

# The Role of *Calotropis gigantea* Leaves as a Natural Binder in Corncob Briquettes Enhanced with LDPE

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Received: February 16, 2026

Approved: February 24, 2026

## Abstract

Briquetting represents one of the key technological pathways for biomass utilization, particularly when combined with plastic waste that is otherwise difficult to manage. This study aims to analyze the effect of *Calotropis gigantea* (Biduri leaves) as a natural binder on the characteristics of briquettes made from corncob charcoal and low-density polyethylene (LDPE) plastic waste. Corncobs were carbonized at 300-400 °C for approximately 4 hours, and briquettes were formulated with a constant corncob-to-LDPE ratio of 70:30. Five binder compositions (15%, 20%, 25%, 30%, and 35% of total briquette mass) were tested to determine the optimal formulation. Physical and chemical properties including moisture content, ash content, volatile matter, fixed carbon, calorific value, density, and bulk density, were analyzed. The results demonstrated that the 15% binder composition (V1) achieved the best performance, meeting SNI requirements with a moisture content of 2.947%, ash content of 6.790%, volatile matter of 3.536%, fixed carbon of 86.727%, calorific value of 7216.649 cal/g, density of 0.932 g/cm<sup>3</sup>, and bulk density of 0.326 g/cm<sup>3</sup>. This research highlights the novelty of employing *Calotropis gigantea* leaves as a sustainable binder in LDPE-modified biomass briquettes. The findings confirm that natural binders can enhance briquette quality while reducing reliance on synthetic adhesives, offering a viable pathway toward environmentally friendly household energy solutions.

**Keywords:** *Calotropis gigantea* leaves, biomass briquette, corncob, LDPE plastic, renewable energy

## Abstrak

Salah satu jalur teknologi pemanfaatan biomassa adalah proses briketisasi, khususnya ketika dikombinasikan dengan limbah plastik yang sulit ditangani. Penelitian ini bertujuan untuk menganalisis pengaruh penggunaan daun *Calotropis gigantea* (daun biduri) sebagai perekat alami terhadap karakteristik briket berbahan dasar arang tongkol jagung dan limbah plastik low-density polyethylene (LDPE). Tongkol jagung dikarbonisasi pada suhu 300-400 °C selama ±4 jam, kemudian diformulasikan menjadi briket dengan rasio tetap tongkol jagung terhadap LDPE sebesar 70:30. Lima variasi komposisi perekat (15%, 20%, 25%, 30%, dan 35% dari total massa briket) diuji untuk menentukan formulasi optimal. Sifat fisik dan kimia yang dianalisis meliputi kadar air, kadar abu, zat volatil, karbon tetap, nilai kalor, densitas, dan densitas curah. Hasil penelitian menunjukkan bahwa komposisi perekat 15% (V1) memberikan performa terbaik dan memenuhi standar SNI, dengan kadar air 2,947%, kadar abu 6,790%, zat volatil 3,536%, karbon tetap 86,727%, nilai kalor 7216,649 kal/g, densitas 0,932 g/cm<sup>3</sup>, dan densitas curah 0,326 g/cm<sup>3</sup>. Penelitian ini menegaskan kebaruan penggunaan daun *Calotropis gigantea* sebagai perekat berkelanjutan dalam briket biomassa yang dimodifikasi LDPE. Temuan ini membuktikan bahwa perekat alami mampu meningkatkan kualitas briket sekaligus mengurangi ketergantungan pada perekat sintesis, sehingga menawarkan jalur potensial menuju solusi energi rumah tangga yang ramah lingkungan.

**Kata Kunci:** Daun *calotropis gigantea*, briket biomasa, , tongkol jagung, plastic LDPE, energi terbarukan

## 1. Introduction

The global reliance on fossil fuels has raised significant concerns regarding environmental degradation, greenhouse gas emissions, and long-term energy security. In Indonesia, fossil energy continues to dominate the national energy mix, contributing to air pollution and climate change. To address these challenges, renewable energy sources are increasingly being explored, with biomass emerging as one of the most promising alternatives due to its abundance, renewability, and potential to reduce carbon footprints.

Among various biomass utilization strategies, briquetting has gained attention as a practical method to convert agricultural residues into solid biofuels with improved handling, storage, and combustion properties. Corn cobs, a widely available agricultural byproduct, represent a valuable feedstock for briquette

production [1]. However, the performance of biomass briquettes is strongly influenced by the choice of binders and additives, which determine their mechanical strength, calorific value, and compliance with fuel standards. Binder selection has been identified as a critical factor in briquette quality and sustainability, with recent reviews emphasizing its role in durability, calorific performance, and environmental impact [2], [3], [4], [5].

