Jurnal Serambi Engineering JSE
Volume X, No.4, Oktober 2025 Hal 14910 - 14914
p-ISSN : 2528-3561
e-ISSN : 2541-1934

# Characterization of Coconut Husk Briquettes Treated with Acetic Acid: Evaluation of Combustion Quality and Alkali Metal Content

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Received: August 6, 2025 Approved: August 11, 2025

**Abstract**
The high content of sodium (Na) and potassium (K) in biomass materials such as coconut husk can cause fouling and slagging during the combustion process. This study aims to characterize coconut husk briquettes that have been soaked in acetic acid solution to reduce alkali metal content and improve fuel quality. The coconut husk was soaked in 0–4% acetic acid solution for 30–360 minutes, and the best-conditioned husk was then carbonized and pressed into briquettes. The resulting briquettes were tested for calorific value, moisture content, ash content, and residual sodium and potassium levels. The soaking treatment successfully reduced potassium content by 75.78% and sodium by 67.33%; these treated husks were then used as raw material for briquette production. The final briquettes contained 0.5645 mg/g of potassium, 0.0052 mg/g of sodium, a calorific value of 5,535 cal/g, 8.31% moisture content, and 4.59% ash content. These results indicate that soaking coconut husk in acetic acid is an effective pretreatment method to enhance the combustion quality of biomass briquettes by reducing alkali metal content.
**Keywords:** *coconut husk, briquettes, sodium, potassium, acetic acid, soaking, biomass fuel*

**Abstrak**
Kandungan natrium (Na) dan kalium (K) yang tinggi dalam bahan biomassa seperti sabut kelapa dapat menyebabkan fouling dan slagging selama proses pembakaran. Penelitian ini bertujuan untuk mengkarakterisasi briket sabut kelapa yang telah direndam dalam larutan asam asetat guna menurunkan kadar logam alkali dan meningkatkan kualitas bahan bakar. Sabut kelapa direndam dalam larutan asam asetat 0-4% selama 30-360 menit, kondisi sabut terbaik kemudian dikarbonisasi dan dipres menjadi briket. Briket yang dihasilkan diuji untuk mengetahui nilai kalor, kadar air, kadar abu, serta kadar sisa natrium dan kalium. Perlakuan perendaman berhasil menurunkan kadar kalium sebesar 75,78% dan natrium sebesar 67,33%, hasil ini yang akhirnya digunakan sebagai bahan baku pembuatan briket. Briket akhir memiliki kadar kalium sebesar 0,5645 mg/g dan kadar natrium sebesar 0,0052 mg/g nilai kalor sebesar 5.535 kal/g, kadar air 8,31%, dan kadar abu 4,59%. Hasil ini menunjukkan bahwa perendaman sabut kelapa dalam asam asetat merupakan metode pretreatment yang efektif untuk meningkatkan kualitas pembakaran briket biomassa melalui penurunan kandungan logam alkali.
**Kata Kunci:** *sabut kelapa, briket, natrium, kalium, asam asetat, perendaman, bahan bakar biomassa*

## 1. Introduction

Indonesia is one of the largest coconut producers in the world, generating over 3.3 million tons of coconut husk annually as agricultural waste (Badan Pusat Statistik, 2023). Coconut husk has great potential as a renewable energy source due to its lignocellulosic composition and high carbon content, making it suitable for conversion into solid fuel in the form of briquettes (Ahmad et al., 2023). However, one of the main challenges in using coconut husk as biomass fuel is its high content of alkali metals such as sodium (Na) and potassium (K), which can cause serious problems during combustion (Mansor et al., 2019).

Excessive Na and K in biomass can lead to fouling and slagging in boilers, reducing combustion efficiency and causing long-term damage to thermal equipment (Baxter et al., 1998). These alkali metals vaporize at high temperatures and react with silicates to form sticky deposits, which accumulate on heat exchange surfaces (Demirbaş, 2001). Therefore, pre-treatment methods that reduce the alkali content in biomass materials are essential to produce cleaner and more efficient briquettes.(Singhal et al., 2021)

One of the most accessible and environmentally friendly methods is soaking the raw biomass in weak acid solutions (Mierzwa-Hersztek et al., 2019). Acetic acid is a mild organic acid that has been proven to effectively reduce alkali metal content in lignocellulosic materials (Zhao et al., 2013). Compared to strong inorganic acids, acetic acid is safer to handle, less corrosive, and more compatible with small- to mediumscale fuel processing industries. Previous research shows that soaking can improve fuel characteristics by decreasing ash content and enhancing combustion quality (Amanda, 2021).

Despite its potential, there is limited research focusing on the systematic application of acetic acid soaking on coconut husk for briquette production. This study aims to characterize the combustion quality and alkali metal content of coconut husk briquettes treated with varying concentrations and soaking durations of acetic acid. The objective is to determine an effective pre-treatment method that reduces sodium and potassium content, while also producing briquettes with optimal calorific value, moisture content, and ash levels in accordance with national fuel standards (Badan Standardisasi Nasional, 1998; Coford, 2010).

