INNOVATIVE DESIGN AND EVALUATION OF A TRIPLE EXTRUDER BRIQUETTING MACHINE WITH TAPERED SCREW MECHANISM FOR IMPROVED BIOMASS PROCESSING

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Date of publication: 25 July, 2026

ABSTRACT: This research investigates the design and evaluation of a tapered screw-type triple extruder briquetting machine, focusing on improvements in biomass processing efficiency and briquette quality. The theoretical framework is based on principles of mechanical engineering and renewable energy technology, emphasizing the significance of optimizing operational parameters such as revolutions per minute (RPM). A comprehensive methodology was employed, varying RPM settings at 30, 40, and 50 RPM to evaluate their effects on physical properties and throughput capacity. Key results revealed that an RPM of 30 achieved the highest efficiency, producing briquettes with a bulk density of 0.568 g/cm³, shatter index values below 10% (specifically 1.54%), and water absorption rates of 14%, indicating robust mechanical integrity. The throughput capacity was observed to peak at 147 kg/hr at the optimal RPM, while higher RPMs resulted in decreased briquette quality due to increased brittleness and lower density. These findings underscore the potential advancements in biomass briquetting technology, showcasing a pathway to enhance energy sustainability through better resource utilization.

I. INTRODUCTION

Biomass is a vital renewable energy source that reduces reliance on fossil fuels by utilizing organic materials such as agricultural waste and forestry residues. Its use promotes environmental sustainability, lowers greenhouse gas emissions, supports waste management efforts, enhances energy security, and contributes to rural development [1, 2]. Among the many biomass conversion technologies, briquetting has gained significant attention as it transforms loose biomass into high-density, compact fuel forms that are easier to store, transport, and utilize [3]. Charcoal briquettes, in particular, are recognized for their efficient thermal output and potential as sustainable fuel alternatives. Their energy-generating capacity—measured through calorific value—varies based on raw material composition and production methods. For instance, briquettes made from agricultural wastes can reach calorific values as high as 5154.58 kcal/kg [4]. The incorporation of starch-based binders and inorganic fillers has been shown to enhance both the physical integrity and combustion performance of the briquettes, improving ignition characteristics and overall heat release efficiency [5]. As such, charcoal briquettes are increasingly being promoted as viable substitutes for conventional fossil fuels like coal due to their comparable energy potential and environmental advantages. Various technologies are available for producing biomass briquettes, each offering distinct advantages depending on the scale of production and type of feedstock. Manual die compressors are commonly used in small-scale or low-resource settings, while piston-type hydraulic presses are preferred for producing high-density briquettes with consistent quality. In commercial applications, roller presses and die-based systems, such as ring die and flat die machines, are utilized to produce briquettes in specific shapes and sizes suitable for diverse combustion needs [6, 7].

Among the widely adopted technologies, screw-type extrusion has gained attention for its ability to deliver uniform and durable briquettes across a wide range of biomass materials [8]. These technologies continue to evolve to improve production efficiency, product quality, and adaptability to different biomass resources, supporting the broader goal of sustainable energy development. Single screw extrusion is an efficient and reliable drying technology for briquetting applications. It features a simple design capable of generating high pressure, allowing effective compaction of viscous and dense materials. This continuous process supports long production runs with stable operating conditions and consistent product quality [9]. Its operational characteristics also enable uniform material dispersion, making it suitable for shaping briquettes with desirable mechanical properties. Additionally, the process is associated with lower energy consumption and simplified system control, which supports scalable and steady briquette production. The tapered screw type extrusion system is a specialized form of single screw extrusion designed to optimize the briquetting process through a gradually decreasing screw diameter from the feed zone to the discharge zone [10, 11]. This tapering facilitates progressive compression of the material, enabling the formation of high-density briquettes with improved structural integrity and combustion performance. The tapered screw design is intended to improve progressive compression and material flow, which may help reduce process instability and support efficient briquette formation [12]. Additionally, Optimized screw design and operating conditions can influence torque demand, throughput, and energy-use behavior in briquetting systems. Recent studies on screw-type briquetting machines and related technoeconomic analyses indicate that screw geometry and speed affect power requirement, briquetting efficiency, and energy consumption rate, but reduced energy use should be treated as a design-dependent outcome rather than as an automatic feature of all tapered screw systems [13]. The extended residence time within the extruder also supports more effective mixing of additives or binders, making the tapered screw type extrusion system a versatile and energy-efficient approach for producing consistent, high-quality briquettes from diverse feedstock materials. The tapering nature of the screws facilitates improved flow dynamics, which aids in reducing the energy consumed during processing and enhancing overall production rates of briquettes.