In parallel, the accumulation of plastic waste, particularly low-density polyethylene (LDPE), poses a major environmental challenge due to its persistence and limited recyclability. Integrating LDPE waste into biomass briquettes not only enhances calorific value and combustion stability but also contributes to waste reduction and circular economy practices. This approach aligns with global sustainability efforts, particularly the United Nations Sustainable Development Goals (SDGs), including SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Global studies continue to explore diverse raw materials and densification technologies to improve biomass briquettes, highlighting both opportunities and challenges in scaling biomass energy [6]. Novel lignocellulosic binders have also shown promise in reducing production costs and enhancing briquette sustainability [7], [8]. Despite these advances, limited research has examined the synergistic use of natural binders with polymer additives such as low-density polyethylene (LDPE), particularly in corncob briquettes. Emadi et al. (2017) reported that adding 1–10% LLDPE to wheat briquettes improved density, tensile strength, calorific value, and reduced ash content. [9]

Although numerous studies have examined biomass briquettes using either natural binders such as starch, molasses, or Arabic gum, or synthetic additives like polymers, [10], [11], [12], [13] limited attention has been given to the combined use of natural adhesives with plastic waste. Existing research has primarily focused on improving calorific value or mechanical strength separately, without addressing the dual challenge of enhancing energy performance and reducing waste. Moreover, the potential of *Calotropis gigantea* (*biduri* leaves) as a binder remains largely unexplored in scientific literature, despite its availability and adhesive properties.

This study presents a novel hybrid approach that combines *Calotropis gigantea* leaves with low-density polyethylene (LDPE) waste to form corncob briquettes. The innovation lies in simultaneously enhancing briquette quality and valorizing plastic waste, thereby contributing to circular economy practices and aligning with global sustainability goals (SDGs 7, 12, and 13). The primary objective is to evaluate the physicochemical properties of the briquettes with natural binder and assess their compliance with the briquette standard. By examining variations in binder composition, this research aims to identify the optimal formulation and demonstrate the potential of combining natural adhesives with polymer additives to produce high-quality, sustainable bio-briquettes. The findings contribute to the development of environmentally friendly household energy solutions and highlight the role of agricultural residues in advancing renewable energy technologies.

## 2. Material and Methods

### Materials

Corn cobs (*Zea mays* L.) were collected from agricultural areas in Jember, East Java. The corncobs were cleaned, sun-dried, and then used as the main biomass feedstock. LDPE plastic waste (primarily packaging) was sourced from the campus environment. The plastic was cleaned, dried, and then cut into small pieces before being mixed. Biduri leaves (*Calotropis gigantea*) were collected from local surroundings, washed, dried, and ground into fine powder. The powder was mixed with water to form a paste, which was used as an adhesive. Distilled water was used in adhesive preparation and some tests.

### Corncob Carbonization

Corncobs were carbonized in a simple carbonization furnace at a temperature of 300–400°C for approximately 4 hours until a stable charcoal was obtained. The charcoal was then crushed and sieved to obtain particles with a size distribution of 40–60 mesh.

### Briquette Formulations

The briquettes were produced with a constant corncob–LDPE ratio of 70:30 (dry mass basis), while the Biduri leaf adhesive content was varied. Five formulations (V1–V5) were prepared by adjusting adhesive content as a percentage of total briquette mass (30 g):

- V1: 15% adhesive
- V2: 20% adhesive

- V3: 25% adhesive
- V4: 30% adhesive
- V5: 35% adhesive

For each formulation, the required masses of corncob charcoal, LDPE plastic, and Biduri adhesive were weighed so that the adhesive accounted for 15–35% of 30 g, and the remaining 65–85% was composed of corncob and LDPE at a fixed ratio of 70:30.

#### *Briquette Production*

Corn cob charcoal (powder) and chopped LDPE were homogenized according to the required 70:30 ratio. Biduri leaf adhesive paste was gradually added and mixed until a uniform dough-like mixture was obtained. The mixture was placed into a cylindrical mold, and then the briquettes were compacted using a manual press. Pressed briquettes were removed from the mold and dried in an oven at approximately 105°C until a constant mass was achieved to minimize residual moisture.

