

Engineering Design of Vertical and Horizontal Briquette Printing Machines on Briquette Quality

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Abstrak

Briket biomassa merupakan salah satu sumber energi terbarukan yang potensial, namun kualitas briket sangat dipengaruhi oleh mekanisme densifikasi dan orientasi gaya tekan yang dihasilkan oleh mesin pencetak briket. Penelitian ini bertujuan untuk menganalisis pengaruh desain mesin pencetak briket tipe vertikal dan horizontal terhadap karakteristik fisik dan mekanik briket biomassa. Penelitian dilakukan secara eksperimental dengan pendekatan komparatif menggunakan campuran biomassa berupa arang sekam padi (40%), arang serbuk kayu (40%), perekat tapioka (10%), dan air (10%). Mesin pencetak tipe vertikal menggunakan sistem pemadatan pneumatic-hydraulic dengan variasi tekanan sebesar 206.842, 344.738, 482.633, dan 620.528 Pa, sedangkan mesin tipe horizontal menggunakan mekanisme screw press yang digerakkan motor listrik 1,5 HP dengan diameter screw 6 cm, panjang screw 26 cm, dan kapasitas produksi 200 kg/jam. Tekanan pemadatan pada mesin horizontal tidak dapat dinyatakan sebagai satu nilai tetap seperti pada mesin vertikal karena mekanisme screw press menghasilkan tekanan dinamis yang berubah secara kontinu selama proses pencetakan. Kualitas briket dianalisis berdasarkan densitas, ketahanan mekanik (drop test), water resistance index (WRI), dan laju pembakaran. Hasil penelitian menunjukkan bahwa peningkatan tekanan pemadatan pada mesin vertikal mampu meningkatkan densitas briket dari 0,551 menjadi 0,731 g/cm³ serta menurunkan persentase kerusakan drop test dari 45,15% menjadi 18,51%. Selain itu, laju pembakaran menurun dari 0,215 menjadi 0,158 g/menit yang menunjukkan terbentuknya struktur briket yang lebih padat dan stabil. Mesin horizontal menghasilkan densitas rata-rata sebesar 0,654 g/cm³ dengan laju pembakaran sebesar 0,175 g/menit serta menunjukkan variasi struktur yang relatif lebih besar. Hasil penelitian menunjukkan bahwa orientasi gaya tekan vertikal menghasilkan distribusi tekanan yang lebih merata dan proses densifikasi biomassa yang lebih efektif sehingga menghasilkan briket dengan kekuatan mekanik dan kestabilan pembakaran yang lebih baik. Penelitian ini memberikan kontribusi ilmiah dalam menjelaskan hubungan antara orientasi gaya tekan, mekanisme densifikasi, dan kualitas briket pada sistem pencetakan biomassa.

Kata Kunci: briket biomassa, densifikasi, mesin pencetak, gaya tekan, kualitas briket.

Abstract

Biomass briquettes are a promising renewable energy source; however, briquette quality is strongly influenced by the densification mechanism and the force orientation generated by the briquetting machine. This study aims to analyse the effect of vertical and horizontal briquetting machine designs on the physical and mechanical characteristics of biomass briquettes. A comparative experimental approach was employed using a biomass mixture consisting of rice husk charcoal (40%), sawdust charcoal (40%), tapioca binder (10%), and water (10%). The vertical briquetting machine utilised a pneumatic-hydraulic compaction system with pressure variations of 206.842, 344.738, 482.633, and 620.528 Pa, while the horizontal machine employed a screw press mechanism driven by a 1.5 HP electric motor with a screw diameter of 6 cm,

screw length of 26 cm, and production capacity of 200 kg/h. The compaction pressure in the horizontal machine could not be expressed as a single constant value as in the vertical machine because the screw press mechanism generates dynamic and continuously varying pressure during the briquetting process. Briquette quality was evaluated based on density, mechanical durability (drop test), water resistance index (WRI), and combustion rate. The results showed that increasing compaction pressure in the vertical machine improved briquette density from 0.551 to 0.731 g/cm³ and reduced drop test damage from 45.15% to 18.51%. In addition, the combustion rate decreased from 0.215 to 0.158 g/min, indicating the formation of a denser and more stable briquette structure. The horizontal machine produced an average density of 0.654 g/cm³ with a combustion rate of 0.175 g/min and showed relatively greater structural variability. The findings demonstrate that vertical force orientation provides more uniform pressure distribution and more effective biomass densification, resulting in briquettes with better mechanical strength and combustion stability. This study contributes to understanding the relationship between force orientation, densification mechanism, and briquette quality in biomass briquetting systems.

