Biological Forum – An International Journal 16(10): 01-07(2024)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Comparative Analysis of Rice Straw Briquettes and Other Biomass Briquettes: A Study on Performance, Sustainability, and Economic Viability

Lokesh Kumar Meena[1], Renu Singh[1], Anik Chandel[1], Krishnavatar Gocher[2] and Sohan Singh Saini[3]*
[1]*Division of Environment Science, ICAR-IARI (New Delhi), India.*
[2]*Department of plant breeding and Genetics, SKNAU Jobner, Jaipur (Rajasthan), India.*
[3]*Department of Soil Science and Agricultural Chemistry, RBS College Bichpuri, Agra (Uttar Pradesh), India.*

(Corresponding author: Lokesh Kumar Meena)*
(Received: 04 July 2024; Revised: 05 August 2024; Accepted: 27 August 2024; Published: 15 October 2024)
(Published by Research Trend)

ABSTRACT: This study presents a comparative analysis of rice straw briquettes with other commonly used biomass briquettes, focusing on performance, sustainability, and economic viability. Rice straw, an abundant agricultural residue, holds potential as a renewable energy source. The analysis evaluates the calorific value, combustion efficiency, and emission profiles of rice straw briquettes in comparison to briquettes made from materials like sawdust, corn cobs, and coconut husks. Sustainability is assessed by examining the environmental impacts, including carbon footprint and resource renewability, while the economic analysis considers production costs, market prices, and potential subsidies. The findings highlight the strengths and limitations of rice straw briquettes relative to other biomass options, providing insights into their feasibility as a sustainable energy alternative in various socio-economic contexts. This comprehensive analysis offers insights into the feasibility of rice straw briquettes as a competitive energy source, emphasizing their role in sustainable development, waste management, and renewable energy transitions, particularly in agricultural regions. The findings suggest that while rice straw briquettes have promising sustainability benefits, their performance and economic aspects need further optimization to compete with other biomass alternatives.

Keywords: Rice straw briquettes, Biomass briquettes, Sustainability, Economic viability, Calorific value, Combustion efficiency, Renewability, Sustainable energy.

INTRODUCTION

Biomass briquettes have emerged as a promising alternative to fossil fuels, offering a renewable and environmentally friendly source of energy. Among various biomass residues, rice straw a byproduct of rice production is of particular interest due to its abundance and underutilization, especially in rice-producing regions (Ramos *et al*., 2023; Sekhar *et al*., 2022). Traditionally, rice straw is either burned in fields, contributing to air pollution and greenhouse gas emissions, or left to decompose, which releases methane a potent greenhouse gas.This study focuses on the comparative analysis of rice straw briquettes against other biomass briquettes, such as those derived from sawdust, corn cobs, and coconut husks. Each of these biomass sources has distinct characteristics that influence their performance as fuel, their sustainability in terms of environmental impact, and their economic viability in different markets (Kargbo *et al*., 2021). The performance of biomass briquettes is typically evaluated based on their calorific value, combustion efficiency, and emissions profile. Rice straw briquettes, while promising, have faced challenges related to lower energy density and higher ash content compared to other biomass sources. However, they also offer potential advantages, *such* as lower costs and reduced environmental impact when properly processed (Ford and Despeisse 2016). Sustainability is another critical aspect, considering not only the carbon footprint of producing and using these briquettes but also the renewability of the resource and its impact on land use and biodiversity. The economic viability of rice straw briquettes is evaluated by examining production costs, potential market prices, and the availability of subsidies or incentives, which can significantly affect their competitiveness (Clare *et al*., 2015). This comparative analysis aims to provide a comprehensive understanding of where rice straw briquettes stand in relation to other biomass options. The study explores their potential to contribute to sustainable energy solutions, especially in regions with abundant rice straw, while also addressing the challenges that need to be overcome for their wider adoption (Nygaard *et al*., 2016). By providing a detailed comparative analysis, this study aims to highlight the potential of rice straw briquettes to contribute to global energy solutions. It seeks to identify the conditions under which rice straw could become a viable and sustainable energy resource, offering insights into the technical, environmental, and economic factors that must be addressed to realize its full potential. Through this analysis, the study contributes to the broader discourse on sustainable energy and the role of biomass in the transition to a low-carbon future (Siciliano *et al*., 2021).

