Jurnal Agrotek UMMAT
p-ISSN 2356-2234 | e-ISSN 2614-6541 | SINTA accredited
Volume 13, issue 2, 2026

Design and performance analysis of a coconut coir briquette press machine using an electric motor-driven screw extruder system

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Received: 16th May, 2026 | accepted: 22nd June, 2026

ABSTRACT

Coconut coir waste biomass has strong potential as a renewable energy source through densification into charcoal briquettes. The novelty of this study lies in the development of a small-scale electric motor-driven screw extruder briquetting machine, combined with a comprehensive performance analysis including efficiency, torque, and transmission system, specifically for charcoal material with granular and low-cohesion characteristics. This study aims to design, fabricate, and evaluate the machine performance as well as the quality of the produced charcoal briquettes. An experimental method was employed, including design, manufacturing, assembly, and performance testing of the machine, along with briquette characterization based on SNI standards. The results show that the machine utilizes a 1.5 HP electric motor with a gearbox ratio of 1:35, producing a screw rotation of 40 rpm, a production capacity of 9 kg/h, and an efficiency of 85.24%. The torque at the gearbox output was 267.05 Nm and decreased to 227.6 Nm at the screw, indicating acceptable mechanical energy losses. The produced briquettes exhibited a moisture content of 7.5% and ash content of 7.6% (meeting SNI standards), a calorific value of 4780 cal/g (slightly below the standard), and a burning time of 64.1 minutes. Overall, the developed machine demonstrates effective performance in processing coconut coir charcoal into briquettes, with further improvement potential through optimization of material composition to enhance the calorific value.

Keywords: biomass, briquettes, briquette quality, renewable energy, screw extruder

INTRODUCTION

One of the renewable energy sources with significant potential is biomass derived from organic waste. Biomass is a renewable organic material with relatively high energy content that can be utilized as an alternative fuel (IEA, 2022). The use of biomass not only reduces dependence on fossil fuels but also contributes to more effective waste management and the reduction of greenhouse gas emissions (Osman et al., 2023)

Indonesia, as an agrarian country, has abundant biomass resources, one of which originates from agricultural waste such as coconut coir. Coconut coir is often underutilized and treated as waste, despite its potential to be converted through carbonization into charcoal with high fixed carbon content, making it more suitable as a raw material for briquettes (Kambey et al., 2023).

Charcoal briquettes are solid fuels produced through the densification of charcoal under pressure, resulting in higher density (Dewi et al., 2022a). This densification process aims to improve calorific value, combustion efficiency, and ease of storage and transportation (Bailo et al., 2025). In addition, charcoal briquettes offer advantages such as lower emissions and more stable combustion compared to raw biomass fuels (Waheed et al., 2023).

The quality of charcoal briquettes is strongly influenced by parameters such as moisture content, ash content, calorific value, and mechanical strength. These parameters are affected not only by the raw material and carbonization process but also by the briquetting process and the technology used during densification (Sunardi et al., 2019). In the production process, the briquetting machine plays a crucial role in determining the shape, density, and final quality of the product (Dahlan, 2024).

Briquetting machines operate based on the compaction of material using mechanical pressure generated by an electric motor-driven system. The selection of an electric motor as the primary driver is based on its high efficiency, ease of operation, and stability in controlling speed and torque (Ojo & Mohammed, 2015).

However, the novelty of this study lies in the integration of a direct rotational transmission system combined with a screw extruder mechanism. In this design, the electric motor is directly connected to the gearbox and subsequently to the briquetting shaft, which drives the screw extruder. This configuration differs from conventional systems that typically involve more complex transmission components and less efficient material compaction mechanisms (Orisaleye et al., 2020). The use of a screw extruder enables continuous densification and significantly affects briquette quality, as reported in previous experimental studies (Bello & Onilude, 2021). Therefore, the proposed design is expected to improve torque transmission efficiency, reduce mechanical losses, and produce briquettes with more uniform density and better structural integrity.