This study focuses on the design and fabrication and performance evaluation of a tapered screw-type triple extruder briquetting machine equipped with independently controlled barrels, with the goal of enhancing production efficiency, improving briquette quality, and promoting sustainable energy practices. Biomass briquetting—particularly from agricultural and food industry waste—is increasingly recognized as an effective strategy for waste valorization and renewable energy generation, offering both environmental and economic benefits by reducing reliance on fossil fuels [14, 15]. The use of a tapered screw design facilitates gradual compression of biomass materials, resulting in higher-density briquettes and reduced energy consumption [16, 17]. Integrating multiple screws with independently operated barrels allows for precise control over critical processing parameters such as pressure, temperature, and mixing, thereby increasing throughput capacity and enabling the consistent processing of various biomass types. To evaluate the performance of the developed machine, the study examined the effects of different screw revolution per minute (RPM) settings on productivity and briquette quality, using metrics such as shatter index, bulk density, and resistance to water absorption.

Findings from this research will contribute to advancements in biomass briquetting technology by addressing design and operational inefficiencies. These insights could lead to innovative solutions for large-scale sustainable energy production, reinforcing biomass as a key player in the renewable energy landscape. By improving machine efficiency and briquette quality, this study supports the broader goal of making biomass energy production more economically viable and environmentally sustainable. Moreover, this research aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), by promoting cleaner energy sources, enhancing resource efficiency, and reducing environmental impact [18].

II. MATERIALS AND METHODS

II.1 DESIGN OVERVIEW

Figure 1 shows the isometric view of the briquetting machine. It was designed with high-strength materials designed to ensure durability and operational efficiency. The hopper (1) is fabricated from 5mm thick mild steel, providing structural integrity. The tapered extruders (2) are equipped with a 25 mm diameter shaft made from mild steel, supporting the mechanical functions of the system. A 220V photoelectric sensors (3) were integrated into the system for precise control. The cutter (4) was constructed from 2mm mild steel. The catch pan (5), made of 5mm mild steel, was used for material collection. Swivel caster wheels (6) with locks are installed to provide both mobility and stability. The air compressor (7) has a 30L capacity, powered by a 220V electrical supply. The electric motor (8), rated at 1.5 HP and 1740 RPM, delivers consistent power. The frame (9) consists of 2-inch angle bars, offering solid support for the machine's components. The control panel (10), with dimensions of 40cm x 20cm x 30cm, served as the interface for machine operation.

II.2 PRINCIPLE OF OPERATION

As demonstrated in Figure 1. The machine employed a screw-type extrusion mechanism to compact pretreated biomass, mixed with organic binders such as corn starch and molasses, into dense, uniform briquettes. The process begins with manual feeding of the biomass-binder mixture through the hopper into the machine. Once the hopper is filled, the electric motor powers the screw extruder through a belt and gear reducer, while a variable frequency drive is used to regulate motor speed and adjust the revolutions per minute of the screw during operation. At the outlet, a pneumatically actuated cutting mechanism trims the extruded briquettes to the desired length. A photoelectric sensor was also integrated into the system to detect and count the briquettes as they pass through the discharge section. This sensor-based system provides real-time monitoring and process control, ensuring precise tracking and enhancing the efficiency of the briquetting process. The combination of manual feeding, precise speed control, automated cutting, and sensor-based counting guarantees consistent, high-quality briquette production.

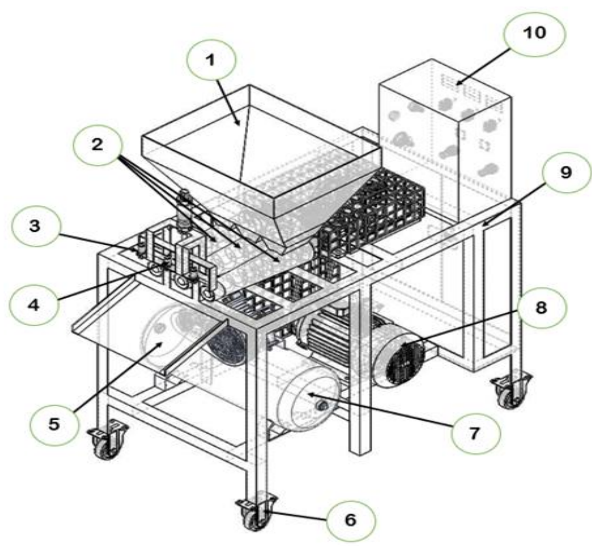

Figure 1. Isometric Layout of Setup Source: Authors, (2025)

II.3 DESIGN CALCULATION

Design of the hopper. The volume of the hopper is calculated using equation (1) [19]

$$V = \frac{1}{3}\ x\ h\ x\ (A_1 + A_2\sqrt{A_1 + A_2} \qquad (1)$$

Where V = volume of the hopper in (m^3); A_1 = area of the top in (m^3); A_2 = area of the hopper base in (m^3) and H = height of the hopper in (m). The volume of the hopper was calculated to be 0.0403 cubic meters.

Design of the cylindrical casing. The volume of the casing is calculated using equation 2.

$$V_{Casing} = \frac{\pi h}{3}(R^2 + Rr + r^2) \qquad (2)$$

Where V = volume of the cylindrical casing in (m^3); R= radius of large diameter in (m^3); r=radius of small diameter in

(m^3) and h = Height of the frustum (or the length of the tapered cylinder) in (m). The volume of the casing was calculated to be 0.00139795 cubic meters.