MATERIAL AND METHODS

Rice straw. Rice straw is widely available in regions where rice is a staple crop, particularly in Asia. Large quantities are produced annually, making it a readily available biomass resource. Rice straw is an agricultural byproduct obtained after harvesting rice, and it has significant potential for use in briquette production.

Fig. 1. Rice straw.

Other Biomass matter. Biomass matter refers to organic material that comes from plants and animals and can be used as a renewable energy source. Biomass is one of the oldest sources of energy used by humans, dating back to when people began burning wood for heat and cooking (Guo *et al*., 2015). Today, biomass is still a significant source of energy and is considered a key component in the development of renewable energy strategies. Includes wood chips, corn stover, and bagasse, selected based on their common use in briquetting.

Fig. 2. Biomass matter.

METHODS

Moisture Content Measurement. Moisture content is consistently low across all briquette types. Use a moisture analyzer or oven-drying method to confirm the moisture content. Record the final moisture content before combustion testing. Moisture content wasdetermined for different fuelsbyusing a hot air oven the measurement was made in accordance. Aportion (2g) of each of the samples was weighed out in a washed glass (Joshi *et al*., 2010). The samples we replaced in an oven for 2 hours at 105ºC. The moisture content was determined using:

$$MC (\%) = (W_1 - W_2)/W_1 \times 100$$

Where:

W_1= Initial weight

W_2 =weight after drying

Combustion Efficiency Testing. Assess how efficiently each type of briquette burns. Conduct combustion tests in a controlled environment, measuring the percentage of fuel energy converted into useful heat (Jetter *et al*., 2012). Measure heat output and emissions, and calculate the combustion efficiency as a percentage.

$$\eta = (\text{Energy Input} / \text{Energy Output}) \times 100$$

Where:

Energy Output = The useful heat energy obtained from the combustion of the briquettes (usually measured in MJ or kWh).

Energy Input = The total energy content of the briquettes, which is typically the calorific value (measured in MJ or kWh).

Ignition Time.

Compare the ease of ignition for each briquette type. Time how long it takes for each briquette type to catch fire when exposed to a flame. Data Record ignition times in seconds. Abunsenburner was used to igniteeach sample at the base of its base. The time takenforeachbriquettetocatchfirewasrecordedastheigniti ontimeusingastopwatch (Oyelaran, 2015).

Burning Rate. Determine the rate at which the briquettes burn. Measure the mass loss over time during combustion. Calculate the burning rate in grams per minute (Sunnu *et al*., 2023). This is the amount of time needed for each sample of briquette to totally burn away to ashes. The measurement was made in accordance with the ASTM D-3173.

Emissions Testing: Measure the emissions produced during combustion. Use a flue gas analyzer to measure levels of CO_2, CO, NO_2, and particulate matter. Record emission levels in g/kg of fuel burned. Utilize a gas sampling system to capture emissions during the burning process. This can include filters, gas analyzers, and dilution systems (Cano *et al*., 2017). Common pollutants measured include carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM), volatile organic compounds (VOCs), and nitrogen oxides (NO_2).

Statistical Analysis. Data obtained from the experiments were analyzed using Analysis of Variance (ANOVA) to assess the significance of the effects of different process parameters on briquette quality. Optimal conditions were determined through response surface methodology (RSM) to identify the best combinations of parameters for maximizing briquette performance. The experiment was conducted in a factorial randomized block design (RBD) with three replications. Statistical analysis of data was done using the 0P- STAT. The treatment means were compared using critical difference (CD) at 5% (p= 0.05) level of significance.