## 2. Material and Methods

*Materials*

The raw material used in this study was coconut husk obtained from a traditional market in Surabaya. Analytical grade acetic acid ($CH_3COOH$) was used as the leaching agent. Other tools used include a digital scale, oven, furnace, briquette mold, universal testing machine, bomb calorimeter, and Atomic Absorption Spectrophotometer (AAS) for metal content analysis. The initial potassium and sodium content of the coconut husk used in this study is as shown in **Table 1**.

**Table 1**. Initial Potassium and Sodium Content of Coconut Husk

| **Parameter** | **Content** | **Unit** |
|---|---|---|
| Potassium | 2,100 | mg/g |
| Sodium | 0,015 | mg/g |

Source : Analysis results (2025)

*Pre-treatment Process*

The coconut husks were first cleaned, cut into small pieces, and dried in an oven at 105°C for 24 hours. The dried samples were then soaked in acetic acid solution with varying concentrations of 0%, 2% and 4% for soaking durations of 30, 195, and 360 minutes, respectively. The solid-to-liquid ratio was maintained at 1:50 (w/v) during soaking, as suggested by previous studies (Jenkins et al., 1996).

*Carbonization and Briquette Formation*

After the soaking treatment, the coconut husks were air-dried and then carbonized in a furnace at 350°C for 1 hour. The resulting charcoal was ground into powder and mixed with tapioca starch as a binder (7,5% by weight). The mixture was then compressed using a hydraulic press into cylindrical briquettes with a diameter of 2.5 cm and a height of 3.5 cm, following the Indonesian briquette standard (Badan Standardisasi Nasional, 1998).

*Briquette Characterization*

To evaluate the quality and combustion performance of the treated biomass briquettes, a series of physicochemical characterizations were conducted. The parameters tested include alkali metal content (potassium and sodium), calorific value, moisture content, and ash content. The testing methods and corresponding units are summarized in **Table 2**.

**Table 2**. Testing Methods for Biomass Briquette Characteristics

| Parameter | Analytical Methods | Unit |
|---|---|---|
| Potassium | *Atomic Absorption Spectrophotometer* | mg/g |
| Sodium | *Atomic Absorption Spectrophotometer* | mg/g |
| Calorific Value | *Bomb Calorimeter* (ASTM D5865-13) | cal/g |
| Moisture Content | SNI 01-6235-2000 | % |
| Ash Content | SNI 01-6235-2000 | % |

Source : Analysis results (2025)

All measurements were carried out in triplicate to ensure data reliability and reproducibility. The values reported in the results section represent the average of the three replicate tests for each parameter. The atomic absorption spectrophotometer (AAS) was employed to accurately quantify trace levels of potassium and sodium, while the bomb calorimeter was used to determine the energy content of the briquettes following ASTM standards. Moisture and ash contents were assessed according to Indonesian National Standards (SNI 01-6235-2000), which are commonly applied in biomass fuel quality evaluation.

## 3. Results and Discussion

*Alkali Metal Content in Treated Briquettes*

Soaking coconut husk in acetic acid solution proved effective in reducing alkali metal content specifically sodium (Na) and potassium (K) which is a critical step in improving the combustion quality of biomass briquettes. Based on optimization using Response Surface Methodology (RSM), the optimal treatment conditions were found at 1.325% acetic acid concentration and 359.8 minutes soaking time. Under these conditions, the model predicted potassium and sodium contents of 0.591905 mg/g and 0.0050322 mg/g, respectively.

These predictions were confirmed through laboratory testing of briquettes produced from coconut husk treated under the optimal conditions. The experimental results showed actual potassium and sodium contents of 0.5191 mg/g and 0.0049 mg/g, respectively. These values fall within the 95% prediction intervals of the model 0.447035–0.736775 mg/g for potassium and 0.00418794–0.00587647 mg/g for sodium as shown in **Table 3**, indicating that the predictive model was accurate and statistically valid.

**Table 3**. Model Confirmation Results at Optimum Conditions (1.325% acetic acid, 359.8 minutes)

| Solution 1 of 41 Response | Predicted Mean | Predicted Median | Observed | Std Dev | n | SE Pred | 95% PI low | Data Mean | 95% PI high |
|---|---|---|---|---|---|---|---|---|---|
| Potassium | 0,591905 | mg/g | | 0,051892 | 1 | 0,0612656 | 0,447035 | 0,5191 | 0,736775 |
| Sodium | 0,0050322 | mg/g | | 0,0002924 | 1 | 0,0003570 | 0,0041879 | 0,0049 | 0,005876 |

To further validate the results, additional testing was conducted on the final briquette product. The results showed potassium and sodium contents of 0.5645 mg/g and 0.0052 mg/g, respectively, as shown in **Table 4**. These values are in close agreement with the model confirmation test, indicating that the reduction in alkali content remains effective even in the final solid fuel product.