Keywords: biomass briquette, densification, briquetting machine, force orientation, briquette quality

1. INTRODUCTION

Bioenergy is energy that comes from organic materials or living creatures. Biofuels (like biodiesel and bioethanol), biogas, and solid biomass (such wood chips, biobriquettes, and agricultural leftovers) are the three primary forms of energy produced by bioenergy [1], [2]. Briquettes are one of the alternative energy sources with significant potential as a solid fuel among the different types of bioenergy[3]–[5]. As an alternative to fossil fuels like petroleum, biomass briquettes provide a sustainable energy source. A variety of biomass materials, including coconut shells, rice husks, charcoal, sawdust, corn cobs, leaves and livestock manure, can be used to make briquettes, which could promote the use of biomass waste and boost local energy security [6].

Technology for producing briquettes has advanced quickly in tandem with the growing demand for alternate energy sources. For the biomass densification process, a variety of briquette-making devices, such as screw presses, roller presses, piston presses (mechanical and hydraulic), and manual presses, have been created with varying compaction mechanisms and working principles [7]. As seen in Figure 1, the biomass compaction process and the properties of the final briquettes are impacted by the various mechanical designs and operating principles of these machines.

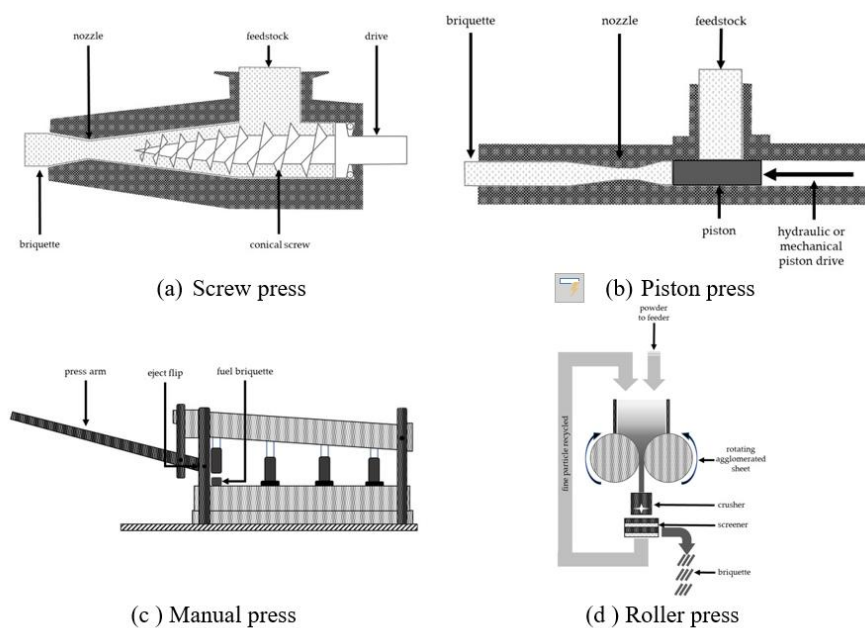


Figure 1. Briquette making technology: (a) *screw press*, (b) *piston press* [8], (c) *manual press* [7], (d) *roller press* [9]

Despite the widespread usage of briquette technology, there is still considerable variety in the quality of the final briquettes, especially when it comes to mechanical strength and density. During handling, storage, and transportation, this quality variation has a direct impact on the briquettes' dependability, energy efficiency, and combustion performance. Low density, briquettes that are prone to cracking or crumbling, and internal structural defects are the key issues that are frequently observed in the field. These issues eventually impede the adoption of briquette technology on a home and small-scale industrial scale. Compaction pressure and the effective distribution of forces during the densification process have been demonstrated to affect briquette properties in earlier experimental investigations.

The optimisation of raw material properties and process parameters has been the main focus of prior research. Physical and mechanical characteristics including density, compressive strength, impact resistance, abrasion resistance, and resistance to water penetration are typically used to assess the quality and applicability of briquettes for energy applications [10], [11]. There hasn't been much research done on how machine setup functions as a force-transferring mechanical system. In addition to being a briquette press, the briquette press also controls the density of briquette particles and the distribution of internal stress [12], [13].

