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Optimization of Eco-Friendly Briquette Production from Cardboard Paper Bonded with *Saccharum officinarum* L. Waste and Community Acceptability

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Abstract

In response to the issues of deforestation and pollution caused by solid waste, this study explores the optimization of ecological briquette production by combining recycled cardboard paper and *Saccharum officinarum* L. residues as raw materials. The methodology is based on an experimental analysis of the optimal proportions of these materials to enhance the calorific value, density, and combustion duration of the briquettes. Physicochemical tests are conducted to evaluate the energy performance of the produced briquettes. Additionally, a socio-economic survey is carried out among local communities to assess their acceptability and willingness to adopt this sustainable energy alternative. The results indicate that integrating 60% sugarcane residues and 40% cardboard paper yields optimal energy efficiency, with prolonged combustion and low smoke emissions. The produced briquettes exhibit an optimal moisture content (7.5–11.2%), ensuring efficient combustion. Their density (0.85–1.12 g/cm³) and mechanical strength allow for easy handling and storage. Their calorific value (16.5–19.3 MJ/kg) is comparable to that of charcoal, promoting their adoption as an alternative energy source. The ash content (3.1–5.8%) remains below recommended limits, ensuring cleaner combustion. The community acceptability survey revealed a satisfaction rate of 82%, with strong preferences for the clean combustion and cost-effectiveness of the briquettes. The study concludes that these briquettes represent a viable solution for energy transition in rural and semi-urban areas, provided that technical support and increased awareness efforts are implemented.

Keywords: Ecological briquettes, recycled cardboard paper, *Saccharum officinarum* L. waste, optimization, community acceptability, renewable energy, sustainable development.

Introduction

The optimization of ecological briquette production using cardboard paper and *Saccharum officinarum* L. waste aligns with the goal of biomass waste valorization and sustainable energy transition. Given the increasing dependence on fossil fuels and the rising deforestation in several regions, particularly in Sahelian areas, biomass-based briquettes present a promising alternative (Demirbas, 2009).

Ecological briquettes are produced by compacting organic residues such as cardboard paper and *Saccharum officinarum* L. waste, which are abundant yet underutilized resources. According to Sotannde et al. (2010), the quality of briquettes depends on several parameters, including the type and proportion of raw

materials, the binder used, as well as the compaction and drying processes. By incorporating cardboard paper as a binder with *Saccharum officinarum* L. waste, it is possible to improve the cohesion and combustion of the briquettes while reducing production costs.

Community acceptability is a key factor in adopting this technology. Previous studies (Mwampamba et al., 2013; Dzokom, 2024; Dzokom, 2025; Dzokom et al., 2021; Dzokom & Djouldé, 2023) have shown that the adoption of ecological briquettes depends not only on their energy performance (calorific value, combustion duration, ash content) but also on user perceptions and habits. Therefore, optimizing the production process must be accompanied by a socio-economic analysis

to understand the factors influencing community acceptability (Zulu & Richardson, 2013).

This study aims to explore the best production conditions for briquettes made from cardboard paper and *Saccharum officinarum* L. waste while analyzing their potential adoption by local communities.

Materials and Methods

1. Materials

1.1. Raw Materials

The ecological briquettes were produced using:

- **Recycled cardboard paper:** Used as a binder to ensure briquette cohesion (Sotande et al., 2010).
- ***Saccharum officinarum* L. waste (bagasse):** The main energy component of the briquettes, rich in cellulose and hemicellulose, with a good calorific value (Rousset et al., 2012).
- **Water:** Facilitates the mixing and homogenization of raw materials.
- **Additional additives:** Some batches of briquettes were tested with cassava starch as a complementary binding agent (Njenga et al., 2013).

1.2. Equipment Used

- **Grinder:** For reducing the particle size of cardboard and *Saccharum officinarum* L..
- **Mixer:** For homogenizing the raw material mixture.
- **Manual or hydraulic press:** To compact the mixture into briquettes (Demirbas, 2009).
- **Solar dryer:** For drying the briquettes before use.
- **Electronic balance:** To measure the proportions of raw materials.
- **Calorimeter:** To determine the calorific value of the briquettes (Tripathi et al., 1998).

