Krisna, Pratama Pela, Taufikurahman and Sundari, Ella. (2020). STUDI EKSPERIMENTAL: ANALISA KEGAGALAN RODA GIGI PADA GEAR BOX MESIN SCREW PRESS KELAPA SAWIT. *AUSTENIT*, *12*(2), 54-58. https://doi.org/10.5281/zenodo.4547906

Nasional, Badan Standar (2000). Standar Nasional Indonesia Briket Arang Kayu (SNI 1-6235-2000).

Nasional, Badan Standar. (1998). Standar Nasional Indonesia Serbuk Sabut Kelapa (SNI 19-4791-1998).

Papuangan, N., & Jabid, A. W. (2019, May). Pre-design of bio-briquette production using kenari shell. In IOP Conference Series: Earth and Environmental Science (Vol. 276, No. 1, p. 012051). IOP Publishing. http://doi.org/10.1088/1755-1315/276/1/012051

Sanchez, Philip D. C., Aspe, Mia M. T., & Sindol, Kenneth N. (2022). An Overview on the Production of Bio-briquettes from Agricultural Wastes: Methods, Processes, and Quality. Journal of Agricultural and Food Engineering, 1, 2716-6236. http://doi.org/10.37865/jafe.2022.0036

Saputro, Erwan Adi, Laksminingsih, Arieanthi, Mardiansyah, Yuda Eka, Yogaswara, Rachmad, Ramadhan, and Erliyanti, Nove, K. (2020). Utilizing organic waste (sugarcane bagasse and sugarcane leaves) as bio briquettes through pyrolysis process. Nusantara Science and Technology Proceedings, 216-220. http://dx.doi.org/10.11594/nstp.2020.0534

Tan, X. F., Liu, S. B., Liu, Y. G., Gu, Y. L., Zeng, G. M., Hu, X. J., ... & Jiang, L. H. (2017). Biochar as potential sustainable precursors for activated carbon production: Multiple applications in environmental protection and energy storage. Bioresource technology, 227, 359-372. https://doi.org/10.1016/j.biortech.2016.12.083

Tumuluru, Jaya S., Wright, Christopher T., Hess, J. Richard, & Kenney, Kevin L. (2011). A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application. Biofuels, Bioproducts and Biorefining, 5(6), 683-707. https://doi.org/10.1002/bbb.324

Tursi, A. (2019). A review on biomass: importance, chemistry, classification, and conversion. Biofuel Research Journal, 6(2), 962-979. http://doi.org/10.18331/BRJ2019.6.2.3

Veranika, Rita M., Madagaskar, M., and Aprianti, Tine. (2022). THE MANUFACTURE OF SUGARCANE PEELER AND SQUEEZER: PEMBUATAN MESIN PENGUPAS DAN PEMERAS TEBU. *AUSTENIT*, *14*(1), 37-41. https://doi.org/10.5281/zenodo.6499818

Wardhana, A. T., Zamheri, Ahmad, and Puspa, Dilia. (2023). IMPLEMENTATION OF PLC BASED AUTOMATIC SORTING SYSTEM. *AUSTENIT*, *15*(1), 36-40. https://doi.org/10.5281/zenodo.7935360

Yuliah, Y., Kartawidjaja, M., Suryaningsih, S., & Ulfi, K. (2017, May). Fabrication and characterization of rice husk and coconut shell charcoal-based bio-briquettes as alternative energy source. In IOP Conference Series: Earth and Environmental Science (Vol. 65, No. 1, p. 012021). IOP Publishing. http://doi.org/10.1088/1755-1315/65/1/012021