In mechanical engineering, performance analysis is a critical step in evaluating whether a machine operates according to its design specifications (Deshmukh et al., 2022). This analysis includes production capacity, operational efficiency, and energy consumption, which can be used to identify system weaknesses and improve design performance.

Several studies have shown that coconut coir-based charcoal has strong potential as a raw material for briquettes (Alfarizi et al., 2025). However, previous studies still exhibit several limitations: (1) the lack of quantitative data on machine efficiency in the briquetting process, (2) limited technical analysis of torque requirements and transmission system performance in screw extruder-type machines, and (3) the absence of studies on screw design—particularly taper screw configurations—tailored to the characteristics of coconut coir charcoal, which is granular and has low cohesion. These gaps indicate that the engineering aspects of briquetting machines have not been comprehensively investigated.

Based on this background, this study aims to design and develop a coconut coir charcoal briquetting machine driven by an electric motor and to perform a comprehensive performance analysis, including production capacity, efficiency, torque, and transmission system evaluation. In addition, a taper screw design is implemented to enhance the effectiveness of the compaction process. The results of this study are expected to contribute to the development of appropriate technology and support the utilization of biomass waste as an economically valuable and environmentally friendly alternative energy source.

METODOLOGI/METHODOLOGY

1. Time and location of the study

This research was conducted from January to June 2024. The experimental work took place at the Mechanical Workshop and Agricultural Machinery Design Laboratory, as well as the Chemistry Laboratory, Faculty of Agriculture, Universitas Muhammadiyah Mataram.

2. Materials and equipment

The, main material used in this study was coconut coir charcoal as the raw material for briquettes, while tapioca flour was used as the binder. The equipment used in this study included a screw extruder briquetting machine (electric motor power: 1,5 HP, rotation speed: 1400 rpm, gearbox ratio: 1:35), an analytical balance (accuracy: ±0.001 g), a digital scale (capacity: 5 kg, accuracy: ±1 g), an oven, a furnace (maximum temperature: 1000°C), a bomb calorimeter, a desiccator, porcelain crucibles, a mortar, a 40-mesh sieve (425 μm), a stove, a stopwatch, and other supporting tools.

3. Research method

This study employed an experimental method consisting of three main stages: design, fabrication, and testing, aimed at evaluating machine performance and the quality of the produced charcoal briquettes.

Design (Machine design)

The design stage included the conceptual design and technical drawing of a screw extruder-type briquette press machine. The main components were determined, including the frame, transmission system, shaft, gearbox, and mold. Technical parameters such as power requirement, torque, and screw rotational speed were also calculated. A tapered screw design was implemented to improve the compaction process of coconut coir charcoal material.

Fabrication (Manufacturing and assembly)

This stage involved the manufacturing and assembly of the machine based on the finalized design. The processes included frame construction, fabrication of main components, installation of the transmission system and electric motor, assembly of the screw extruder and mold, and initial testing (trial run) to ensure proper machine operation prior to the main testing phase.

Testing (Machine performance and briquette quality testing)

a. Material preparation

Coconut coir charcoal was ground and sieved using a 40-mesh sieve. The charcoal powder was then mixed with tapioca adhesive at 20% of the total mass until a homogeneous mixture was obtained. A 20% tapioca binder was selected to ensure adequate briquette cohesion and to prevent structural failure during the extrusion process, considering the low natural binding properties of coconut coir charcoal.

b. Briquetting process

The prepared mixture was fed into the machine and compressed into briquettes using the screw extruder system.

c. Variables and replications

Each experiment was conducted with three replications to ensure data reliability.

Controlled variables: (1) Material composition (charcoal : binder = constant); (2) Particle size (40 mesh); (3) Screw rotational speed (constant). Observed variables: (1) Production capacity; (2) Machine efficiency; (3) Power and torque; (4) Briquette quality

d. Briquette drying

The briquettes were dried under sunlight for approximately 4 days until reaching a dry condition.

e. Briquette quality testing

The quality of briquettes was evaluated according to SNI 01-6235-2000, including moisture content, ash content, calorific value, and burning duration

4. Data analysis

The experimental data were analyzed using a quantitative descriptive approach by comparing the results with SNI standards. In addition, an evaluation of machine performance and the quality of the produced briquettes was carried out.