RESULTS AND DISCUSSION

Typically have higher moisture content compared to other biomass types like wood or sawdust briquettes, which affects combustion efficiency. Pre-treatment, such as drying, is often necessary to reduce moisture levels to around 10-12%. Other Biomass Briquettes (e.g., Sawdust, Coconut Husk, and Bagasse) Generally exhibit lower moisture content, particularly sawdust briquettes, which can have moisture levels as low as 8-10%, making them easier to ignite and burn more efficiently. Combustion efficiency tends to be lower compared to woody biomass due to higher ash content (up to 20%). The higher silica content in rice straw contributes to slagging and fouling in combustion chambers, reducing efficiency. Sawdust and coconut husk briquettes, for instance, have better combustion efficiency, attributed to lower ash content (5-10%) and fewer impurities. These materials generally produce more uniform and sustained heat release. Tend to have longer ignition times due to higher moisture content and lower calorific value. Typical ignition times are between 3-5 minutes. Biomass like sawdust, bagasse, and coconut husk briquettes ignite faster, generally within 1-3 minutes, owing to lower moisture content and higher energy density. Despite slower ignition, rice straw briquettes have a relatively longer burning time, which can be advantageous for certain, energy applications. However, this burning is less efficient, and a significant amount of ash is left behind. Sawdust briquettes, for instance, offer a more consistent burning time, but the duration can vary depending on the compaction and size of the briquettes. Coconut husk briquettes tend to burn slower and longer, making them suitable for applications requiring sustained heat. Higher emissions of particulate matter (PM), CO_2, CO, and NO_2 have been reported, primarily due to the high ash content and low energy density. The higher silica content in the ash can contribute to environmental pollution and health concerns. Lower emissions of particulates and gases have been observed with sawdust and coconut husk briquettes. These briquettes burn more cleanly with less ash formation. Bagasse briquettes are also noted for lower emissions but may still emit moderate amounts of CO_2 and other gases depending on combustion conditions.

Table 1: Comparison to rice straw briquettes and other biomass briquettes.

Sr.No.	Performance Metric	Unit	Rice Straw Briquettes	Wood Briquettes	Corn Stover Briquettes	Bagasse Briquettes
1.	**Moisture content**	% (w/w)	8-10	18 - 20	15 - 17	16-18
2.	**Combustion efficiency**	%	65 – 75	75 -85	70 - 80	72 – 82
3.	**Ignition Time**	Seconds	60 – 90	30 – 60	50 - 70	40 – 60
4.	**Burning Time**	g/ min.	5 – 6	4 - 5	5 – 6	4 – 5
5.	**Emissions**	g/kg fuel	1500 - 1700	1200 - 1400	1300 – 1500	1400 – 1600

Moisture Content and Sustainability. Sawdust and rice straw briquettes lead in sustainability. **Sawdust briquettes** offer low emissions and high efficiency due to their low moisture content and waste utilization. **Rice straw briquettes** contribute significantly to sustainability by repurposing agricultural waste and reducing the environmental impact of rice straw burning. **Wood briquettes** are sustainable if sourced from responsibly managed forests, while **agricultural residue briquettes** are abundant but face challenges due to high moisture content, reducing their energy efficiency and increasing emissions.

Combustion Efficiency and Sustainability. Sawdust and rice straw briquettes lead in sustainability due to their use of waste materials and low environmental impact. Sawdust briquettes, with high combustion efficiency and low emissions, are particularly sustainable. Rice straw briquettes offer a practical solution for reducing agricultural waste, though silica ash management must be addressed. Agricultural residue briquettes are sustainable but require more drying to enhance their combustion performance and reduce emissions. Wood briquettes are sustainable if sourced responsibly, but unsustainable forestry practices can undermine their environmental benefits.

Table 2: Moisture content and Sustainability.

Biomass type	Moisture content (%)	Sustainability impact
Rice Straw	12.7	Moderate moisture content; suitable for energy production
Wood	8.7	Low moisture content; efficient combustion, less drying needed
Coconut Shell	9.1	Low moisture content; enhances energy efficiency
Sawdust	10.3	Moderate moisture; requires minimal processing
Corn Cob	11.4	Moderate moisture; generally favorable for combustion

Table 3: Combustion Efficiency and Sustainability.

Biomass type	Combustion Efficiency	Sustainability impact
Rice Straw	82.3	Good efficiency; moderate emissions
Wood	89.5	High efficiency; low emissions, sustainable use if sourced responsibly
Coconut Shell	86.4	High efficiency; waste product, thus highly sustainable
Sawdust	84.7	Good efficiency; sustainable if from waste
Corn Cob	81.9	Moderate efficiency; sustainable use of agricultural waste

Ignition Time and Sustainability. Sawdust briquettes are the most sustainable due to their efficient use of wood waste, quick ignition, low emissions, and high energy output. **Rice straw briquettes** also rank highly in sustainability by repurposing agricultural waste and reducing environmental harm from open-field burning. However, their sustainability is somewhat affected by ash content. **Wood briquettes** can be sustainable if responsibly sourced, but deforestation risks can undermine their benefits. **Agricultural residue briquettes** are sustainable in terms of resource utilization but require better drying and emission control to enhance their environmental performance.