Previous studies by Prasetyo et al. (2025) showed the connection between briquette mould shape and briquette quality. Significant density values were produced by changes in the hydraulic press briquette mold's shape. These results validate that a briquette's mechanical quality is mostly determined by the distribution of compressive forces and stress concentrations resulting from mould geometry [14]. However, because earlier research only examined one kind of machine and did not compare different machine configurations, it is still highly limited and incomplete when evaluating the performance other briquette moulding machine designs. Thus, there is a need for more research since the relationship between the orientation of the compressive force, the compaction process, and

briquette quality has not been fully described.

Given this context, the purpose of this study is to examine how briquette quality is affected by vertical and horizontal briquette press designs. In order to objectively assess the impact of the pressure force orientation, the analysis was carried out using a comparison method by regulating process factors and material characteristics in the same way. The briquettes' mechanical strength and density are the primary indications of the quality criteria examined. This study's scientific contribution goes beyond identifying the best kind of machine to include an understanding of how shear force and pressure force orientation affect the mechanism of particle arrangement and biomass deformation during densification. The study's findings are anticipated to contribute to science by offering a fundamental mechanical engineering framework for forecasting briquette structural properties based on the force transfer model in the press.

2. RESEARCH METHOD

The impact of vertical and horizontal briquette press designs on the final briquette quality is examined in this study using a comparative experimental method. Analysing the mechanisms and orientations of various pressing forces on the biomass densification process is the study's main goal. Differences in briquette quality can be directly linked to variations in press designs and mechanisms because all material variables and process parameters are controlled similarly.

a. Raw Materials and Mixture Composition

Based on mass percentage, the biomass combination used to make briquettes is made up of 40% rice husk charcoal, 40% sawdust charcoal, 10% tapioca starch adhesive, and 10% water. To guarantee consistent adhesive distribution and reduce changes in material properties during compaction, all ingredients are combined until homogenous before the moulding process. Throughout the test, this composition is employed regularly. To prevent variations in mould geometry on densification outcomes, both machines use the same outer mould size of 40 mm x 40 mm x 40 mm.

b. Tool Mechanical Specifications and Operating Conditions

Two different kinds of briquette moulding machines with various pressing mechanisms are used in the moulding process. The pressing mechanism of the vertical moulding machine is pneumatic-hydraulic. The horizontal moulding machine, on the other hand, employs a screw press mechanism that continuously presses horizontally. Table 1 presents the technical parameters and operational capacities of both machines to assure the test's objectivity.

Table 1. Technical Specifications of Vertical and Horizontal Briquette Making Machines

Parameter Category	Vertical Type Machine	Horizontal Type Machine
Main Mechanical Specifications		
Primary Compaction Mechanism	Pneumatic-hydraulic Piston (Single Axial)	Screw press (Continuous Axial Rotation)
Tool Operating System	Intermittent Cycle	Continuous Cycle
Source of Prime Mover	Air Compressor	1.5Hp Electric Motor
Transmission and Control Systems	Static air pressure regulator valve	Mechanical gear reducer
Compression Component Dimensions	Piston diameter: 50mm, Piston stroke length: 150mm	Thread shaft diameter: 60mm, Thread length 260mm
Mold Geometry and	Solid square	Solid rectangle

Dimensions	(40mmx40mmx40mm)	(40mmx40mm) with an extrusion hole length of 150mm
Real Operational Parameters		
Kapasitas Produksi	50kg/hour	200kg/hour
Cycle time per unit	180-240 seconds per briquette	30-40 seconds per briquette
Properties of compaction pressure	Static control (2068420Pa; 3447380Pa; 4826330Pa; 6205280Pa)	Linear dynamic (constant formation due to the retraction of the material rate and the geometry of the die tip)
Analysis of Mechanical Phenomena		
Orientation of force distribution	Unidirectional axial hydrostatic force	Rotational dynamic shear force
Scientific mechanism	Triggers constant plastic deformation of the material	Triggering particle rearrangement
Final Product Characterization	Solid square (40mmx40mmx40mm)	Solid square (40mmx40mmx40mm)

The four regulated static compaction pressure variations for the vertical type machine are 2068420 Pa, 3447380 Pa, 4826330 Pa, and 6205280 Pa. The pressure regulator valve of the pneumatic-hydraulic drive system is integrated to accomplish the setting. The horizontal type machine rotates its screws at a fixed pace of 60 revolutions per minute. The accumulation of screw force, feeding rate, and geometric constraints at the die end generate the pressure dynamically, making it impossible to modify the pressure magnitude separately. Testing the continuous screw press machine under a single condition to determine its optimal operating performance representation.