5. Parameters and equations

Production capacity

Production capacity indicates the amount of briquettes produced by the machine per unit operating time (Heizer et al., 2024).

$k = \frac{m}{t}$................................... *(1)*

Where:

K = production capacity (kg/h)
m = mass of briquettes produced (kg)
t = operating time (hour)

Machine working efficiency (%)

Efficiency is defined as the ratio of useful output power to input power, expressed as a percentage (Vegeesh et al., 2020).

$\eta = \frac{P_{out}}{P_{in}} \times 100\%$ ....(2)

Where:
η = machine working efficiency (%)
P_{out} = output power (Watt)
P_{in} = input power (Watt)

Power and torque

Power is the energy used to perform work, while torque is the rotational force acting on a shaft (Vegeesh et al., 2020).

$P = T.\omega$..(3)

Angular velocity is formulated as:

$\omega = \frac{\pi.n}{60}$ ....(4)

Thus, the relationship between power, torque, and rotational speed is expressed as:

$T = \frac{P \times 60}{2\pi.n}$..(5)

Where:

P = power generated or required by the machine (Watt)
T = torque (Nm)
ω = angular velocity (rad/s)
n = rotational speed (rpm)

Moisture content analysis

According to Putra & Hidayat, (2022), the moisture content of briquettes can be determined using the following equation:

Moisture Content = $\frac{a-b}{a}$x100% .....(6)

Where:
a = mass of sample before drying (g)
b = mass of sample after drying (g)

Ash content analysis

According Dewi et al., (2022), *the ash content of briquettes can be determined using the following equation:*

Ash Content = $\frac{wo}{wd}$x100% ....(7)

Where:
wo = mass of sample after ashing (g)
wd = mass of sample before ashing (g)

RESULTS AND DISCUSSION

1. Design of briquette printing machine

The briquette printing machine designed in this study uses an electric motor as the main power source **(Figure 1).** The machine was designed to produce a briquette printing device capable of operating effectively and efficiently in the biomass compaction process. The machine design consists of several main components, namely the frame, electric motor, gearbox, screw extruder shaft, hopper, and molding system. The design serves as a reference for the fabrication and assembly process so that each component can be installed according to its function and operational requirements.

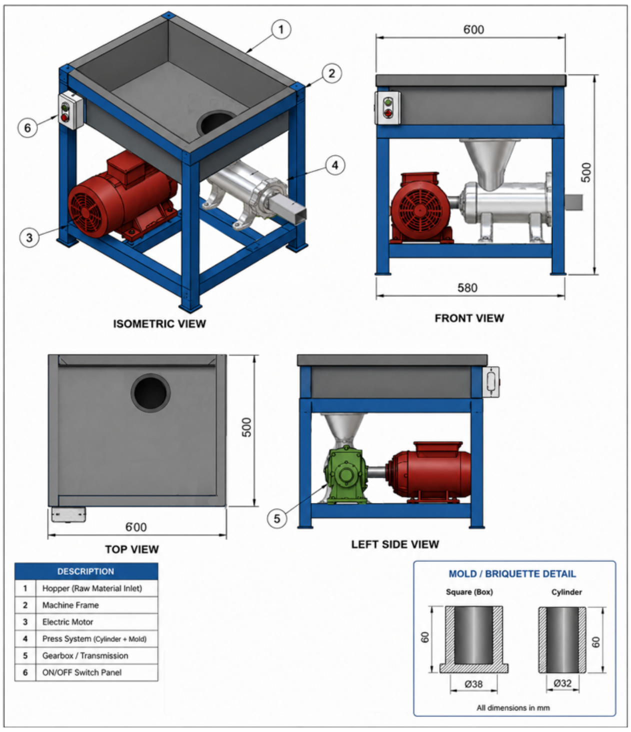


Figure 1. Design of charcoal briquette printing machine

Motor power planning

The electric motor was selected based on the power requirement needed to rotate the screw extruder during the briquette printing process.