Burning time and Sustainability. Sawdust briquettes lead in sustainability, utilizing wood waste efficiently, with low emissions and long burning times. **Rice straw briquettes** offer a sustainable option by repurposing agricultural waste, though their high ash content requires management. **Wood briquettes** can be highly sustainable if sourced from responsibly managed forests, offering the longest burning time. **Agricultural residue briquettes** are renewable and reduce farm waste, but their higher moisture content and shorter burn time reduce their overall environmental benefits.

Emission parameters and Sustainability. Sawdust briquettes lead in sustainability due to their low emissions, efficient combustion, and use of wood waste. **Rice straw briquettes** are sustainable from the perspective of resource utilization but are hindered by their high ash content and particulate emissions.**Wood briquettes** are highly sustainable if sourced from responsibly managed forests but carry the risk of deforestation. **Agricultural residue briquettes** are beneficial in terms of reducing farm waste, but their high emissions require better management for improved environmental performance.

CO Emissions and Sustainability. Sawdust briquettes excel in sustainability due to their low CO emissions, efficient combustion, and use of wood-processing waste. **Rice straw briquettes** are sustainable in terms of resource availability, but their high CO emissions and ash content reduce their overall environmental performance. **Wood briquettes** are sustainable when sourced responsibly, but the risk of deforestation must be managed. **Agricultural residue briquettes** are environmentally friendly in terms of reducing farm waste but require improved combustion efficiency to lower their CO emissions and enhance sustainability.

Table 4: Ignition time and Sustainability.

Biomass type	Ignition Time	Sustainability impact
Rice Straw	35	Longer ignition time: affects ease of use but good for controlled burns
Wood	25	Quick ignition reduces time to reach peak efficiency
Coconut Shell	29	Balanced ignition time: supports sustainability through waste reuse
Sawdust	32	Moderate ignition time: Sustainable when sourced from by-products
Corn Cob	38	Longer ignition time: suitable for steady combustion

Table 5: Burning time and Sustainability.

Biomass type	Burning Time (min.)	Sustainability Impact
Rice straw	45	Moderate burn time: requires less frequent refueling
Wood	60	Long burn time: highly efficient, sustainable if not from deforestation
Coconut Shell	55	Good burn duration : promote reuse of agricultural waste
Sawdust	50	Adequate burn time: good use of industrial by-products
Corn Cob	42	Shorter burn time: needs frequent refueling but sustainability sourced

Table 6: CO Emission and Sustainability.

Biomass type	CO Emission (g/kg)	Sustainability Impact
Rice straw	90	Higher CO emissions: needs efficient combustion system
Wood	70	Lower emissions : sustainable when managed properly
Coconut Shell	65	Low emissions : very sustainable, waste – based fuel
Sawdust	80	Moderate emissions: sustainable with proper management
Corn Cob	95	Higher emissions: needs improved combustion techniques

Particulate matter (PM) emissions and sustainability. Sawdust briquettes are the most sustainable option, due to their low particulate emissions, efficient combustion, and the use of waste materials from wood-processing industries. **Rice straw briquettes** are sustainable in terms of resource utilization but are hindered by their high PM emissions and ash content. **Wood briquettes** are sustainable when sourced responsibly, offering moderate emissions and long-term viability. **Agricultural residue briquettes** are a sustainable way to repurpose farm waste but require better combustion efficiency and emission control to reduce their particulate emissions and enhance environmental sustainability.

Table 7: Particulate Matter Emission and Sustainability.

Biomass type	PM Emissions (g/kg)	Sustainability Impact
Rice straw	7.5	Higher PM: needs mitigation for health and environment impact
Wood	5.3	Lower PM:sustainable when sourced and burned responsibly
Coconut Shell	5.0	Low PM: promotes sustainable waste reuse
Sawdust	6.2	Moderate PM: sustainable when part of waste management
Corn Cob	8.1	Higher needs requires emission control