Design of the die. Volume of die is calculated using equation 3. [20].

$$V_{die} = \pi r^2 h \quad (3)$$

Where V = volume of the die in (m^3); r=radius of the base of the cylinder in (m^3) and h = Height of the cylinder (or the length of the cylinder) in (m). The volume of the casing was calculated to be 2.30126×10^5 cubic millimeters.

II.4 ELECTRICAL SYSTEM DESIGN

Figure 2 illustrates the electro-pneumatic control system integrating electrical, pneumatic, and sensor-based automation components to operate a double-acting pneumatic cylinder and an electric motor drive. The system was designed to enable precise, automated motion control by combining advanced sensing capabilities, reliable switching mechanisms, and robust safety features.

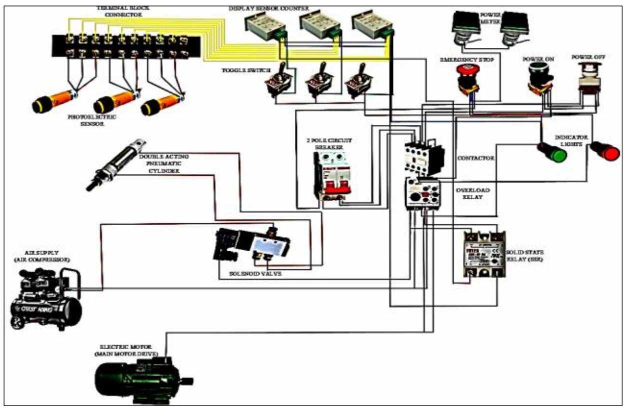

Figure 2. Electrical Diagram of the System Source: Authors, (2025)

II.5 FABRICATION AND ASSEMBLY

The fabrication and assembly of the briquetting machine were executed at the fabrication and welding shop of USTP Jasaan campus, utilizing a combination of welding, fastening, and bolting techniques to ensure structural integrity and operational reliability. The frame, constructed from 2-inch angle bars, provides a robust foundation for the machine. A 5mm mild steel hopper was mounted on the frame to hold the material for briquetting. The extruder, with a 20mm diameter shaft made of 5mm mild steel, was welded into position and responsible for compressing the raw material into briquettes. Following the extrusion process, a 220V photoelectric sensor was installed to detect the passage of the output briquette. This sensor signals the cutter to automatically trim the briquette to the desired length, ensuring precision and efficiency. The cutter, constructed from 2mm mild steel, was welded into place to perform the trimming function. A catch pan, made from 5mm mild steel, was secured below the cutter to collect the finished briquettes. To ensure mobility and stability, the machine is equipped with four swivel caster wheels with locks. An air compressor and a 1.5 Hp electric motor are mounted to provide the necessary airflow and power for the briquetting process. The motor was securely fastened to the frame to drive the extruder and other components. The control panel, positioned for easy access, enables efficient operation of the machine. The fabrication process emphasizes durability, precision, and ease of operation, with the final assembly undergoing rigorous testing to ensure optimal performance and reliability.

II.6 PERFORMANCE EVALUATION

The performance evaluation of the briquetting machine in this study was focused on determining the optimum RPM for efficient operation and assessing key physical properties of the briquettes produced. These properties include shatter resistance, water absorption, and bulk density, which are critical in determining the quality and durability of the briquettes [21, 22]. The study aims to identify the RPM that maximizes the production of high-quality briquettes with optimal physical characteristics. Following the determination of the optimum RPM, the throughput capacity of the machine is evaluated to assess its ability to meet production demands. This section provides a comprehensive analysis of the machine's performance, ensuring its effectiveness in producing durable and reliable briquettes while optimizing operational efficiency.

II.6.1 Evaluation of Physical Properties of Briquettes at various RPM

Briquettes were produced using charcoal as the primary material, with corn starch and molasses serving as binders in a 70:30 ratio. The charcoal powder was thoroughly mixed with the binders to ensure a uniform consistency, facilitating the necessary adhesive properties for shaping. This uniformity assures that the briquettes can withstand the physical stresses during compaction and subsequent handling [23].The mixture was then fed into a briquetting machine and compressed into uniform briquettes at varying machine speeds of 30, 40, and 50 RPM. After production, the briquettes were air-dried and then sun-dried prior to testing to reduce their moisture content and improve handling and combustion performance. Briquette production manuals emphasize that finished briquettes should be dried to low moisture levels to ensure mechanical strength, storage stability, and satisfactory fuel behaviour. Traditional open sun drying is widely used but can require several days to reach acceptable moisture levels and is sensitive to weather conditions; more controlled systems such as solar tunnel dryers have been shown to reduce briquette moisture to around 10% more efficiently. Practical guidance for charcoal briquetting recommends targeting moisture in the approximate range of 8–12%, since excessive moisture produces soft, easily deformed briquettes and raises drying costs, whereas overly low moisture can lead to cracking, dust formation, and reduced mechanical integrity[24], [25], [26], [27]. During the evaluation, each sample was replicated three times to ensure the reliability and consistency of the results. Evaluating the physical properties of briquettes produced at different RPM levels is important for understanding how machine speed influences product quality. Experimental studies on screw-type and related briquetting systems show that process parameters such as auger speed, feeding speed, and temperature can significantly affect density, shattering resistance, moisture behavior, and other indicators of briquette performance [28].

