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Original Research

PROXIMATE ANALYSIS AND CALORIFIC VALUE OF WATER HYACINTH CHAR BRIQUETTES AS ALTERNATIVE FUEL

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ABSTRACT

Proximate Analysis and Calorific Value of Water Hyacinth Char Briquettes as Alternative Fuel. *This study aimed to utilize water hyacinth (Eichhornia crassipes) as a renewable alternative fuel. Water hyacinth, which grows abundantly and often becomes an aquatic weed in Indonesian waters, possesses substantial biomass potential. The research stages included the production of biobriquettes through drying, carbonization, and molding processes. Briquette characterization involved proximate analysis to determine moisture content, ash content, volatile matter content, fixed carbon content, and calorific value. The proximate analysis results showed that water hyacinth briquettes had average values of 12.233% moisture content, 18.315% ash content, 50.900% volatile matter content, and 18.552% fixed carbon content. The average calorific value obtained was 4049.097 cal/g. These findings contribute to the development of local biomass energy by providing proximate characteristics and calorific value data of water hyacinth biobriquettes as a basis for the sustainable utilization of aquatic biomass resources.*

INTRODUCTION

The high dependence on fossil fuels has triggered an energy crisis and serious environmental impacts, including increased greenhouse gas emissions and global warming. Therefore, the exploration of efficient and environmentally friendly renewable energy sources has become an urgent necessity (1,2). Indonesia, with its abundant natural resources, possesses substantial biomass potential as a biofuel source. The utilization of biomass waste not only improves energy efficiency but also reduces waste management costs and minimizes the need for landfill areas, particularly in urban regions (3).

One of the most abundant biomass resources and frequently regarded as an aquatic weed in Indonesian waters is water hyacinth (*Eichhornia crassipes*). This aquatic plant exhibits an extremely rapid vegetative reproduction rate, leading to uncontrolled growth (4). Such phenomena often result in serious environmental problems, including river sedimentation, blockage of irrigation channels, and degradation of aquatic ecosystems. For instance, in Banjarmasin City, South Kalimantan, dense mats of water hyacinth covering the surface of the Martapura River have hindered water transportation and local community activities (5). Its relatively high bioethanol and biogas contents indicate that water hyacinth (*Eichhornia crassipes*) can be considered a promising energy crop capable of supplying clean and renewable energy with significant environmental benefits (6).

Numerous studies have demonstrated the successful conversion of various biomass wastes into briquettes as alternative fuels, such as coffee grounds [7], corn cobs [8], and sawdust [9,10]. Although studies on the utilization of water hyacinth as a briquette feedstock have been conducted, limitations remain, particularly regarding the characterization of briquettes produced from pure water hyacinth without the addition of other materials [11,12]. Water hyacinth biomass has also exhibited an adsorption capacity exceeding 89% for Methylene Blue dye, indicating its potential as a natural and renewable adsorbent for wastewater treatment applications [13]. Previous studies have generally focused on mixed briquettes or have analyzed only a limited number of briquette characteristics. Therefore, this study aims to address this research gap by conducting an in-depth characterization of charcoal briquettes produced solely from water hyacinth.

Previous studies have shown that water hyacinth (*Eichhornia crassipes*) has considerable potential as a renewable biomass-based energy feedstock. Balong et al. [11] reported that water hyacinth biobriquettes can be utilized as alternative fuels, although challenges remain in the form of high ash content and low calorific value. The quality of water hyacinth briquettes is strongly influenced by the carbonization process [4], particularly the temperature and heating duration, which play a critical role in reducing volatile matter content and increasing calorific value. Water hyacinth briquettes are considered feasible for local-scale applications as a solution for aquatic weed utilization [12], although they do not yet fully meet national and international standards. Non-conventional biomass, including aquatic plants and organic residues, has the potential to serve as a sustainable alternative energy source when supported by optimized production processes [1,7].

Processing water hyacinth into briquettes with the addition of binders (starch) has shown promising results. Proximate analysis revealed low moisture content (~2.76%), ash content of ~15.26%, volatile matter of ~67.32%, and a net calorific value of ~15.24 MJ/kg (≈ 3647 cal/g) [14]. The highly abundant biomass potential of water hyacinth (*Eichhornia crassipes*), characterized by high cellulose and hemicellulose contents and its capacity to produce bioethanol, biogas, and bioelectricity, makes it an ideal candidate for renewable fuel applications. Combustion tests indicated that increasing the proportion of water hyacinth in bio-briquettes resulted in decreased O_2 and CO levels, while CO_2, NO, NO_2, and SO_2 emissions increased. Consequently, the results concluded that biomass bio-briquettes derived from water hyacinth and empty fruit bunches have significant potential as alternative substitutes for conventional coal to minimize greenhouse gas emissions [15].