(a)



(b)

Figure 2 Briquette making machine (a) horizontal type (b) vertical type

c. Briquette Making Procedure

The first step in creating briquettes is to combine biomass and adhesive until a uniform mixture is achieved. After that, the mixture is put into a molding machine and compacted in accordance with each machine's operational specifications. In horizontal machines, the compaction process is carried out at a single screw mechanism operating state, but in vertical machines, the compaction process is carried out at a predefined pressure level. Before being examined for quality, the molded briquettes are dried at room temperature until they attain a stable mass. Figure 3 shows the entire briquette-making process.



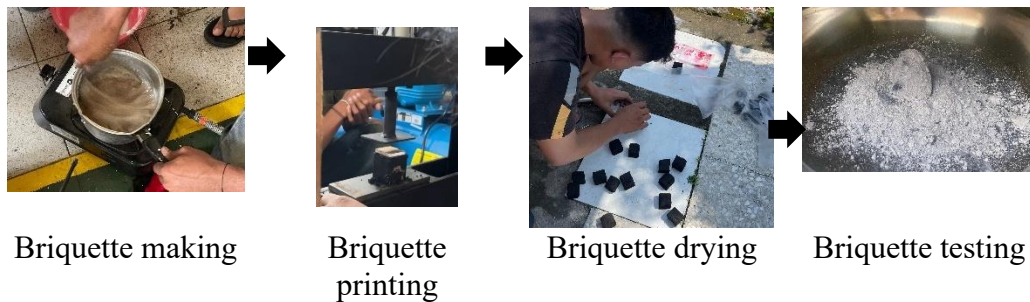


Figure 3. Briquette making process

d. Briquette Quality Testing Procedure

The quality of the briquettes was assessed using a number of important factors, including density, combustion rate, water resistance, and mechanical resistance. After drying, the mass to volume ratio of the briquettes was used to calculate their density. The ASTM D440-86 drop test method was used to assess mechanical resistance. The briquettes were dropped from a height of 1.8 meters onto a hard surface, and the percentage of damage was determined based on the change in mass. The briquettes were soaked in water at room temperature for half an hour to evaluate their water resistance. The water resistance index was then determined by measuring the mass change. The mass loss of the briquettes during the controlled combustion process was used to calculate the burning rate. The quality of briquettes made by vertical and horizontal molding machines was compared using both descriptive and comparative analysis of the test data.

e. Data Analysis and Machine Performance Equations

The following mathematical formula can be used to evaluate each briquette moulding machine's performance and energy consumption characteristics:

1) Calculating Briquette Density

The following formula is used to get the geometric density of solid briquettes (ρ) by dividing the sample mass by the cube mould volume:

$$\rho = \frac{m}{V}$$

where m is the mass of the weighted briquette, V is its geometric volume, and ρ is the briquette's density.

2) Particular Electrical Power Usage

The electrical energy consumption can be computed using the following mathematical formula in order to assess the mechanical energy efficiency of the vertical and horizontal briquette press machine design:

$$SEC = P \times \left(\frac{t}{3600} \right)$$

P is the electrical power of the hydraulic pump or drive motor, t is the dwelling time or cycle time for producing a single briquette, and SEC is the specific electrical energy consumption.

3) Statistical Inference (Independent Samples t-Test)

An inferential statistical analysis utilising the Independent Samples t-Test at a significance threshold of $\alpha = 0.05$ (95% confidence level) is necessary to confirm the scientific validity and significance of the quality differences between the two machine configurations. The briquette quality data from the horizontal machine and the vertical machine's greatest pressure optimisation will be compared in this analysis. The following mathematical formula is used to determine the t-coefficient value:

$$t = \frac{X_1 - X_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

X_1 and S_1^2 is the average value and variance of the vertical briquette group under optimal conditions, X_2 and S_2^2 represents the average value and variance of the horizontal machine briquette group. n_1 and n_2 is the number of samples or replications of testing for each group.

3. RESULTS AND DISCUSSION

The densification process and the final briquette quality are directly impacted by variations in the design and orientation of the pressure force in briquette presses. Briquette quality tests, including those for density, tensile strength, water resistance, and combustion rate, were carried out to assess these effects. By connecting new trends to the densification mechanisms in vertical and horizontal presses, the test results were compared.

a. Characteristics of Density and Mechanics of Compaction Density

Briquette density is used as the main indicator to evaluate the effectiveness of the densification process in vertical and horizontal briquette molding machines, because it directly represents the degree of compaction and density of the internal structure of the briquette [15]. Comparative data of density testing are presented in Table 2.