The evaluation of the physical properties of briquettes produced at varying RPMs (30, 40, and 50) is essential in understanding how machine speed affects the quality and durability of the briquettes [29]. Standard testing procedures are followed to assess shatter resistance, water absorption, and bulk density—key indicators of briquette quality; For the shatter resistance test, briquettes are subjected to controlled impacts, allowing researchers to measure their ability to withstand breakage. This is critical because higher shatter resistance indicates enhanced mechanical integrity, which is vital for handling and transportation. The water absorption test involved immersing the briquettes in water for a specified duration to measure their porosity, while bulk density is calculated as the mass per unit volume, reflecting the material's compactness and potential strength. These physical characteristics are paramount in determining the application and efficacy of briquettes as a fuel source.

Shatter Index

The durability of the briquettes was assessed using the shatter index which determines the ability of briquettes to withstand mechanical stress [30]. The formula for SI is given in equation (4),

$$SI = \frac{W_{initial} - W_{final}}{W_{initial}} \quad (4)$$

where $W_{initial}$ is the initial weight of the briquette sample (g) and W_{final} is the weight after shattering (g). A lower percentage of mass loss after impact suggests better mechanical integrity and durability of the briquettes.

Water Absorption Test

Additionally, the absorption test evaluates the water absorption capacity of briquettes, a crucial property that affects their usability in different environmental conditions [31]. This is calculated using the formula in equation (5),

$$AR = \frac{W_{absorbed}}{W_{dry}} \quad (5)$$

$W_{absorbed}$ represents the weight of water absorbed (g) and W_{dry} denotes the dry weight of the briquette (g). High water absorption may indicate susceptibility to degradation in humid conditions, making this test essential for determining briquette quality.

Bulk Density

The bulk density of briquettes reflects how tightly they are compacted and is critical for evaluating their energy content and handling characteristics. According to best practices, the bulk density can be determined by placing the briquette in a graduated cylinder of known volume, allowing for a direct measurement of the volume occupied by the briquette [32, 33]. The formula for bulk density is by in equation (6):

$$Bulk\ Density = \frac{Weight\ of\ Briquette,(kg)}{Volume\ of\ Briquette,(m^3)} \quad (6)$$

II.6.2 Throughput Capacity of the Machine

Throughput capacity refers to the ability of a briquetting machine to process a specific amount of material within a given time frame, reflecting its efficiency and productivity. This metric is essential for assessing the machine's suitability for large-scale operations. After determining the optimal RPM, the throughput capacity of the machine was evaluated by feeding a consistent amount of raw material into the hopper and recording the time required for processing. The output was then measured in terms of weight, and throughput was calculated as the weight of briquettes produced per unit of time. To ensure accuracy, the results were averaged across three separate trials to account for variability and provide a reliable measure of the machine's performance [34]. The formula for throughput Capacity (Q) is given by in equation (7):

$$Q = \frac{M}{t} \quad (7)$$

where M represents the mass of biomass processed (kg), and t is the time taken for processing.

III. RESULTS AND DISCUSSIONS

III.1 THE DEVELOPED BRIQUETTING MACHINE

Figure 3 shows the designed Tapered Screw-Type Triple Extruder Charcoal Briquetting Machine. It is a triple extrusion tapered screw type, featuring essential components including a driving motor, speed reducer gearbox, tapered screw, die/barrel, and housing with a hopper. Power transmission from the motor to the screw is achieved through the speed reducer. As the machine operates, raw materials are fed into the compaction chamber via the hopper. Within the barrel, the raw materials undergo compression by the screw and are subsequently extruded through the die. The screw persistently pushes the materials into the die for extrusion.

Figure 3. Developed briquetting machine Source: Authors, (2025)

III.2 PHYSICAL PROPERTIES OF BRIQUETTES AT VARIOUS RPM

Figure 4 shows the water absorption test results. As shown, as RPM increases, so does the absorption rate, with values of 19.21% at RPM 30, 24.74% at RPM 40, and 29.44% at RPM 50. While higher RPMs likely enhance mechanical action, leading to greater water interaction, these absorption rates exceed the ideal threshold for biomass briquettes (10-20%). Research suggests that briquettes with absorption rates below 15% maintain good mechanical properties and durability, while those above 20% may experience swelling, degradation, and reduced combustion efficiency, negatively impacting their performance as a fuel source [35].

