Available *online* at: https://journal.gioarchitect.co.id/index.php/localengineering/issue/current

Local Engineering

Journal of Local Architecture and Civil Engineering

| Doi: 10.59810/localengineering | ISSN (Online) 2987-7555 |

Architecture – Research Article

Biomass Pelletizing Machines as a Tool for Waste Valorization and Renewable Energy: A Review Based on an Indigenous Machine Development

Oladimeji A. O., Fawohunre A. J., Olajide O. G.

Department of Agricultural and Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria.

ARTICLE INFORMATION

Received: August 21, 2025
Revised: October 16, 2025
Available online: December 01, 2025

KEYWORDS

Agricultural waste, biomass pelletizing, briquettes, machine design, performance evaluation, renewable energy

CORRESPONDENCE

Oladimeji A. O.

E-mail: azeeztreasure@gmail.com

ABSTRACT

Biomass pelletizing technology is increasingly recognized as a sustainable solution to address global energy demands, waste management challenges, and rural energy poverty. This review presents a comprehensive analysis of biomass pelletizing technology through the lens of a recent research study that involved the design, fabrication, and performance evaluation of an indigenous biomass pelletizing machine in Nigeria. The paper discusses the global relevance of biomass as an energy source, the significance of agricultural waste valorization, the mechanical design principles behind pelletizing equipment, and the technical outcomes of a locally built machine. Key findings revealed an average pelleting capacity of 10.62 kg/hr and an efficiency of 64.8%, with proximate and ultimate analyses supporting the suitability of agricultural waste materials for fuel pellets. The review concludes by affirming the value of biomass pelletizers in fostering sustainable rural development and energy security.

INTRODUCTION

The ongoing global energy crisis and environmental degradation have propelled interest in renewable alternatives to fossil fuels. Over 80% of global energy consumption still comes from fossil sources, contributing significantly to greenhouse gas emissions and climate change (IEA 2021). Biomass, especially agricultural residues, has emerged as a promising and underutilized energy resource.

In Nigeria, with over 79 million hectares of arable land and a largely agrarian population, the abundance of crop waste offers considerable potential. Yet much of this biomass is discarded or improperly managed, posing both environmental hazards and lost economic opportunities. Biomass pelletizing machines can help address these issues by converting waste into high-energy-density fuel for cooking, heating, and power generation (Demirbas, 2020; Ghorbani et al. 2017).

Agricultural waste and biomass energy potential

Agricultural waste includes materials like corn stalks, husks, sawdust, cocoa pods, and other residues generated during farming and processing activities. While often treated as waste, these materials have significant calorific value. Globally, biomass contributes 10–14% of total energy consumption (McKendry 2002).

The reviewed study utilized sawdust, corn cobs, cocoa pods, and monkey kola as feedstocks. Their transformation into pellets enhances combustion efficiency, improves transportation, and minimizes waste accumulation (Lim et al. 2012). Biomass pellets are carbon-neutral, as the CO_2 released during combustion is offset by that absorbed during plant growth (Demirbas 2020).

Design and fabrication of the pelletizing machine

The indigenous pelletizing machine was designed with affordability, simplicity, and local material availability in mind. Major components include: Feeding chamber, Die and roller

©2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY-NC-SA 4.0 DEED) license (https://creativecommons.org/licenses/by-nc-sa/4.0/)

press assembly, Shaft and bearing assembly and Electric motor (prime mover).

Design considerations were based on material strength, ease of fabrication, and mechanical reliability (Kaliyan & Morey, 2009). The machine's die and roller configuration aimed to ensure adequate compression and pellet formation while avoiding excessive energy demands.

Performance evaluation and results

The developed pelletizer was evaluated for its pelleting capacity, efficiency, and fuel quality of resulting pellets.

Pelleting Capacity and Efficiency

The machine achieved an average pelleting capacity of 10.62 kg/hr and an average efficiency of 64.8%, calculated as the ratio of output pellets to input biomass material. These values compare favorably with similar small-scale pelletizers reported in the literature (Karkania et al. 2012).

Ultimate and Proximate Analyses

Carbon content was highest in corn husk briquettes (12.6%), supporting its strong combustion potential. Nitrogen content was also higher in corn husk (6.3%), influencing NOx emission potential.

Ash content varied significantly, with cocoa pod (5.6%) showing the lowest ash—indicating higher quality—while corn husk reached 14.07%, which could lower combustion efficiency (Food and Agriculture Organization, 1996). Moisture content ranged between 6.78–12.26%, aligning with optimum conditions for durable pellet formation. Low moisture and ash content are desirable for stable combustion and minimal smoke.

Technical considerations in biomass pelletizing

Key design and performance factors include:

Die and roller geometry: Affects compression, pellet durability, and throughput (Borén et al., 2016).

Feedstock characteristics: Lignin content, moisture, and particle size influence binding and density (Kaliyan & Morey, 2010).

Binder usage: Pupuru flour was used as a binder in a 100:100 ratio with biomass samples. Binders improve cohesion but may reduce fuel quality if used excessively (Stelte et al., 2012).

Mechanical durability and energy consumption trade-offs must be balanced to optimize output without increasing operational costs.