Table 2. Density Test Results

Actuator Pressure (Pa)	Testing	1	2	3	4	5	Average
2068420	Massa (gram)	26.15	26.06	24.23	26.1	26.11	25.73
	Volume (cm ³)	46.656	46.656	46.656	46.656	46.656	46.656
	Densitas (gram/cm ³)	0.560	0.559	0.519	0.559	0.560	0.551
3447380	Massa (gram)	29.13	30	28.29	28.16	29.06	28.928
	Volume (cm ³)	46.656	46.656	46.656	46.656	46.656	46.656
	Densitas (gram/cm ³)	0.624	0.643	0.606	0.604	0.623	0.620
4826330	Massa (gram)	30.41	33.42	34.07	31.08	31.29	32.054
	Volume (cm ³)	46.656	46.656	46.656	46.656	46.656	46.656
	Densitas (gram/cm ³)	0.652	0.716	0.730	0.666	0.671	0.687
6205280	Massa (gram)	31.22	35.2	34.36	35.92	33.84	34.108
	Volume (cm ³)	46.656	46.656	46.656	46.656	46.656	46.656
	Densitas (gram/cm ³)	0.669	0.754	0.736	0.770	0.725	0.731
Horizontal	Massa (gram)	34.28	33.53	32.13	35.26	35.44	34.128
	Volume (cm ³)	51.901	54.345	51.474	47.704	56.251	52.335
	Densitas (gram/cm ³)	0.660	0.617	0.624	0.739	0.630	0.654

According to Table 2, the average density of briquettes produced by the horizontal type moulding machine is 0.654 g/cm³, whereas the density of briquettes in the vertical type moulding machine gradually increases from 0.551 g/cm³ at a pressure of 2068420 Pa to 0.731 g/cm³ at a pressure of 6205280 Pa. The amount of

hydrostatic-axial force continuously applied during the holding period affects the rise in density values in vertical machine briquettes. The circumstance compels our powder and the rice husk charcoal particles to go through the reset phase till they undergo irreversible plastic deformation [9]. Although the pressing process takes around 30 to 40 seconds, the horizontal machine's screw mechanism, which depends on dynamic shear forces, can generate a constant density of 0.654 g/cm³, which is demonstrated to be denser than the vertical machine mould at a low pressure of 0.551 g/cm³. This is consistent with the fundamental idea that axial compression tends to make biomass briquettes more uniform and dense [16].

b. Relationship of Density to Mechanical Resistance (Droptest)

The mechanical resistance of briquettes to shock loads, which reflects the compactness of the internal structure and the strength of the interparticle linkages arising from the densification process, is assessed using the drop test [17]. Table 3 shows comparative statistics from the drop test results.

Table 3. Drop test results

Actuator Pressure (Pa)	Testing	1	2	3	4	5	Average
2068420	Initial Weight (gram)	26.15	26.06	24.23	26.1	26.11	25.73
	Final Weight (gram)	13.79	10.58	13.48	17.47	15.24	14.112
	<i>Droptest</i> (%)	47.27%	59.40%	44.37%	33.07%	41.63%	45.15%
3447380	Initial Weight (gram)	29.13	30	28.29	28.16	29.06	28.928
	Final Weight (gram)	16.41	15.72	19.2	18.55	18.27	17.63
	<i>Droptest</i> (%)	43.67%	47.60%	32.13%	34.13%	37.13%	39.06%
4826330	Initial Weight (gram)	30.41	33.42	34.07	31.08	31.29	32.054
	Final Weight (gram)	20.09	21.82	22.34	20.45	21.33	21.206
	<i>Droptest</i> (%)	33.94%	34.71%	34.43%	34.20%	31.83%	33.84%
6205280	Initial Weight (gram)	31.22	35.2	34.36	35.92	33.84	34.108
	Final Weight (gram)	26.03	28.3	26.64	28.91	29.1	27.796
	<i>Droptest</i> (%)	16.62%	19.60%	22.47%	19.52%	14.01%	18.51%
Horizontal	Initial Weight (gram)	33.64	32.07	32.79	31.15	32.69	32.468
	Final	24.55	23.44	25.67	26.91	27.09	25.532

	Weight (gram)						
	<i>Droptest</i> (%)	27.02%	26.91%	21.71%	13.61%	17.13%	21.36%