**Table 4**. Laboratory Results of Sodium and Potassium Content in Treated Briquettes

| Sample Label | Parameter | Value (mg/g) | Analytical Methods |
|---|---|---|---|
| Optimized coconut husk | Potassium | 0,5191 | *Atomic Absorption Spectrophotometer* |
| Optimized coconut husk | Sodium | 0,0049 | *Atomic Absorption Spectrophotometer* |
| Briquette | Potassium | 0,5645 | *Atomic Absorption Spectrophotometer* |
| Briquette | Sodium | 0,0052 | *Atomic Absorption Spectrophotometer* |

When compared to the initial alkali content in untreated coconut husk—2.100 mg/g for potassium and 0.015 mg/g for sodium—the treatment resulted in reductions of 75.29% for potassium and 67.33% for sodium. The total alkali metal content in the treated briquette product (based on the confirmed actual values) was 0.5240 mg/g, consisting of 0.5191 mg/g potassium and 0.0049 mg/g sodium.

According to Vassilev et al. (2010), biomass fuels with potassium levels below 1000 mg/kg (1 mg/g) and combined Na + K levels below 2000 mg/kg (2 mg/g) are considered less likely to cause slagging, fouling, or corrosion in combustion systems. The treated briquettes in this study contain a combined alkali content well below those critical thresholds, making them suitable for use in industrial combustion applications such as boilers (Vassilev et al., 2010).

*Ash Content*

Ash content is an important parameter that influences combustion efficiency and residue management. The briquettes produced under optimal treatment conditions showed an ash content of 4.59%, which complies with the SNI 01-6235-2000 standard that permits a maximum of ≤ 8% ash content. Compared to the untreated samples, the ash content decreased notably, which is attributable to the effective removal of inorganic compounds, including alkali salts, during the acid soaking process. The results align with the report by Obernberger & Thek (2004), which suggested that ash content below 5% is preferable for biomass briquettes intended for boiler systems, as higher ash levels contribute to increased operational downtime and maintenance costs (Obernberger & Thek, 2004).

*Calorific Value*

The calorific value of the treated briquettes reached 5982.4 cal/g, which exceeds the SNI minimum requirement of 5000 cal/g and is comparable to international standards (Coford, 2010), where typical values range from 6000–7000 cal/g. This high energy content is primarily due to the effective carbonization process at 350°C, which removes volatile matter and enriches the fixed carbon content of the briquettes.

The use of 7.5% tapioca binder did not significantly reduce the calorific value, as confirmed by earlier studies (Kambey et al., 2023). The optimized treatment not only reduced undesirable alkali metals but also preserved the energy potential of the biomass, demonstrating that acetic acid pretreatment does not compromise fuel quality.

*Moisture Content*

The moisture content of the final briquettes was recorded at 8.31%, falling within the acceptable range defined by SNI (≤ 8%) and Coford (6–10%). This relatively low moisture level ensures easier ignition, stable combustion, and reduced smoke production. Although slightly above the strict SNI limit, this value can be attributed to the hygroscopic nature of coconut husk and the presence of the tapioca binder, which tends to retain water. Similar observations were made by Kunta et al. (2021), who found that imperfect carbonization or the use of water-based adhesives can lead to moisture retention in the final product (Kunta & coauthors, 2021).

## 4. Conclusion

The results of this study confirm that soaking coconut husk in acetic acid is an effective pretreatment method to reduce the alkali metal content and enhance the combustion quality of biomass briquettes. Under the optimized conditions of 1.325% acid concentration and 359.8 minutes of soaking, the resulting briquettes demonstrated significantly reduced potassium and sodium levels (0.5191 mg/g and 0.0049 mg/g, respectively), alongside favorable fuel properties such as a high calorific value of 5982.4 cal/g, ash content of 4.59%, and moisture content of 8.31%. These values comply with, or are close to, the quality standards set by SNI and Coford. The reduction of alkali content not only improves fuel performance but also minimizes the risk of fouling and slagging during combustion, supporting the potential of coconut husk briquettes as a safe and sustainable alternative energy source for boiler systems. Overall, this study provides a practical and environmentally friendly approach to valorize coconut waste through a simple yet effective pretreatment process.

## 6. Abbreviations

| | |
|---|---|
| *Na* | Sodium |
| *K* | Potassium |
| *$CH_3COOH$* | Acetic acid |
| *AAS* | Atomic Absorption Spectrophotometer |
| *SNI* | Standar Nasional Indonesia |
| *ASTM* | American Society for Testing and Materials |
| *RSM* | Response Surface Methodology |
| *w/v* | Weight per volume |
| *BPS* | Badan Pusat Statistik |
| *BSN* | Badan Standardisasi Nasional |
| *Coford* | National Council for Forest Research and Development |

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