Environmental and economic relevance

Biomass pelletization achieves several environmental and economic goals:

Environmental Benefits: Mitigates open burning of waste (Saidur et al. 2011).

Reduces methane emissions from decaying organic matter (Skreiberg et al. 2012).

Promotes cleaner household energy use

Economic Opportunities: Adds value to waste that was previously discarded (Mahapatra et al. 2019).

Reduces rural energy poverty, Encourages local entrepreneurship and job creation. The indigenous machine's low-cost build and straightforward operation enable rural adoption and localized fuel supply chains.

Challenges and future improvements

While the fabricated machine is cost-effective and functional, it has certain limitations:

Manual feeding and discharge reduce throughput. Wear and tear of die-roller system affects long-term performance. Pellet density was moderate due to limited compaction pressure compared to commercial units (Mani et al. 2004). Future improvements may include integrating automated feeding, increasing die compression ratios, and introducing variable speed drives to optimize pressure for different biomass types (Tumuluru et al. 2014).

Contribution to indigenous technological development

This study contributes to national development goals in several ways:

Demonstrates locally adaptable technology for renewable energy generation. Encourages small-scale mechanization for waste utilization. Provides empirical data on briquette fuel characteristics from Nigerian biomass. Reinforces the need for rural-based, sustainable energy systems (Njenga et al., 2019). Such innovations support the decentralization of energy production and align with broader strategies for circular economy development in sub-Saharan Africa.

Conclusion

The design and evaluation of a biomass pelletizing machine using locally sourced materials and biomass feedstocks represent a pivotal step toward sustainable rural energy solutions in Nigeria. The system provides a viable pathway for waste-to-energy conversion, enhances agricultural resource utilization, and addresses pressing environmental and energy concerns. Although there is room for technical refinement, the study demonstrates that simple, affordable technologies can significantly contribute to climate action and energy equity.

REFERENSI

Borén, E., Larsson, S. H., & Tumuluru, J. S. (2016). Pelletizing properties of torrefied spruce. Fuel Processing Technology, 148, 184-192.

Ghorbani, R., Zarrabi, H., Tabatabaei, M., & Keyhani, A. (2017). The effect of moisture content and particle size on the quality of wood pellets produced from sugarcane bagasse and eucalyptus sawdust. Energy Conversion and Management, 150, 136-145

Demirbas, A. (2020). Biomass pellets for heat and power production. Elsevier.

 https://doi.org/10.59810/lejlace.v3i2.215

IEA (2021), World Energy Balances: Overview, IEA, Paris https://www.iea.org/reports/world-energy-balances-overview, Licence: CC BY 4.0

Kaliyan, N., Morey, R. V., & White, D. R. (2011). Drying kinetics of switchgrass. Biosystems Engineering, 108(2), 120-129.

Karkania, V., Fanara, E. & Zabaniotou, A., Review of sustainable biomass pellets production – a study for agricultural residues pellets' market in Greece. Renewable & Sustainable Energy Reviews, 16, pp. 1426–1436, 2012.

Lim J.S., Manan Z.A., Alwi S.R.W., Hashim H. 2012. A review on utilization of biomass from rice industry as a source of renewable energy. Renewable and Sustainable Energy Reviews, 16: 3084–3094.

Mani, S., Tabil, L. G., & Sokhansanj, S. (2006). Grinding performance and physical properties of wheat and barley straws, corn stover, and switchgrass. Biomass and Bioenergy, 30(11), 961-969.

Mahapatra, A., Khoiyangbam, R. S., & Kumar, A. (2019). Techno-economic analysis of decentralized biomass pellet production: A case study in India. Biomass and Bioenergy, 126, 39-48

McKendry, P. (2002). Energy production from biomass (part 1): overview of biomass. Bioresource Technology, 83(1), 37-46.

Njenga, M., Muthoni, F., Reddy, K., & Sieglinde, S. (2019). Impact of briquetting parameters: moisture content and particle size on briquette fuel characteristics and indoor air pollution. Biomass Conversion and Biorefinery, 9(3), 605-616.Shahzad, U. (2012). The need for renewable energy sources. International Journal of Information Technology & Electrical Engineering, 2, 16-18.

Saidur, R., Abdelaziz, E. A., Demirbas, A., Hossain, M. S., & Mekhilef, S. (2011). A review on biomass as a fuel for boilers. Renewable and Sustainable Energy Reviews, 15(5), 2262-2289.

Skreiberg, Ø., Várhegyi, G., & Kjelstrup, S. (2012). Co-firing of biomass with coal: Constraints and role of biomass pretreatment. Energy & Fuels, 26(1), 145-161.

Stelte, W., Holm, J. K., Sanadi, A. R., Barsberg, S., & Ahrenfeldt, J. (2012). Effects of feedstock type and pre-treatment on solid product composition and bio-oil produced by fast pyrolysis. Biomass and Bioenergy, 46, 561-572.

Tumuluru, J. S., Sokhansanj, S., Hess, J. R., & Wright, C. T. (2014). A review on biomass pelletization: Process, combustion and sustainability. Biomass and Bioenergy, 46, 475-485.

This page is intentionally left blank

https://doi.org/10.59810/lejlace.v3i2.215