Given:

Motor power = 1.5 HP

Motor speed = 1400 rpm

Motor power conversion:

$$1HP = 746Watt$$
$$P = 1{,}5 \times 746$$
$$P = 1119Watt \ = 1{,}12kW$$

Thus, the electric motor used has a power rating of 1.12 kW.

Motor torque calculation

Motor torque was calculated to determine the torsional capability produced by the electric motor (Vegeesh et al., 2020).

$$T = \frac{P \times 60}{2\pi.n}$$

Where:

T = motor torque (Nm)

P = motor power (Watt)

n = motor rotational speed (rpm)

$$T = \frac{P \times 60}{2\pi.n} = \frac{1119 \times 60}{2\pi.(1400)} = 7{,}63\ Nm$$

Based on the calculation, the motor torque obtained was 7.63 Nm.

Gearbox planning

The gearbox was used to reduce the motor rotational speed and increase the torque on the screw shaft.

Given:

Motor speed (n1) = 1400 rpm

Screw speed (n2) = 40 rpm

Gearbox ratio equation (Khurmi & Gupta, 2005):

$$i = \frac{n_1}{n_2} = \frac{1400}{40} = 35$$

Therefore, a gearbox with a reduction ratio of 1:35 was selected.

Gearbox output torque calculation

The gearbox output torque was calculated to determine the torsional force transmitted to the screw shaft (Budynas & Nisbett, 2020).

given:

Motor torque = 7.63 Nm

Gearbox ratio = 35

$$T_2 = T_1 \times i = 7{,}63 \times 35 = 267{,}05\ Nm$$

The torque of 267.05 Nm was used to rotate the screw extruder during the biomass compaction process.

Screw extruder planning

The screw extruder functions to convey and compact the biomass mixture toward the mold. In this study, a taper screw type was used, in which the screw diameter gradually decreases toward the end to increase the compaction pressure.

Screw parameters:

- Screw type: taper screw extruder
- Screw length: 200 mm
- Outer screw diameter: 60 mm
- Core shaft diameter: 32 mm
- Screw rotational speed: 40 rpm
- Number of screw flights: 5 flights
- Average pitch: 35 mm

The taper screw design was intended to increase biomass compaction pressure before the material exits through the mold, resulting in denser and more uniform briquettes.

Screw flight calculation

The number of screw flights was calculated using the following equation (Oberg et al., 2020):

$$N = \frac{L}{p}$$

Where:

N = number of screw flights

L = screw length (mm)

p = screw pitch (mm)

$$N = \frac{200}{35} = 5{,}71$$

Thus, the screw was designed with approximately 5–6 flights. The screw pitch was made tighter toward the end section to increase material compaction pressure before exiting the mold.

Screw linear velocity calculation

The screw linear velocity was calculated to determine the ability of the screw to convey biomass material. Linear velocity of the screw is derived from rotational motion principles, where the peripheral velocity equals the circumference multiplied by rotational speed (Oberg et al., 2020).

$$V = \pi . D . n$$

Where:
V = screw linear velocity (m/s)
D = screw diameter (m) = 0,06 m
n = screw rotational speed (rps)= (40/60=0,667 rps)

$$V = \pi . (0{,}06) . (0{,}667) = 0{,}1257\ m/s$$

Therefore, the screw linear velocity was 0.126 m/s. This velocity was considered sufficient to maintain stable biomass material flow during the briquette molding process.

Safe diameter calculation of screw shaft

The screw shaft diameter was calculated based on the torque received during machine operation.

Given:

Gearbox output torque = 267.05 Nm

Allowable shear stress of ST37 material = 40 MPa

Torque conversion:

$$T = 267{,}05\ Nm = 267050\ Nmm$$

Shaft diameter equation:

$$d = \sqrt[3]{\frac{16T}{\pi . \tau}}$$

Where:
d = shaft diameter (mm)
T = torque (Nmm)
τ = allowable shear stress (MPa)
(Budynas & Nisbett, 2020)

$$d = \sqrt[3]{\frac{16 \times (267050)}{\pi . (40)}} = 32{,}4\ mm$$

Based on the calculation results, a standard shaft diameter of 35 mm was selected to increase the safety factor.