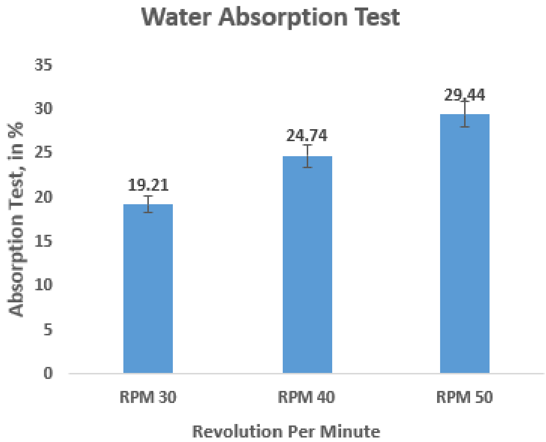

Figure 4. Water Absorption Testing Source: Authors, (2025)

The Shatter Index Test results in Figure 5 demonstrates that the biomass briquettes possess strong mechanical durability, with shatter index values of 1.54%, 2.79%, and 3.80% at RPMs of 30, 40, and 50, respectively, all well below the 10% threshold typically indicative of high durability. a shatter index under 10% suggests that the briquettes have strong resistance to impact and are less likely to fracture during handling or combustion, These results align with that finding, confirming the briquettes' resilience even at higher RPMs. The briquettes exhibited low shatter-index values, indicating strong resistance to breakage under the test conditions. Additionally, briquettes with low shatter indices generate fewer particulate emissions during combustion, improving efficiency [36]. Factors such as biomass composition, densification methods, and moisture content are crucial in determining the shatter index [37]. The observed values suggest that the tested briquettes are durable and suitable for various applications without significant risk of fragmentation.

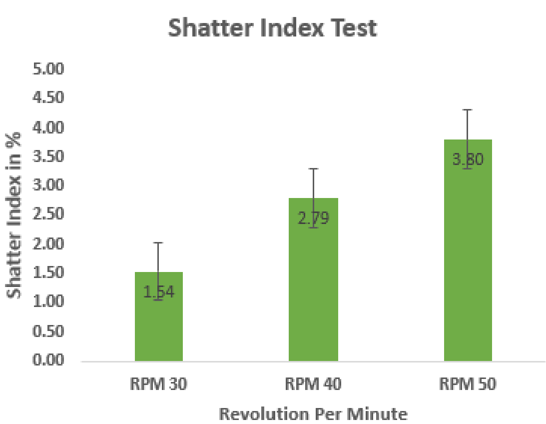

Figure 5. Shatter Index Test Source: Authors, (2025)

Figure 6 presents the bulk density of biomass briquettes at different RPM settings: RPM 30 (0.568 g/cm³), RPM 40 (0.547 g/cm³), and RPM 50 (0.528 g/cm³), showing a decrease in bulk density with increasing RPM. This trend aligns with research that highlights the significant role of bulk density in biomass briquettes, influencing transport efficiency, energy content, and combustion performance [38]. Bulk density is typically within the range of 600 to 800 kg/m³ in high-quality briquettes, with Bulk density is an important indicator of compactness, handling behavior, and potential fuel performance and efficient handling [39] . Studies by [40] report a higher bulk density (0.87 g/cm³) for briquettes made from a 40:60 charcoal to molasses mix, suggesting that binders like molasses can significantly enhance bulk density. Additionally, the findings of [41, 42] support the importance of densification in overcoming logistical challenges associated with low bulk density materials.

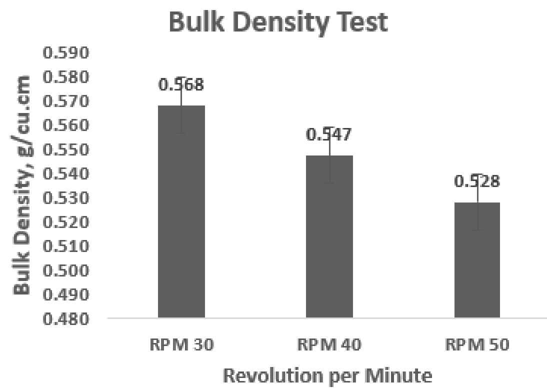

Figure 6. Bulk Density Test Source: Authors, (2025)

Based on the results, RPM 30 was identified as the most favorable operating condition for this machine because it produced the best balance between throughput and briquette quality under the tested conditions. Previous experimental studies have shown that machine operating parameters such as screw speed, feed conditions, and process settings significantly influence briquette density, shatter resistance, moisture-related behavior, and production performance. In particular, studies on screw-type charcoal briquetting machines have reported that auger speed affects output capacity, energy consumption rate, briquetting efficiency, density, moisture resistance, and shattering resistance, indicating that different speed levels produce different trade-offs between productivity and briquette quality. In the present study, increasing RPM from 30 to 50 was associated with lower bulk density and higher water absorption, which suggests reduced compactness of the briquettes at higher operating speeds. Accordingly, RPM 30 was selected as the preferred setting for evaluating throughput capacity in this machine [24]

Higher operating speeds may also increase the mechanical demand on screw-based extrusion systems, but wear was not directly measured in the present study. Previous work on tapered screw briquetting and extruder wear has shown that wear progression depends on loading conditions, abrasive interaction, and operating configuration, and therefore wear should be treated as an engineering consideration rather than a direct outcome established by the current experiment.