Table 3, shows that the average percentage of briquette damage on the vertical type moulding machine dropped from 45.15% at 2068420 Pa to 18.51% at 6205280 Pa. This phenomena demonstrates the material's structural causal relationship: a rise in briquette density is directly correlated with the briquette's mechanical resistance. When a shock force is applied from a height of 1.8 meters, a denser macrostructure will reduce the volume of porosity, removing the stress concentration area that is fragile and turns into a briquette crack [18]. Because of the properties of the dynamic shear force of the screw shaft, horizontal machines have been shown to have superior mechanical strength when compared to vertical machines under low and medium pressure circumstances [19]. The rice husk charcoal and sawdust particles undergo micro-fractionation as a result of friction from rotation, which causes the cross-oriented binding fibres to disperse and compels the tapioca gelatin to cover the particle cell walls uniformly [20]. Particles are strongly bonded together as a result of this phenomenon. When the hydraulic pressure is raised to 6205280Pa, horizontal machines are believed to perform better on briquettes than vertical machines.

c. Visual Validation of Porosity and Internal Structure of Briquettes

To ascertain the phenomenon of particle fragmentation, interfacial cohesiveness, and mechanical failure behaviour resulting from distortion of the compaction force orientation, post-test briquette surface morphology characterisation was carried out. Figure 4 shows the briquettes from the three samples' physical degradation and pore structure.

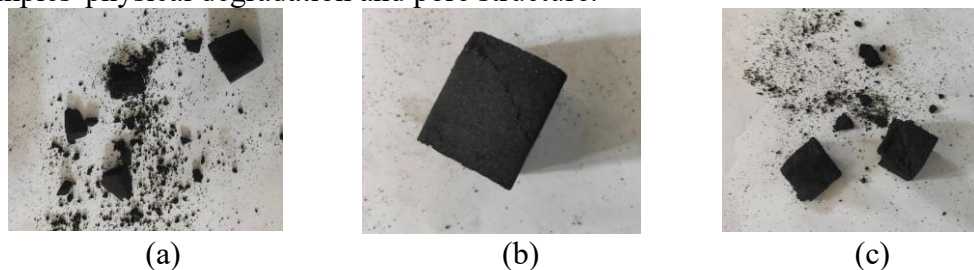


Figure 4. Visualization of briquette structure (a) low pressure vertical molding machine 2068420Pa, (b) vertical molding machine pressure 6205280Pa, (c) horizontal molding machine.

Due to the predominance of open macro porosity, the low-pressure vertical specimen in Figure 4(a) exhibits the most severe disintegration phase through the grain shedding phenomena, which is consistent with the highest mechanical damage rate of 45.15%. The high-pressure vertical specimen in Figure 4(b), on the other hand, confirms the achievement of a minimum damage rate of 18.51% while producing a homogeneous single cleave failure mode without granule release. In contrast, the horizontal machine specimen in Figure 4(c) exhibits a ductile failure mode with a continuous damage rate of 21.36% in the form of big fragments that retain their geometric integrity. This physical pattern confirms that the screw shaft's dynamic shear stress penetrates the biomass particles, causing them to reorient and form a helical interlocking network that strengthens the briquettes' mechanical toughness [21].

d. Relationship between Density and Water Absorption Capacity of Briquettes

The degree of porosity and density that results from the densification process are directly correlated with water resistance, which is used to assess the stability of the briquette structure under humid conditions [22]. Table 4 displays the results of the water resistance test.

Table 4. Water Resistance Test Results

Actuator Pressure (Pa)	Testing	1	2	3	4	5	Average
2068420	BA	24	23.87	25.22	23.36	24.42	24.174
	BH	53	52	54.96	50.18	53.45	52.718
	WRI	54.72%	54.10%	54.11%	53.45%	54.31%	54.14%
3447380	BA	26.3	26.4	27.48	27.51	26.7	26.878
	BH	54.2	55.1	56.22	56.28	55.49	55.458
	WRI	51.48%	52.09%	51.12%	51.12%	51.88%	51.54%
4826330	BA	28.09	31.38	27.96	28.64	29.63	29.14
	BH	57.13	65.81	51	58.12	59.95	58.402
	WRI	50.83%	52.32%	45.18%	50.72%	50.58%	49.92%
6205280	BA	29.03	30.35	27.91	28.36	30.61	29.252
	BH	52.89	51.46	55.6	51.1	51.81	52.572
	WRI	45.11%	41.02%	49.80%	44.50%	40.92%	44.27%
Horizontal	BA	33.8	34.56	35.97	35.11	33.03	34.494
	BH	62.5	66.89	63.23	64.08	66.89	64.718
	WRI	45.92%	48.33%	43.11%	45.21%	50.62%	46.64%