Input electrical power calculation

The input electrical power was calculated based on a motor efficiency of 85%. The required input power was determined using the following equation:

$$P_{in} = \frac{P_{out}}{\eta}$$

Given:
$P_{out} = 1119\ Watt$
$\eta = 0{,}85$

$$P_{in} = \frac{1119}{0{,}85} = 1316{,}47\ Watt$$

Therefore, the required input electrical power was $P_{in} \approx 1{,}32\ kW$

2. Machine Manufacturing and Assembly

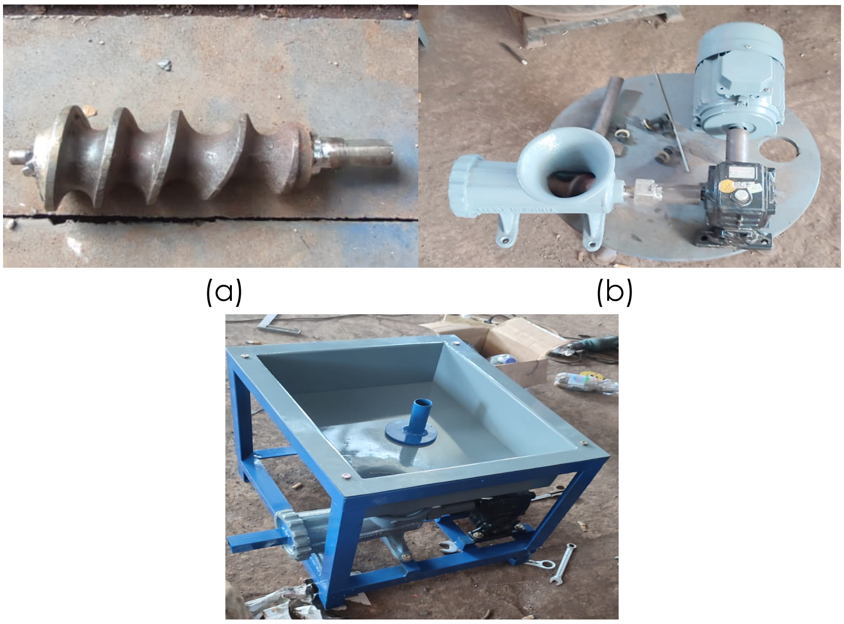
The manufacturing or fabrication process was carried out based on the design and calculation results that had been previously prepared. The fabrication stages included frame material cutting, welding, screw shaft machining, gearbox installation, electric motor installation, and assembly of all machine components.

The machine frame was constructed using angle steel arranged and welded to form a rigid structure with overall dimensions of 600 mm × 580 mm × 500 mm (length × width × height), as shown in **Figure 2.** The briquetting system utilizes a screw extruder mechanism driven by an electric motor connected directly to a gearbox and subsequently to the extrusion shaft.

The screw extruder was designed to accommodate biomass material flow and compaction, while the mold produces briquettes in two shapes, namely square and cylindrical forms with diameters of 38 mm and 32 mm, respectively. The dimensional design of the mold directly influences the compaction pressure and final briquette density.

The rotational motion from the electric motor is transmitted through the gearbox to reduce speed and increase torque, ensuring sufficient compressive force for low-cohesion charcoal material. This dimensional configuration supports stable machine operation and effective material densification during the briquetting process.

Furthermore, all components were assembled and adjusted to ensure that the transmission system and screw mechanism operated properly. The manufacturing and assembly process of the briquette molding machine can be seen in Figure 2. The fabrication results showed that the machine operated stably and all components functioned according to the planned design.



(a) (b)

(c)

Figure 2. Manufacturing and assembly process of the briquette molding machine: (a) Screw shaft; (b) Machine component assembly; (c) Completed and assembled machine.