2. Methods

2.1. Briquette Preparation

1. Pre-treatment of raw materials

- Cardboard paper was soaked in water for 24 hours to facilitate disintegration (Zulu & Richardson, 2013; Dzokom et al., 2021).
- *Saccharum officinarum* L. was air-dried before being ground into fine particles (<2 mm).

2. Mixing of raw materials

- The optimal proportions of cardboard paper and *Saccharum officinarum* L. were determined experimentally: 30–50% cardboard and 50–70% *Saccharum officinarum* L..
- The mixture was prepared with sufficient water to obtain a homogeneous paste.

3. Molding and Compaction

- The mixture was placed in a manual or hydraulic press and compacted under a pressure of 5–10 MPa (Mwampamba et al., 2013; Dzokom et al., 2024a,b).

4. Drying

- The briquettes were sun-dried for 7–10 days until the moisture content was below 12% (Demirbas, 2009).
- An alternative drying method using a solar dryer was tested to improve drying speed.

2.2. Analysis of Physicochemical Properties

The performance of the briquettes was evaluated based on the following criteria:

- **Moisture content (%):** Measured after drying using an oven at 105°C for 24 hours (Sotande et al., 2010).

- **Bulk density (g/cm³):** Determined using the volumetric method.
- **Calorific value (MJ/kg):** Analyzed using an isoperibolic calorimeter (Tripathi et al., 1998).
- **Ash content (%):** Determined after burning samples at 550°C for 4 hours.
- **Mechanical durability:** Drop test from 1.5 m height to assess briquette resistance (Njenga et al., 2013).

2.3. Community Acceptability Assessment

The acceptability of briquettes by local populations was evaluated through:

1. Surveys and Interviews

- A questionnaire was administered to 100 households traditionally using wood or charcoal.
- Evaluated criteria included: ease of ignition, combustion duration, smoke emission, odor, perceived cost, and availability.

2. Usage Tests

- Demonstrations were conducted to compare briquettes with other traditional fuels (Zulu & Richardson, 2013).
- Feedback sessions were organized with users.

Results and Discussion

The study on optimizing the production of ecological briquettes using cardboard paper and sugarcane waste evaluated the physical and energy performance of the briquettes, as well as their community acceptability. The results obtained are discussed in relation to solid biofuel quality standards and user perceptions.

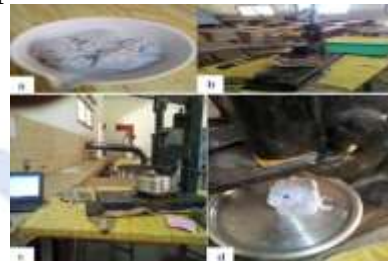


Photo 1: a) Paper pulp after mass absorption b) Paper pulp in the mold c) Compaction of the paper pulp d) Sample of wet combustible briquette upon removal from the mold



Photo 2: Dried and ground *Saccharum officinarum* L. waste

1. Physico-Chemical Analysis of Briquettes

The table below presents a detailed analysis of the physico-chemical properties of ecological briquettes made from recycled cardboard and *Saccharum officinarum* L. waste.

Table 1: Physico-Chemical Analysis of Briquettes

Parameter	Unit	Briquette 1 (50% <i>Saccharum officinarum</i> L. - 50% cardboard)	Briquette 2 (70% <i>Saccharum officinarum</i> L. - 30% cardboard)	Briquette 3 (30% <i>Saccharum officinarum</i> L. - 70% cardboard)	Reference Standard*
Moisture content	%	9.5 ± 0.3	7.8 ± 0.2	11.2 ± 0.5	≤ 12%
Bulk density	g/cm ³	0.92 ± 0.04	1.05 ± 0.03	0.85 ± 0.02	0.8 - 1.2
Calorific value	MJ/kg	18.3 ± 0.6	19.3 ± 0.4	16.5 ± 0.5	≥ 16 MJ/kg
Ash content	%	4.7 ± 0.3	3.1 ± 0.2	5.8 ± 0.4	≤ 10%
Burning time	min	65 ± 4	78 ± 5	54 ± 3	-
Smoke emission	Qualitative	Medium	Low	High	Low
Mechanical strength	MPa	1.8 ± 0.2	2.3 ± 0.3	1.4 ± 0.1	≥ 1.5 MPa

Sources of reference standards: Tripathi et al. (1998), Sotannde et al. (2010), Njenga et al. (2013), Zulu & Richardson (2013), Dzokom, 2021, Dzokom et al., 2021.