III.3 THROUGHPUT CAPACITY OF THE MACHINE

Based on the shatter index, bulk density, and water absorption results, RPM 30 was selected for the throughput evaluation because it offered the best observed combination of product integrity and process stability under the experimental conditions. The throughput capacity test at RPM 30 resulted in an output of 147.5 kg/hr. These findings indicate that, for this machine and feedstock, RPM 30 provided the most favorable operating point among the tested speeds [43].

IV. CONCLUSIONS

This study has successfully evaluated the performance of a tapered screw-type triple extruder briquetting machine aimed at optimizing biomass briquette production. The findings underscore the critical influence of operational parameters, particularly revolutions per minute (RPM), on the physical properties and throughput capacity of the briquettes produced. Notably, the evaluation revealed a substantial correlation between RPM settings and briquetting outcomes; specifically, an RPM of 30 yielded the highest quality briquettes with superior shatter resistance, lower water absorption, and optimal bulk density, measured at 0.568 g/cm³. Conversely, increasing the RPM to 50 resulted in a marked decrease in bulk density to 0.528 g/cm³ and diminished briquette integrity, substantiating the observation that excessive speeds impose undue strain on the material, leading to brittleness and lower overall quality of the briquettes. The study's results confirmed that briquettes exhibiting a shatter index lower than 10% signified robust performance and minimized transport losses, thus enhancing their practical appeal in commercial applications. This research recommends that further investigations explore the scalability of the tapered screw design for broader applications in biomass briquetting. Moreover, advancing equipment technology to maintain lower energy consumption while improving procedural efficiency could enhance the operational viability of biomass briquetting systems in the renewable energy landscape.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Brian D. Genon
Methodology: Brian D. Genon, Consorcio S. Namoco Jr.
Investigation: Brian D. Genon
Discussion of results: Brian D. Genon, Consorcio S. Namoco Jr.
Writing – Original Draft: Brian D. Genon
Writing – Review and Editing: Consorcio S. Namoco Jr.
Resources: Consorcio S. Namoco Jr.
Supervision: Consorcio S. Namoco Jr.
Approval of the final text: Consorcio S. Namoco Jr.

VI. ACKNOWLEDGMENTS

The authors would like to thank University of Science and Technology of Southern Philippines for the assistance and support in conducting the study.

VII. REFERENCES

[1] N. Nelson, J. Darkwa, and J. Calautit, "Prospects of Bioenergy Production for Sustainable Rural Development in Ghana," *Journal of Sustainable Bioenergy Systems*, vol. 11, no. 04, pp. 227–259, 2021, doi: 10.4236/jsbs.2021.114015.

[2] Z. Al-Hamamre, M. Saidan, M. Hararah, K. Rawajfeh, H. E. Alkhasawneh, and M. Al-Shannag, "Wastes and biomass materials as sustainable-renewable energy resources for Jordan," *Renewable and Sustainable Energy Reviews*, vol. 67, pp. 295–314, 2017, doi: 10.1016/j.rser.2016.09.035.

[3] S. Jha, J. A. Okolie, S. Nanda, and A. K. Dalai, "A Review of Biomass Resources and Thermochemical Conversion Technologies," *Chemical Engineering & Technology*, vol. 45, no. 5, pp. 791–799, 2022, doi: 10.1002/ceat.202100503.

[4] G. Patil, "The possibility study of briquetting agricultural wastes for alternative energy," *Indonesian Journal of Forestry Research*, vol. 6, no. 2, pp. 133–139, 2019, doi: 10.20886/IJFR.2019.6.2.133-139.

[5] G. Borowski, W. Stępniewski, and K. Wójcik-Oliveira, "Effect of starch binder on charcoal briquette properties," *International Agrophysics*, vol. 31, no. 4, pp. 571–574, 2017, doi: 10.1515/intag-2016-0077.

[6] L. V. Gentil and A. T. Vale, "Energy balance and efficiency in wood sawdust briquettes production," *Floresta*, vol. 45, no. 2, pp. 281–288, 2015, doi: 10.5380/rf.v45i2.36954.

[7] T. Lei, Z. Wang, Z. Li, J. Xu, X. He, and J. Zhu, "A biomass briquetting fuel machine and its large-scale operation system," *Journal of Renewable and Sustainable Energy*, vol. 5, no. 1, 2013, doi: 10.1063/1.4781089.

[8] D. Wilczyński, I. Malujda, J. Górecki, and P. Jankowiak, "Research on the process of biomass compaction in the form of straw," *MATEC Web of Conferences*, vol. 254, p. 05015, 2019, doi: 10.1051/matecconf/201925405015.

[9] K. Baiul *et al.*, "A Novel Approach to the Screw Feeder Design to Improve the Reliability of Briquetting Process in the Roller Press," *Eksploatacja i Niezawodność – Maintenance and Reliability*, vol. 25, no. 3, 2023, doi: 10.17531/ein/167967.