3. Machine Testing

Briquette Raw Material Preparation

Before the molding process, coconut coir was first carbonized into charcoal. The charcoal was then ground and sieved using a 40-mesh sieve to obtain more uniform particle sizes. Uniform particle size improves the compaction process and produces a better briquette structure (Onukak et al., 2017). Tapioca flour adhesive at a concentration of 20% was mixed homogeneously with coconut coir charcoal powder. The adhesive was first dissolved in hot water to form a uniform starch gel capable of improving the bonding strength between biomass particles (Olugbade et al., 2019). The biomass mixture was then fed into the hopper of the briquette molding machine.

During machine operation, a 1.5 HP electric motor was activated, and power was transmitted directly to the gearbox reducer through a direct coupling system. The gearbox functioned to reduce motor speed and increase torque on the screw extruder shaft. The screw extruder then pushed and compacted the biomass mixture toward the mold until cylindrical briquettes were formed. The compaction process using a screw extruder is considered capable of producing briquettes with better density compared to manual molding methods (Bello et al., 2024).

The briquettes exiting the mold were cut accordisg to the desired size and then dried under sunlight for approximately ±4 days **(Figure 3).** The drying process aimed to reduce moisture content so that the combustion process became more stable and the calorific value increased (Lubwama et al., 2022).

Figure 3. Briquette drying process

Machine Performance Testing

Machine performance testing was conducted to determine the capability of the briquette molding machine during operation. The analyzed parameters included motor power, operating speed, gearbox output torque, production capacity, and machine working efficiency. The tests were performed during the briquette molding process using coconut coir charcoal with 20% tapioca adhesive.

a. Production Capacity Calculation

Given:

Briquette mass (m) = 3 kg

Time (t) = 20 minutes = 0.33 hours

$$K = \frac{m}{t} = \frac{3}{0{,}33} = 9 \text{ kg/h}$$

The result indicates that the machine is capable of producing briquettes at a capacity of 9 kg/hour, which falls into the small-to-medium production category. This capacity is influenced by several factors, such as screw rotational speed, raw material characteristics, and continuity of the feeding process.

Although the gearbox output speed was relatively low at 40 rpm, the production capacity remained stable. This indicates that the screw system was still capable of continuously conveying material without significant obstruction, allowing the production process to run effectively.

b. Machine Working Efficiency

Machine efficiency represents the comparison between output power and input power. Based on the test results, the motor power used was 1.5 HP or equivalent to 1119 Watts. Considering the transmission efficiency consisting of direct coupling (0.98) and gearbox reducer (0.87), the total transmission efficiency was:

$$\eta_{transmision} = \eta_{coupling} = \eta_{gearbox}$$

$$\eta_{transmision} = 0{,}98 = 0{,}87 = 0{,}8526$$

The output power was calculated as follows:

$$P_{out} = \eta \times P_{in} = 0{,}8526 \times 1119$$
$$= 953{,}064\, Watt$$

The machine working efficiency was then obtained from:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$
$$= \frac{953{,}064}{1119} \times 100\% = 85{,}24\%$$

An efficiency value of 85.24% indicates that the transmission system worked effectively in transmitting power from the motor to the screw. The energy losses occurring in the system were relatively small and still within the acceptable range for a mechanical system using a gearbox.

c. Screw Torque

Torque is an important parameter in the briquetting process because it is directly related to the machine's ability to compact the material. Based on the test results, the measured gearbox output rotation was 40 rpm with an output power of 953.06 Watts.

Angular velocity was calculated using the following equation:

$$\omega = \frac{2\pi n}{60} = \frac{2\pi 40}{60} = 4{,}19\, rad/s$$

The screw torque was calculated using the equation:

$$T = \frac{P \times 60}{2\pi . n} = \frac{953{,}06 \times 60}{2\pi 40} = 227{,}6\, Nm$$

The difference between the theoretical torque (267.05 Nm) and the experimental torque (227.6 Nm) indicates the presence of mechanical losses in the transmission system, primarily caused by friction in the gearbox and screw shaft. This result is consistent with typical mechanical systems, where efficiency losses of 10–20% commonly occur (Budynas & Nisbett, 2020).