#### *Proximate Analysis and Physical Testing*

Briquette quality was evaluated according to SNI 01-6235-2000 for charcoal briquettes.[7] The following parameters were measured:

- a. Moisture content (%)  
Determined by oven-drying at 105°C until constant mass. The procedure is based on the Association of Official Analytical Chemists (AOAC).
- b. Ash content (%)  
Determined by burning samples in a muffle furnace at high temperature (typically 600–700°C) until all combustible material was removed and only ash remained. The steps are followed from ASTM D3174-04 (2006).
- c. Volatile matter (%)  
Determined by heating the sample in a covered crucible in a muffle furnace at a specified temperature and time, volatile matter was calculated from mass loss excluding moisture. Volatile matter testing was conducted using the ASTM D5142-02 method.

$$\text{Volatile matter} = (b-c)/a * 100\% \quad (1)$$

Where,

- a = mass of empty crucible (g)  
b = mass of crucible and sample (g)  
c = mass of sample after ignition (g)

- d. Fixed carbon (%)\*\*

Calculated by difference:

$$\text{Fixed carbon} = 100\% - (\{\text{moisture} + \text{ash} + \text{volatile matter}\}) \quad (2)$$

- d. Calorific value (cal/g)

Measured using a bomb calorimeter, with the resulting calorific value compared to the minimum requirement of 5000 cal/g stated in SNI 01-6235-2000.

- e. Density (g/cm<sup>3</sup>)\*\*

Calculated from the mass and volume of the briquette.

- f. Bulk density (g/cm<sup>3</sup>)\*\*

Determined by measuring the mass of multiple briquettes occupying a known volume.

Each test was performed for all five briquette formulations (V1-V5), and average values were calculated.

### **3. Results and Discussion**

#### *Effect of Adhesive Content on Moisture and Volatile Matter*

The level of moisture present in charcoal briquettes plays a crucial role in determining their performance, as it affects ignition, combustion efficiency, energy yield, and smoke release. Briquettes with minimal moisture tend to ignite more easily, produce greater heat, and burn more cleanly, whereas excessive moisture lowers the energy value and results in heavier smoke emissions. The specific moisture content values for each treatment are presented in **Table 1**. The results of this study show that moisture content increased with adhesive content, from 2.974% at 15% adhesive (V1) to 6.952% at 35% adhesive (V5). This trend is expected because higher adhesive content introduces more bound water and hydrophilic components. Although moisture levels increased, all values remained within SNI limits, with the lowest

moisture content observed in V1. The incorporation of plastic increases particle cohesion, thereby enhancing density and minimizing residual water.

Volatile matter also showed a slight increasing trend as adhesive content increased. The volatile matter ranged from 3.536% (V1) to 3.719% (V5). Higher adhesive content generally contributes to the presence of more volatile components derived from organic binders. The thesis notes that excessive volatile matter can increase smoke production during combustion; therefore, maintaining relatively low volatile matter is desirable. In this study, all volatile matter values remained low and were well below the SNI limit of 15%.

**Table 1.** Proximate analysis of briquettes with binders of different variations.

Samples	Moisture (%)	Volatile matter (%)	Ash Content (%)	Fixed carbon (%)
V1	2.97	3.53	6.79	86.72
V2	3.37	3.54	6.57	86.50
V3	4.83	3.57	5.59	86.27
V4	6.12	3.71	4.63	85.52
V5	6.95	3.72	4.63	84.59

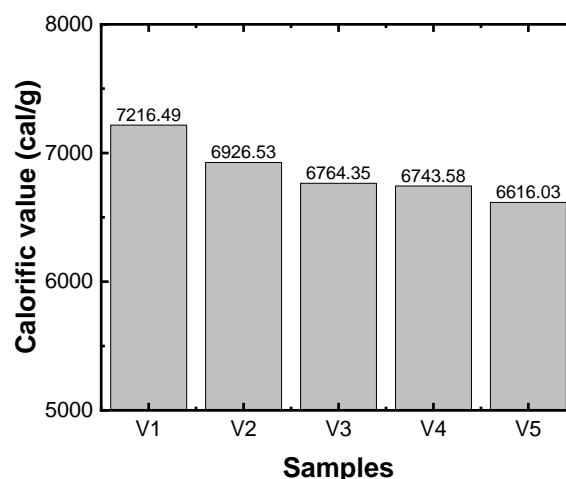
#### Fixed Carbon and Calorimetric Value

Fixed carbon content decreased slightly as adhesive content increased, as seen in Table 1. V1 (15% adhesive) had the highest fixed carbon value at 86.727% while V5 (35% adhesive) had the lowest at 84.899%. The high fixed carbon in V1 indicates a larger fraction of combustible carbon and typically correlates positively with calorific value.