According to Table 4, the horizontal moulding machine generates an average WRI value of 46.64%, while the vertical moulding machine's WRI value decreases from an average of 54.14% at a pressure of 206,842 Pa to 44.27% at a pressure of 620,528 Pa along with an increase in compaction pressure. When considering the physical element of water absorption, a fall in the WRI index % value signifies a decrease in the briquettes' ability to absorb water through their macro pores. The briquettes' internal pore width is successfully decreased by the vertical system's increased pressure, which prevents water molecules from penetrating the briquette pores. This demonstrates how a high densification procedure can lower the biomass briquette solid material's ability to absorb water [13], [23], and [24].

e. Relationship between Pore Density and Combustion Rate Characteristics

The combustion rate is used to analyze the combustion characteristics of briquettes related to the density of the structure and distribution of pores resulting from the densification process, because it affects the heat stability and energy utilization efficiency [25]. The numerical data for the combustion rate test are presented in Figure 5.

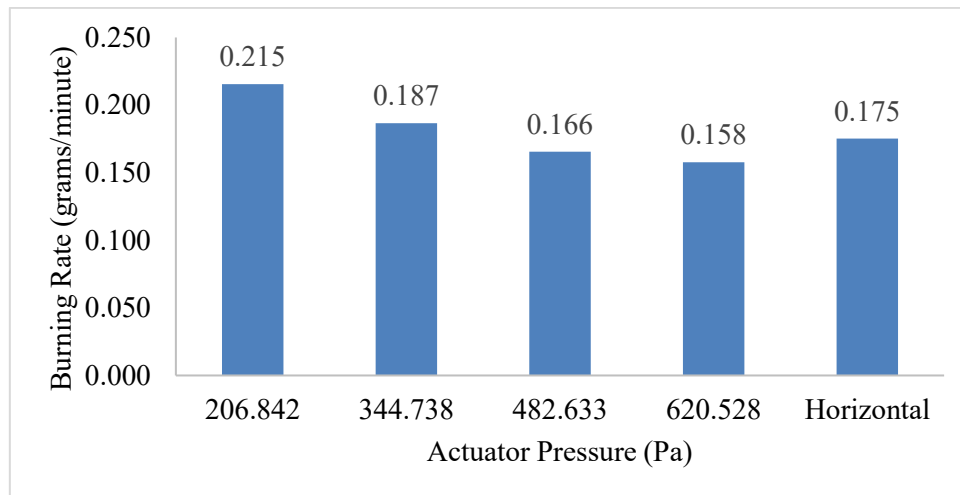


Figure 5. Burning Rate Test Results

Based on Figure 5, the briquette combustion rate in the vertical molding machine decreased from 0.215 g/min at a pressure of 2068420 Pa to 0.158 g/min at a pressure of 6205280 Pa, while the horizontal molding machine produced a combustion rate of 0.175 g/min, this indicates that the briquette pore arrangement in the mold is able to control the combustion rate performance. The vertical briquette machine with a pressure of 6205280 Pa has minimal air cavities, thus limiting the rate of oxygen gas diffusion, so that the thermal oxidation reaction runs slowly, stably and for a long time. The value of the horizontal briquette combustion rate is relatively fast at 0.175 g/min, this is due to the mechanization of briquette formation through a 150 mm extrusion hole which triggers the continuous release of water vapor moisture. This process leaves a microstructure in the interconnected pore network in the briquette, thus facilitating oxygen penetration, accelerating heat transfer and increasing the rate of thermal calorie release per minute [19].

f. Validation and statistical analysis using the Independent Samples t-Test (IST)

The Independent Samples t-Test on the density and combustion rate parameters was utilised in the validation of this research data to make sure that the variation in the physical data of the briquettes was solely caused by the variations in the machines employed and not by chance experimental mistakes. Inferential statistical analysis (IST) and validation data are shown in Table 5.