[10] J. I. Orisaleye, S. J. Ojolo, and J. S. Ajiboye, "Pressure build-up and wear analysis of tapered screw extruder biomass briquetting machines," *Agricultural Engineering International*, vol. 21, no. 1, 2019

[11] Yahaya U. JAURO, Danladi D. USMAN, Lawan G. ABUBAKAR, Yusuf G. SHIMBURA, and Aminu MOHAMMED, "Design and Fabrication of Tapered Screw Briquetting Machine," *FUDMA Journal of Engineering and Technology*, vol. 2, no. 1, pp. 51–58, 2026, doi: 10.33003/1wbff883.

[12] J. Yirijor and A. A. T. Bere, "Production and characterization of coconut shell charcoal-based

bio-briquettes as an alternative energy source for rural communities," *Heliyon*, vol. 10, no. 16, p. e35717, 2024, doi: 10.1016/j.heliyon.2024.e35717.

[13] N. Yarramsetty, V. S. Chinta, K. K. Amireddy, N. K. S, V. Sandhya, and J. Narne, "Sustainable Energy from Biomass Waste: Design and Fabrication of a Screw Briquetting Machine with Calorific Value Assessment," *International Journal of Mechanical Engineering*, vol. 12, no. 11, pp. 48–54, 2025, doi: 10.14445/23488360/IJME-V12I11P105.

[14] H. M. P. Marreiro, R. S. Peruchi, R. M. B. P. Lopes, S. L. F. Andersen, S. A. Eliziário, and P. Rotella Junior, "Empirical Studies on Biomass Briquette Production: A Literature Review," *Energies (Basel).*, vol. 14, no. 24, p. 8320, 2021, doi: 10.3390/en14248320.

[15] O. F. Obi, R. Pecenka, and M. J. Clifford, "A Review of Biomass Briquette Binders and Quality Parameters," *Energies (Basel).*, vol. 15, no. 7, p. 2426, 2022, doi: 10.3390/en15072426.

[16] A. Kocer, O. Kabas, and B. S. Zabava, "Estimation of Compressive Resistance of Briquettes Obtained from Groundnut Shells with Different Machine Learning Algorithms," *Applied Sciences (Switzerland)*, vol. 13, no. 17, 2023, doi: 10.3390/app13179826.

[17] A. Adeleke, J. Odusote, P. Ikubanni, O. Lasode, M. Malathi, and D. Pasawan, "Physical and mechanical characteristics of composite briquette from coal and pretreated wood fines," *International Journal of Coal Science and Technology*, vol. 8, no. 5, pp. 1088–1098, 2021, doi: 10.1007/s40789-021-00438-0.

[18] United Nations, "United Nations Sustainable Development Goals." Accessed: Jul. 24, 2026. [Online]. Available: https://sdgs.un.org/goals

[19] V. J. P. Sundar, Dr. P. M. D'Souza, J. V. Donipati, and T. Kranthi, "Development and evaluation of a screw press briquetting machine for biomass fuel production," *International Journal of Advanced Biochemistry Research*, vol. 8, no. 11, pp. 259–267, 2024, doi: 10.33545/26174693.2024.v8.i11d.2841.

[20] D. Y. Yang and K. J. Kim, "Design of processes and products through simulation of three-dimensional extrusion," *Journal of Materials Processing Technology*, vol. 191, no. 1–3, pp. 2–6, 2007, doi: 10.1016/j.jmatprotec.2007.03.088.

[21] A. G. Mekonen, G. G. Berhe, M. B. Desta, F. A. Belete, and A. F. Gebremariam, "Production and characterization of briquettes from sugarcane bagasse of Wonji Sugar Factory, Oromia, Ethiopia," *Materials for Renewable and Sustainable Energy*, vol. 13, no. 1, pp. 27–43, 2024, doi: 10.1007/s40243-023-00248-1.

[22] S. Y. Kpalo, M. F. Zainuddin, L. A. Manaf, and A. M. Roslan, "A Review of Technical and Economic Aspects of Biomass Briquetting," *Sustainability*, vol. 12, no. 11, p. 4609, 2020, doi: 10.3390/su12114609.

[23] A. M. K. Abdel Aal, O. H. M. Ibrahim, A. Al-Farga, and E. A. El Saeidy, "Impact of Biomass Moisture Content on the Physical Properties of Briquettes Produced from Recycled Ficus nitida Pruning Residuals," *Sustainability (Switzerland)*, vol. 15, no. 15, 2023, doi: 10.3390/su151511762.

[24] J. Escalante and J. Alcaraz, "Performance of a locally developed automated screw-type charcoal briquetting machine," *SciEnggJ*, vol. 18, no. 1, pp. 44–50, 2025, doi: 10.54645/2025181LIL-35.

[25] M. Temmerman, "Briquette Production Manual: Basic and Advanced Technology," Copenhagen, Denmark, 2019.

[26] Tanzania Industrial Research and Development Organization, *Biomass Briquetting Handbook*. Dar es Salaam, Tanzania: Tanzania Industrial Research and Development Organization (TIRDO), 2023.