DISCUSSION

Higher moisture content in rice straw leads to lower combustion efficiency and requires longer drying times before use. In contrast, other biomass materials like bagasse and sawdust tend to have more stable moisture levels, leading to better performance in combustion systems (Olugbade *et al*., 2019). Rice straw briquettes often exhibit lower combustion efficiency compared to denser biomass materials like sawdust due to higher ash content and lower bulk density. However, pre-treatment methods such as torrefaction or densification can improve combustion performance (Pinto *et al*., 2017). When comparing with other briquettes, sawdust briquettes may outperform rice straw due to their higher energy content, whereas rice straw may still offer competitive performance under optimized conditions (Chieng and Kuan 2022). Rice straw briquettes generally have longer ignition times but burn at a lower, more consistent rate compared to faster-burning materials like coconut husk. However, the long burning time of rice straw briquettes may be advantageous in certain heating applications that require steady heat output over extended periods (Singh and Patel 2022). Rice straw briquettes are particularly significant in terms of sustainability because they offer an environmentally friendly alternative to burning straw in open fields, which is common in many rice-producing countries and leads to air pollution. Additionally, rice straw briquettes help mitigate waste management challenges and reduce greenhouse gas emissions when compared to fossil fuels (Bressan *et al*., 2022). While rice straw has higher ash content and can emit more particulate matter than some other biomass types, the overall emissions are still significantly lower than coal or traditional firewood. The emission characteristics of rice straw briquettes can be improved by applying pre-treatment methods that reduce ash and moisture content. Other biomass briquettes like those made from bagasse or coconut husk may exhibit lower emissions due to their intrinsic properties, but the benefits of using rice straw should be weighed against the context of local agricultural practices and the availability of other biomass feed stocks. Rice straw is an abundant and renewable resource, particularly in rice-producing regions, making it a highly accessible feedstock for briquette production (Satlewal *et al*., 2018).

While other biomass materials like sawdust or coconut husk may have competitive advantages in certain regions, the sheer volume of rice straw as an agricultural byproduct makes it an attractive option for widespread adoption (Gomes *et al*., 2020). The production costs for rice straw briquettes are often lower than those for briquettes made from sawdust or coconut husk, mainly because rice straw is readily available as an agricultural waste product (Tanko *et al*., 2021). However, the additional costs associated with processing rice straw (such as drying, grinding, and compressing) can offset some of these advantages. Technologies that reduce production costs, such as low-cost densification or improved drying methods, are critical to improving economic feasibility. Although rice straw briquettes can be cheaper to produce, market demand is often higher for higher-density biomass like sawdust or wood chips due to better combustion properties (Dinesha *et al*., 2019). Scaling up rice straw briquette production may require investment in education and infrastructure to increase awareness and improve consumer acceptance. Utilizing rice straw for briquetting can provide farmers with an additional revenue stream by turning what is typically an agricultural waste into a sellable product. In contrast, sawdust and coconut husk are often sourced from industrial processes, which may limit the direct economic benefits to smallholder farmers (Nelson *et al*., 2021). When comparing rice straw briquettes to alternatives such as sawdust, coconut husk, or bagasse, each material offers unique advantages. Rice straw is cost-effective and sustainable but may require more processing to achieve comparable combustion performance (Logeswaran *et al*., 2020). Sawdust briquettes are dense, energy-rich, and perform well in combustion, but their availability may be limited to regions with active wood-processing industries. Coconut husk briquettes are highly renewable but may have limited availability in non-tropical regions.

CONCLUSIONS

This study aimed to assess the performance, sustainability, and economic viability of rice straw briquettes compared to other biomass briquettes. The analysis reveals that while rice straw briquettes exhibit certain limitations, particularly in combustion efficiency and ash content, they also present significant advantages in terms of sustainability and resource availability. Rice straw briquettes have a relatively lower combustion efficiency and higher ash content compared to other biomass types such as sawdust and coconut husk. However, these shortcomings can be mitigated through pre-treatment methods such as densification and drying, which enhance combustion characteristics. The lower energy density of rice straw briquettes is offset by their longer burning time, which can be beneficial for applications requiring sustained heat output. The use of rice straw briquettes offers considerable environmental benefits, particularly in regions where open-field burning of rice straw is a prevalent practice. By converting agricultural waste into a usable energy resource, rice straw briquettes reduce harmful emissions and contribute to waste management efforts.

Rice straw briquettes emerge as a promising biomass energy source, offering comparable performance to traditional biomass fuels while promoting sustainability and economic benefits. Further research and development can enhance production methods and market accessibility, fostering a transition toward cleaner energy alternatives in both rural and urban settings. Emphasizing the utilization of agricultural waste not only supports local economies but also aligns with global sustainability goals.

Performance: Rice straw briquettes demonstrated competitive calorific values compared to other biomass briquettes, making them a viable alternative for energy production. Their combustion efficiency was generally on par with wood and other agricultural residues, with advantages in ash content and lower emissions of harmful pollutants.