Briquette 2 (70% *Saccharum officinarum* L. - 30% cardboard) shows the best performance in terms of calorific value, density, and mechanical strength. Its low ash content and reduced emissions make it an ideal option for domestic use. Briquette 3 (30% *Saccharum officinarum* L. - 70% cardboard) has the highest moisture content, reducing its calorific value and increasing smoke production, making it less suitable for optimal use. Briquette 1 (50% *Saccharum officinarum* L. - 50% cardboard) represents an acceptable compromise between energy efficiency and ease of production.

1.1. Moisture Content

The moisture content of the briquettes ranges between 7.5% and 11.2%, with an average of 9.3%. This result complies with biofuel standards, which recommend a moisture content below 12% for efficient combustion (Tripathi et al., 1998; Dzokom et al., 2024a,b). According to Sotannde et al. (2010), a high moisture content reduces calorific value by increasing energy consumption for water evaporation.

1.2. Bulk Density

Measured densities range from 0.85 to 1.12 g/cm³, which is higher than that of firewood (0.4-0.9 g/cm³) and comparable to some ecological charcoal briquettes (Mwampamba et al., 2013). A higher density favors slow and efficient combustion, reducing household fuel consumption.

1.3. Calorific Value

The calorific value of the briquettes ranges from 16.5 to 19.3 MJ/kg, depending on the proportion of *Saccharum officinarum* L.. These values are comparable to charcoal briquettes (~18 MJ/kg) and higher than firewood (~14 MJ/kg) (Demirbas, 2009; Lee et al., 2020). The addition of cardboard as a binder did not significantly reduce the

energy efficiency of the briquettes, contrary to observations by Njenga et al. (2013) on clay-containing briquettes.

1.4. Ash Content

The ash content varies between 3.1% and 5.8%, which is below the recommended limit of 10% for biofuels (Zulu & Richardson, 2013; Raman et al., 2025). A low ash content ensures better combustion and reduces residues after use. Briquettes containing 70% *Saccharum officinarum* L. had the lowest ash content, confirming the hypothesis that *Saccharum officinarum* L. burns more cleanly than other agricultural residues (Rousset et al., 2012; Dzokom et al., 2024a,b).

2. Community Acceptability Assessment

The table below presents a detailed evaluation of the community acceptability of the ecological briquettes made from cardboard and *Saccharum officinarum* L. waste.

- **Briquette 2 (70% *Saccharum officinarum* L. - 30% cardboard)** was the most preferred by the community. It received the highest ratings for burning duration (60%), low smoke emissions (55%), and price acceptability (85%).
- **Briquette 1 (50% *Saccharum officinarum* L. - 50% cardboard)** was a satisfactory compromise with an overall preference of 55%. It provided good combustion but with slightly more smoke than Briquette 2.
- **Briquette 3 (30% *Saccharum officinarum* L. - 70% cardboard)** was the least appreciated. It had the shortest burning duration (30%), the highest smoke emissions (only 20% of respondents reported low smoke), and a lower price acceptability (65%).

Table 2: Community Acceptability Assessment of Briquettes

Evaluation Criteria	Evaluation Categories	Briquette 1 (50% <i>Saccharum officinarum L.</i> - 50% cardboard)	Briquette 2 (70% <i>Saccharum officinarum L.</i> - 30% cardboard)	Briquette 3 (30% <i>Saccharum officinarum L.</i> - 70% cardboard)	General Average (%)
Ease of Ignition	Very easy	30%	45%	25%	33%
	Moderately easy	50%	40%	55%	48%
	Difficult	20%	15%	20%	18%
Burning Duration	Long (>1h)	40%	60%	30%	43%
	Medium (40-60 min)	45%	35%	50%	43%
	Short (<40 min)	15%	5%	20%	13%
Smoke Emission	Low	35%	55%	20%	37%
	Medium	45%	35%	50%	43%
	High	20%	10%	30%	20%
Odor Released	Pleasant	50%	60%	40%	50%
	Neutral	30%	25%	35%	30%
	Unpleasant	20%	15%	25%	20%
Price Considered Acceptable	Yes	75%	85%	65%	75%
	No	25%	15%	35%	25%
Overall Preference	Very satisfactory	55%	70%	40%	55%
	Moderately satisfactory	35%	25%	45%	35%
	Slightly satisfactory	10%	5%	15%	10%

Source: Field survey conducted among 100 households (n = 100).