[27] P. D. Grover and S. K. Mishra, "Biomass Briquetting: Technology and Practices," 1996.

[28] J. K. Tanui, P. N. Kioni, P. N. Kariuki, and J. M. Ngugi, "Influence of processing conditions on the quality of briquettes produced by recycling charcoal dust," *International Journal of Energy and Environmental Engineering*, vol. 9, no. 3, pp. 341–350, 2018, doi: 10.1007/s40095-018-0275-7.

[29] T. A. Mamvura and G. Danha, "Biomass torrefaction as an emerging technology to aid in energy production," *Heliyon*, vol. 6, no. 3, p. e03531, 2020, doi: 10.1016/j.heliyon.2020.e03531.

[30] W. Gwenzi, R. S. Ncube, and T. Rukuni, "Development, properties and potential applications of high-energy fuel briquettes incorporating coal dust, biowastes and post-consumer plastics," *SN Applied Sciences*, vol. 2, no. 6, 2020, doi: 10.1007/s42452-020-2799-8.

[31] O. K. Fadele, T. O. Amusan, A. O. Afolabi, and C. A. Ogunlade, "Characterisation of briquettes from forest wastes: Optimisation approach," *Research in Agricultural Engineering*, vol. 67, no. 3, pp. 138–147, 2021, doi: 10.17221/6/2021-RAE.

[32] R. S. Bello and M. A. Onilude, "Physico-mechanical Characteristics of High Density Briquettes produced from Composite Sawdust," *Journal of Applied Sciences and Environmental Management*, vol. 24, no. 5, pp. 779–787, 2020, doi: 10.4314/jasem.v24i5.8.

[33] A. Fadeyibi, K. R. Adebayo, T. M. Obafemi, A. S. Olubo, R. A. Busari, and M. G. Yisa, "Development and evaluation of biomass-based alternative charcoal," *Journal of Agricultural Engineering*, vol. 51, no. 3, pp. 161–168, 2020, doi: 10.4081/jae.2020.1032.

[34] J. I. Orisaleye, S. O. Jekayinfa, C. Dittrich, O. F. Obi, and R. Pecenka, "Effects of Feeding Speed and Temperature on Properties of Briquettes from Poplar Wood Using a Hydraulic Briquetting Press," *Resources*, vol. 12, no. 1, 2023, doi: 10.3390/resources12010012.

[35] S. E. Ibitoye, T.-C. Jen, R. M. Mahamood, and E. T. Akinlabi, "Densification of agro-residues for sustainable energy generation: an overview Bioresources and Bioprocessing, vol. 8, no. 1, p. 75, 2021, doi: 10.1186/s40643-021-00427-w.

[36] E. Puzzolo *et al.*, "Supply Considerations for Scaling Up Clean Cooking Fuels for Household Energy in Low- and Middle-Income Countries," *Geohealth*, vol. 3, no. 12, pp. 370–390, 2019, doi: 10.1029/2019GH000208.

[37] J. S. Lupoi, E. Gjersing, and M. F. Davis, "Evaluating Lignocellulosic Biomass, Its Derivatives, and Downstream Products with Raman Spectroscopy," *Frontiers in Bioengineering and Biotechnology*, vol. 3, 2015, doi: 10.3389/fbioe.2015.00050.

[38] R. I. Muazu, A. L. Borrion, and J. A. Stegemann, "Life Cycle Assessment Model for Biomass Fuel Briquetting," *Waste Biomass Valorization*, vol. 13, no. 4, pp. 2461–2476, 2022, doi: 10.1007/s12649-021-01596-7.

[39] A. A. Huda and A. Dwi Catur, "Design and performance analysis of a coconut coir briquette press machine using an electric motor-driven screw extruder system," *Jurnal Agrotek Ummat*, vol. 13, no. 2, pp. 125–140, 2026, doi: 10.31764/jau.v13i2.48.

[40] N. P. Carnaje, R. B. Talagon, J. P. Peralta, K. Shah, and J. Paz-Ferreiro, "Development and characterisation of charcoal briquettes from water hyacinth (Eichhornia crassipes)-molasses blend," *PLoS One*, vol. 13, no. 11, 2018, doi: 10.1371/journal.pone.0207135.

[41] C. Gong, S. T. Thomsen, L. G. Thygesen, and C. Felby, "Effects of preheating on briquetting and subsequent hydrothermal pretreatment for enzymatic saccharification of wheat straw," *Biotechnology Progress*, vol. 35, no. 4, 2019, doi: 10.1002/btpr.2808.

[42] Q. L. Zhao, F. J. Chen, Y. Y. Wang, and B. L. Zhang, "Combustion properties of straw briquettes," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 5, no. 11, pp. 3226–3229, 2013, doi: 10.19026/rjaset.5.4561.

[43] M. Milos, P. Križan, L. Soos, and J. Beniak, "Development of double screw press and method of controlling the parameters of the briquetting process," *Global Journal of Engineering and Technology Advances*, vol. 9, no. 3, pp. 050–058, 2021, doi: 10.30574/gjeta.2021.9.3.0173.