The machine performance test results, which also represent the technical specifications of the designed briquette molding machine, are presented in **Table 1.**

Table 1.
Specifications and performance test results of the briquette molding machine

No	Parameter	Specification
1	Machine & drive system	Screw extruder, electric motor
2	Power & speed	1.5 HP (1.12 kW); 1400 rpm
3	Transmission	Direct coupling + gearbox (1:35)
4	Output	40 rpm; 267.05 Nm
5	Screw	Ø 60 mm; shaft 32 mm; length 200 mm; 5 threads
6	Mold	Cylindrical & square
7	Performance	9 kg/hour; efficiency 85.24%
8	Material	Coconut coir charcoal + 20% tapioca

The test results showed that the direct coupling transmission system between the electric motor and gearbox operated stably during the molding process. The gearbox reducer successfully increased torque on the screw shaft, making biomass compaction more optimal. In addition, the direct transmission system minimized power losses due to slip, which commonly occurs in pulley and belt systems (Budynas & Nisbett, 2020).

4. Briquette Quality Testing

The briquette quality test results showed that the use of tapioca flour adhesive produced fairly good combustion characteristics. This was influenced by the homogeneity of the mixture and the compaction process using a screw extruder, which improved briquette density (Alfarizi et al., 2025). The briquette quality test results are presented in **Table 2.**

Table 2.
Briquette quality test results

Parameter	Value	SNI Standard
Calorific value	4780 cal/gram	5000 cal/gram
Moisture content	7,5%	8%
Ash content	7,6%	8%
Burning time	64,1minutes	

The calorific value of 4780 cal/g was slightly below the SNI standard (≥5000 cal/g), indicating that the energy content of the briquettes was not yet optimal. This condition is strongly influenced by the binder composition used in this study, where a 20% tapioca adhesive concentration was applied. The selection of this percentage was intended to ensure sufficient mechanical strength and durability of the briquettes during handling and transportation. However, increasing binder content generally reduces the fixed carbon fraction and increases volatile and non-combustible components, which leads to a decrease in calorific value (Uthman et al., 2026).

Previous studies at the national level have confirmed that binder percentage significantly affects briquette quality. Yudi et al., (2026) reported that the best briquette quality was obtained at 10% tapioca binder, producing a calorific value of 5661 cal/g and meeting SNI standards, while higher binder concentrations resulted in decreased calorific value . Similarly, Hidayatullah et al., (2026) showed that a 10% binder composition produced better calorific values compared to higher percentages, indicating that excessive binder reduces energy content.

These findings indicate that the use of 20% binder in this study represents a trade-off between mechanical durability and energy performance.

Higher binder content enhances particle bonding and structural integrity but reduces calorific value due to dilution of fixed carbon content. This explains why the calorific value obtained in this study did not meet the SNI standard.

In contrast, the moisture content of 7.5% met the SNI standard (≤8%), indicating that the drying process was effective and contributed to improved ignition characteristics. The ash content of 7.6% also complied with the standard, although it approached the upper limit, suggesting relatively high mineral residue. The burning time of 64.1 minutes demonstrated stable combustion behavior, which is consistent with studies indicating that higher binder content tends to prolong combustion duration while reducing combustion intensity (Aulia & Huda, 2024).

Based on these findings, it can be concluded that binder percentage plays a critical role in determining briquette quality. Therefore, further studies are required to investigate a wider range of binder compositions (e.g., 10%, 15%, and 20%) to obtain an optimal balance between calorific value, mechanical strength, and combustion stability, ensuring compliance with SNI standards.

CONCLUSION

The screw extruder-based briquette press machine driven by a 1.5 HP motor with a 1:35 gearbox operated stably and effectively, producing sufficient torque for biomass densification and achieving a production capacity of 9 kg/h with 85.24% efficiency. The resulting briquettes met the SNI requirements for moisture and ash content, although the calorific value remained below the standard. This indicates that the designed transmission system and taper screw configuration are effective in ensuring stable material flow, reliable machine performance, and acceptable briquette quality. For future work, it is recommended to optimize the raw material composition, particularly by reducing or substituting the binder, in order to improve the calorific value of the briquettes.

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