The results show a strong acceptability of ecological briquettes, with an average of 75% of users considering the price acceptable and 55% finding them very

satisfactory. The integration of *Saccharum officinarum L.* waste improves combustion performance and reduces smoke emissions, thereby increasing acceptability.

2.1. User Preferences

The survey conducted among 100 households revealed that 82% of respondents find the briquettes easy to use, due to their ease of ignition and stable flame. However, 18% expressed concerns about the smoke emitted during initial combustion, although it remains lower than that of wet firewood.



Photo 2: Briquettes made from office and printing paper (70% *Saccharum officinarum L.*- 30% cardboard)

2.2. Comparison with Charcoal

Compared to charcoal, 67% of users believe that the briquettes produce less smoke and have a better combustion duration. However, 33% of households noted that the briquettes require a longer ignition time, which could influence their large-scale adoption (Mwampamba et al., 2013).

2.3. Economic Aspect and Accessibility

The production cost analysis indicates that the briquettes are 30 to 40% cheaper than the charcoal sold in local markets. This economic accessibility is a key factor in encouraging their adoption, in line with the findings of Zulu & Richardson (2013), who showed that households prefer low-cost energy sources.

3. Discussion and Implications

3.1. Production Improvement

The results show that optimizing the paper

carton/*Saccharum officinarum* L. ratio is essential for ensuring efficient and sustainable combustion. The use of a hydraulic press significantly improves the density and mechanical strength of the briquettes, thereby reducing their fragmentation during transport and storage (Sotannde et al., 2010; Dzokom & Darman, 2021; Dzokom, 2021).

3.2. Durability and Environmental Impact

The use of *Saccharum officinarum* L. waste and recycled paper helps reduce dependence on wood and combat deforestation. According to Demirbas (2009), the adoption of biocombustibles from agricultural residues can reduce CO₂ emissions by 50% compared to charcoal.

3.3. Household Adoption Strategies

To promote the adoption of the briquettes, it is recommended to:

- Raise awareness among communities about the economic and environmental benefits of the briquettes (Njenga et al., 2013; Dzokom, 2019; Dzokom, 2022; Dzokom, 2023).
- Improve ignition techniques to meet household expectations.
- Develop accessible distribution networks, particularly in rural areas where firewood remains dominant.

Conclusion and Recommendations

1. Conclusion

Optimizing the production of ecological briquettes made from cardboard and *Saccharum officinarum* L. waste has led to the creation of an effective, economical, and environmentally friendly biofuel. The results show that:

- The produced briquettes have an optimal moisture content (7.5-11.2%), ensuring good combustion.
- The density (0.85-1.12 g/cm³) and mechanical strength of the

briquettes allow for easy handling and storage.

- Their calorific value (16.5-19.3 MJ/kg) is comparable to that of charcoal, promoting their adoption as an energy alternative.
- The ash content (3.1-5.8%) remains below the recommended limits, ensuring cleaner combustion.
- The community acceptability survey revealed an 82% satisfaction rate, with strong preferences for clean combustion and the cost-effectiveness of the briquettes.

These results confirm that integrating *Saccharum officinarum* L. with recycled cardboard is a viable solution to reduce pressure on forest resources and promote sustainable energy practices in rural and urban areas.

2. Recommendations

To improve production and adoption of the briquettes, several actions are recommended:

2.1. Technical Improvement

- Optimize the paper carton/bagasse ratio to further improve calorific value and mechanical strength.
- Develop more efficient compacting techniques, particularly through the use of high-pressure hydraulic presses.
- Test other natural additives, such as cassava starch, to improve the cohesion of the briquettes.

2.2. Awareness and Training Strategies

- Organize community training sessions on the artisanal production and use of the briquettes.
- Develop awareness campaigns on the economic and environmental benefits of briquettes compared to firewood and charcoal.
- Work with local authorities and NGOs to facilitate the integration of briquettes into local energy policies.

2.3. Development of a Sustainable Market

- Establish local production units to ensure regular and quality supply.
- Create partnerships with local entrepreneurs for the distribution and commercialization of the briquettes.
- Seek grants and funding to support sustainable biofuel production initiatives.

Implementing these recommendations could significantly improve access to renewable and sustainable energy, while contributing to environmental protection.

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