Table 5. Results of comparison of experimental results and validation of IST test

Machine Type	Average value of experimental results ($\bar{X} \pm S$)	IST test validation value
Parameter 1: Density		Degree of Validity (df)= 8 T-table limit value =2,306
Vertical machine (pressure 6205280Pa)	0,731 ± 0,039 g/cm ³	t-count coefficient = 2,715
Horizontal machine	0,654 ± 0,050 g/cm ³	Significance value ($p - value$) = 0,026 ($p < 0,05$)
Parameter 2: Burning rate		Degree of Validity (df)= 8 T-table limit value =2,306
Vertical machine (pressure 6205280Pa)	0,158 ± 0,011 g/cm ³	t-count coefficient = 2,820
Horizontal machine	0,175 ± 0,008 g/cm ³	Significance value ($p - value$) = 0,021 ($p < 0,05$)

The Independent Samples t-Test inferential analysis yielded a density significance value of $p = 0.026$ and a combustion rate significance value of $p = 0.021$ based on Table 5. The test was run with degrees of freedom (df) = 8 and a 95% confidence level ($\alpha = 0.05$). Based on the computed t-coefficient value derived from the difference between the average (mean) and variance of the ideal vertical briquette group and the horizontal briquette, this number represents the critical area under the t-distribution curve. The statistical difference in briquette quality statistics between machines is valid and scientifically significant because both p-values are continuously below the limit ($\alpha = 0.05$).

g. Analysis of Power Requirements and Machine Energy Efficiency

The specific energy performance of the horizontal continuous extrusion system and the vertical hydraulic-axial system was determined by comparing the mechanical compaction efficiency and power utilisation characteristics [26]. Table 6 displays the findings of the mechanical performance parameter summary and energy consumption computations for the two devices.

Table 6. Comparison of Mechanical Performance and Energy Consumption Characteristics of Machines

Evaluation Parameters	Vertical Machine (pressure 6205280Pa)	Horizontal Machine
Motor Power (kW)	1,1	1,12
Waktu Siklus (<i>Dwelling Time</i>)	180 seconds/briquette	30 seconds/briquette
Specific Energy Consumption (SEC)	0,055 kWh/briquette	0,0093 kWh/briquette
Real Production Capacity	$\pm 15-20$ kg/hour	200 kg/hour

Table 6 shows that there are notable variations in the characteristics of energy use. Despite using drive motors with similar power capacities (1.1 kW and 1.12 kW), the machines' operating mechanisms result in different Specific Energy Consumption (SEC) figures. The vertical type machine uses 0.055 kWh of energy per briquette since it needs a long dwell time (180 seconds) to get absolute mechanical strength. The horizontal machine, on the other hand, produces a very low (SEC) value of 0.0093 kWh/briquette by using a continuous extrusion system without a dwell period (30 seconds). These results demonstrate that the horizontal moulding machine's design engineering is more effective than the vertical moulding machine's in terms of energy efficiency and mass operating capacity [26], [27].

4. CONCLUSION

The aforementioned discussion leads to the conclusion that the variations in the pressure transfer systems of vertical and horizontal briquette moulding machines impact how their mechanical performance and product attributes compare. With the highest density of 0.731 ± 0.039 g/cm³, the highest impact resistance of $18.51\% \pm 3.31\%$, and the most stable combustion rate of 0.158 g/minute, the vertical briquette moulding machine with a single hydrostatic force mechanism at an optimal pressure of 620.528Pa yields the best briquette quality. The horizontal briquette press with a screw shaft dynamic shear mechanism performs exceptionally well in terms of operational efficiency because it can produce 200 kg/hour with a cycle time of just 30 to 40 seconds per briquette. When compared to the vertical machine's performance at low to medium pressure ranges, the quality of the horizontal briquettes produced is consistently at 0.654 g/cm³. The validity and significance of every change in briquette qualities between these two machine configurations has

been established. based on the Independent Samples t-Test results, which yielded p-values of 0.021 for the combustion rate and 0.026 for the density parameter. The probability value is less than the $\alpha = 0.05$ cutoff. This number provides scientific evidence that variations in the orientation of the compaction force distribution of each machine design, rather than random experimental data error factors, are responsible for the quality of the briquette output. The vertical type machine arrangement has a comparative advantage for processing premium quality briquettes in a particular market segment (niche market) that prioritises absolute mechanical integrity, according to the technical suggestions derived from this study. On the other hand, the horizontal type machine arrangement is the best way to satisfy the needs of large-scale commercial briquette production, which places a high priority on continuous output capacity and specific energy consumption efficiency.

5. SUGGESTION

Further research is recommended to examine the variation in compaction pressure in horizontal-type molding machines to allow for a more balanced performance comparison with vertical-type machines. Furthermore, analysis of the internal structure of the briquettes, such as density distribution and porosity, is necessary to clarify the densification mechanism. Further studies can also be directed at variations in raw materials and adhesive types, as well as the development of analytical or numerical models to support the design of more efficient and applicable briquette molding machines.

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