Sustainability: The use of rice straw briquettes contributes positively to environmental sustainability. Utilizing agricultural waste helps reduce field burning, thus mitigating air pollution and greenhouse gas emissions. Moreover, rice straw is a renewable resource, ensuring a continuous supply, particularly in rice-producing regions.

Economic Viability: Economically, rice straw briquettes present an attractive option due to their low production costs and the potential for reducing waste disposal expenses for farmers. While initial investment in briquetting technology may be required, the long-term savings on energy and waste management make rice straw briquettes a cost-effective solution for households and industries alike.

Economically, rice straw briquettes have the potential to provide cost-effective energy solutions, especially in rural and agrarian communities. The low cost of rice straw, being an agricultural byproduct, gives it a competitive edge in regions with abundant rice production. While production processes such as drying and densification increase costs, advancements in briquetting technology can reduce these overheads and enhance the economic feasibility of rice straw briquettes. In comparison, biomass materials like sawdust and coconut husk are often tied to specific industries, which may limit their accessibility and increase costs in certain regions. While sawdust and coconut husk briquettes outperform rice straw in combustion efficiency and emissions, rice straw briquettes stand out in terms of sustainability and local availability, particularly in rice-producing regions. The economic benefits of utilizing agricultural waste, combined with the environmental advantages, position rice straw briquettes as a promising alternative for biomass energy production.

FUTURE SCOPE

The future scope of comparative analysis between rice straw briquettes and other biomass briquettes can be explored through several key dimensions:

Performance Enhancement

— **Technological Innovations**: Research could focus on improving the briquetting process, including new binding agents and methods that enhance the durability and combustion efficiency of rice straw briquettes.

— **Combustion Efficiency Studies**: Conducting extensive tests to compare the thermal efficiency, emissions, and ash content of rice straw briquettes against other biomass types.

Sustainability Assessment

— **Life Cycle Analysis (LCA)**: Future studies can delve deeper into the environmental impact of rice straw briquettes compared to other biomass options, considering factors such as carbon footprint, resource usage, and waste management.

— **Resource Availability**: Investigating the availability and accessibility of raw materials, and how their utilization can affect local ecosystems and agricultural practices.

Economic Viability

— **Cost-Benefit Analysis**: Comprehensive economic assessments that compare production costs, market prices, and potential subsidies or incentives for rice straw briquettes vs. other biomass sources.

— **Market Development**: Exploring market trends and opportunities for rice straw briquettes, including potential niche markets and partnerships with industries seeking sustainable energy sources.

Acknowledgement. The author wishes to think the ICAR-Indian Agricultural Research Institute (IARI) for all the support during research as well as the facility to carry out the experimental work and also thank Indian Council of Agricultural Research (ICAR) for the financial support under Junior Research Fellowship to the student during research work.

Conflict of Interest. None.

REFERENCES

Bressan, M., Campagnoli, E., Ferro, C. G. and Giaretto, V. (2022). Rice straw: A waste with a remarkable green energy potential. *Energies*, *15*(4), 1355.

Cano, M., Vega, F., Navarrete, B., Plumed, A. and Camino, J. A. (2017). Characterization of emissions of condensable particulate matter in clinker kilns using a dilution sampling system. *Energy and Fuels*, *31*(8), 7831-7838.

Chieng, S. and Kuan, S. H. (2022). Harnessing bioenergy and high value–added products from rice residues: a review. *Biomass Conversion and Biorefinery*, *12*(8), 3547-3571.

Clare, A., Shackley, S., Joseph, S., Hammond, J., Pan, G. and Bloom, A. (2015). Competing uses for China's straw: the economic and carbon abatement potential of biochar. *Gcb Bioenergy*, *7*(6), 1272-1282.

Dinesha, P., Kumar, S. and Rosen, M. A. (2019). Biomass briquettes as an alternative fuel: A comprehensive review. *Energy Technology*, *7*(5), 1801011.

Ford, S. and Despeisse, M. (2016). Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. *Journal of cleaner Production*, *137*, 1573-1587.

Gomes da Silva, F. J., Gouveia, R. M., Gomes da Silva, F. J. and Gouveia, R. M. (2020). Sustainable production cases. *Cleaner Production: Toward a Better Future*, 281-373.

Guo, M., Song, W. and Buhain, J. (2015). Bioenergy and biofuels: History, status, and perspective. *Renewable and sustainable energy reviews*, *42*, 712-725.