**Figure 1** represents the calorific value of corn cobs-LDPE briquettes with various binder concentrations. The highest calorific value was achieved with 15% adhesive (V1), and the calorific value gradually declined with increasing adhesive content. This is consistent with the understanding that a higher proportion of non-carbonaceous binder (with lower effective energy content after drying and combustion residues) can dilute the carbon fraction and reduce calorific value.

Afandi et al. obtained calorific values around 6757 cal/g for briquettes from sugarcane bagasse and corncob using sago adhesive, which is comparable to V3–V5 in this study [14]. Another group reported calorific values about 7000 cal/g for briquettes combining EFB and LDPE, similar to the 7216.49 cal/g obtained for V1 [15]. Rahmanto et al. demonstrated that Biduri leaf adhesive, when combined with sawdust, can also meet SNI standards, thereby reinforcing the suitability of Biduri as a binder for briquettes [16].

Thus, the calorific performance of the corncob-LDPE briquettes with *Biduri* leaf adhesive is competitive with other biomass and biomass-plastic briquettes reported in the literature.



**Figure 1.** Calorific value results of the sample with various binder compositions.

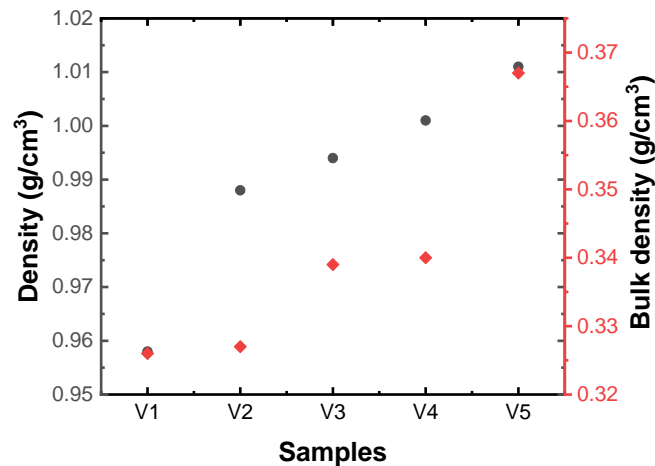
#### Ash Content

Ash content decreased slightly with increasing adhesive content, from 6.79% (V1) to 4.43% (V5). This inverse trend relative to moisture and volatile matter may reflect differences in inorganic content between the base materials and adhesive, as well as variations in combustion completeness during ash

testing. All ash values are within the SNI requirement ( $\leq 8\%$ ) and comparable to other biomass briquettes made from agricultural residues [17].

#### Density and Bulk Density

**Figure 2** shows that the density and bulk density tended to increase with adhesive content. Higher adhesive contents enhance particle bonding and compaction, resulting in denser briquettes. Increased density generally enhances mechanical strength and reduces porosity, which can be beneficial for handling and storage. However, very high density may restrict airflow during combustion, potentially affecting ignition and the burning rate. The achieved density values are in a similar range to those reported by Dewi et al. and other bagasse-based briquette studies, which used sugarcane bagasse and pakcoy-bagasse mixtures [18].



**Figure 2.** Density and bulk density of briquettes with various binder concentrations.

#### 4. Conclusion

The experimental investigation of corncob–LDPE briquettes using biduri leaf (*Calotropis gigantea*) adhesive demonstrates that a 15% adhesive content with a 70:30 corncob–LDPE ratio yields optimal briquette quality, meeting both national (SNI 01-6235-2000) and international standards, while achieving a high calorific value, fixed carbon, and favorable density characteristics. Although increasing adhesive content beyond this level enhances moisture, volatile matter, and bulk density, it compromises energy performance, underscoring the critical role of adhesive optimization. Importantly, this study establishes biduri leaf as a novel and effective natural adhesive, enabling the production of briquettes that not only rival other biomass–plastic systems in calorific performance but also contribute to sustainable solutions for agricultural residue utilization and plastic waste management. These findings highlight the dual environmental and energy benefits of this approach, providing the academic community with a valuable foundation for further research into particle size effects, pressing techniques, and combustion behavior, thereby advancing renewable solid fuel technologies.

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