Jetter, J., Zhao, Y., Smith, K. R., Khan, B., Yelverton, T., DeCarlo, P. and Hays, M. D. (2012). Pollutant emissions and energy efficiency under controlled conditions for household biomass cookstoves and implications for metrics useful in setting international test standards. *Environmental science and technology*, *46*(19), 10827-10834.

Joshi, H., Moser, B. R., Toler, J. and Walker, T. (2010). Preparation and fuel properties of mixtures of soybean oil methyl and ethyl esters. *Biomass and bioenergy*, *34*(1), 14-20.

Kargbo, H., Harris, J. S. and Phan, A. N. (2021). "Drop-in" fuel production from biomass: Critical review on techno-economic feasibility and sustainability. *Renewable and Sustainable Energy Reviews*, *135*, 110168.

Logeswaran, J., Shamsuddin, A. H., Silitonga, A. S. and Mahlia, T. M. I. (2020). Prospect of using rice straw for power generation: a review. *Environmental Science and Pollution Research*, *27*, 25956-25969.

Nelson, N., Darkwa, J. and Calautit, J. (2021). Prospects of bioenergy production for sustainable rural development in Ghana. *Journal of Sustainable Bioenergy Systems*, *11*(4), 227-259.

Nygaard, I., Dembele, F., Daou, I., Mariko, A., Kamissoko, F., Coulibaly, N., Borgstrom R, L. and Bruun, T. B. (2016). Lignocellulosic residues for production of electricity, biogas or second generation biofuel: A case study of technical and sustainable potential of rice straw in Mali. *Renewable and Sustainable Energy Reviews*, *61*, 202-212.

Olugbade, T., Ojo, O. and Mohammed, T. (2019). Influence of binders on combustion properties of biomass briquettes: a recent review. *BioEnergy Research*, *12*, 241-259.

Oyelaran, O. A. (2015). Determination of the Bio-Energy Potential of Melon Shell and Corn Cob Briquette (Research Note). *Iranica Journal of Energy and Environment*, *6*(3).

Pinto, F., Gominho, J., Andre, R. N., Goncalves, D., Miranda, M., Varela, F., Neves, D., Santos, J., Lourenco A. and Pereira, H. (2017). Improvement of gasification performance of Eucalyptus globulus stumps with torrefaction and densification pre-treatments. *Fuel*, *206*, 289-299.

Ramos, M., Laveriano, E., San Sebastian, L., Perez, M., Jimenez, A., Lamuela-Raventos, R. M., Garrigos, M.C. and Vallverdu-Queralt, A. (2023). Rice straw as a valuable source of cellulose and polyphenols: Applications in the food industry. *Trends in Food Science and Technology*, *131*, 14-27.

Satlewal, A., Agrawal, R., Bhagia, S., Das, P. and Ragauskas, A. J. (2018). Rice straw as a feedstock for biofuels: availability, recalcitrance, and chemical properties. *Biofuels, Bioproducts and Biorefining*, *12*(1), 83-107.

Sekhar, G., Naveen, J., Thokchom, S., Bharteey, P. K. and Yadav, R. (2022). Novel and Sustainable Approaches to Combat Climate Change in the Agriculture Sector: A Review.*Biological Forum – An International Journal,14(4)*: 203-210.

Siciliano, G., Wallbott, L., Urban, F., Dang, A. N. and Lederer, M. (2021). Low□carbon energy, sustainable development, and justice: Towards a just energy transition for the society and the environment. *Sustainable development*, *29*(6), 1049-1061.

Singh, R. and Patel, M. (2022). Effective utilization of rice straw in value-added by-products: A systematic review of state of art and future perspectives. *Biomass and Bioenergy*, *159*, 106411.

Sunnu, A. K., Adu-Poku, K. A. and Ayetor, G. K. (2023). Production and characterization of charred briquettes from various agricultural waste. *Combustion Science and Technology*, *195*(5), 1000-1021.

Tanko, J., Ahmadu, U., Sadiq, U. and Muazu, A. (2021). Characterization of rice husk and coconut shell briquette as an alternative solid fuel. *Advanced Energy Conversion Materials*, 1-12.

How to cite this article: Lokesh Kumar Meena, Renu Singh, Anik Chandel, Krishnavatar Gocher and Sohan Singh Saini (2024). Comparative Analysis of Rice Straw Briquettes and Other Biomass Briquettes: A Study on Performance, Sustainability, and Economic Viability. *Biological Forum – An International Journal, 16*(10): 01-07.