However, commercial utilization of water hyacinth biomass remains limited, necessitating further research to optimize its conversion into clean energy [9]. Moreover, most previous studies have focused on mixed briquettes or have not conducted comprehensive proximate characterization of pure water hyacinth briquettes. Studies specifically emphasizing the use of pure water hyacinth without blending with other biomass materials and accompanied by complete proximate analysis remain scarce. Comprehensive proximate characterization—including moisture content, ash content, volatile matter, fixed carbon, and calorific value—is a critical parameter for assessing the feasibility and quality of biobriquettes as alternative biomass-based fuels. Therefore, this study emphasizes novelty in the comprehensive characterization of charcoal briquettes produced solely from water hyacinth without the addition of other materials as a basis for evaluating the quality of local biomass-based alternative energy.

Based on this background and the identified research gaps, this study aims to evaluate the quality of charcoal biobriquettes produced from pure water hyacinth sourced from the Martapura River based on complete proximate analysis results and to compare them with national and international quality standards as a basis for assessing their feasibility as an alternative biomass-based fuel.

MATERIALS AND RESEARCH METHODS

This study employed an experimental design with a quantitative approach to examine and analyze the characteristics of water hyacinth charcoal briquettes. This design was selected to obtain objective and measurable data. The research procedures were conducted systematically through structured and sequential stages.

Sample Collection Procedure

Water hyacinth (*Eichhornia crassipes*) samples were collected from the Martapura River in Banjarmasin City, South Kalimantan, Indonesia. Samples were collected randomly to ensure adequate representation of the water hyacinth population at the study site. Each sample was subsequently cleaned to remove adhering impurities and washed with clean water prior to further processing.

Research Stages

Chronologically, the study followed the stages outlined below:

Drying

The cleaned water hyacinth samples were sun-dried for 3–4 days until a sufficiently dry condition was achieved and the material was ready for subsequent processing.

Carbonization

The dried raw material was subjected to incomplete combustion under limited oxygen conditions until it was converted into charcoal. The carbonization process was carried out using a simple method without quantitative control or measurement of temperature and duration. The endpoint of carbonization was determined based on physical changes in the material, namely its transformation into black and brittle charcoal. This limitation in controlling carbonization temperature and time may influence the proximate characteristics and calorific value of the resulting biobriquettes [4,26].

Grinding and Mixing

The resulting water hyacinth charcoal was ground and pulverized into a fine powder. The charcoal powder was then mixed with a natural binder in the form of tapioca starch at a composition ratio of 95% water hyacinth charcoal powder and 5% binder. The 5% binder ratio was selected as it falls within the optimum range recommended by various biomass biobriquette studies, which report that a 5% binder content can enhance briquette strength without significantly reducing combustion performance [9,14,20].

Briquette Molding and Drying

The mixture was molded using a briquette mold and subsequently sun-dried for two days until the briquettes hardened and dried completely. Each briquette production stage, from drying to molding, was repeated three times (A1, A2, and A3) to ensure result consistency.

Data Analysis Methods

After the briquettes were produced, samples from each repetition (A1, A2, and A3) were analyzed using proximate analysis methods to determine the following parameters:

- Moisture Content (ASTM E871) [16]
- Ash Content (ASTM D3174) [17]
- Volatile Matter Content (ASTM D3175) [18]
- Calorific Value (ASTM D5865) [19]

ASTM standards were used as references for testing methods because they are internationally recognized and widely applied in the characterization of solid fuels derived from biomass and coal, enabling the generation of reliable and scientifically comparable data.

Meanwhile, the Indonesian National Standard (SNI) was used as a benchmark to assess the conformity of biobriquette quality with domestic regulations and utilization requirements. Other international standards, such as those from Japan and the United States, were employed as additional references to provide an overview of the quality positioning of water hyacinth biobriquettes relative to briquette products developed globally.

RESEARCH RESULTS AND DISCUSSION

This section presents the results of proximate characteristics and calorific value testing of water hyacinth charcoal biobriquettes obtained from three experimental repetitions. The test results are presented descriptively to illustrate the quality characteristics of the produced biobriquettes and are subsequently discussed with reference to relevant theories and compared with national and international quality standards to assess their feasibility as biomass-based alternative fuels.

In general, the analyzed parameters include moisture content, ash content, volatile matter content, fixed carbon, and calorific value. A summary of the proximate analysis and calorific value results of the water hyacinth charcoal biobriquettes is presented in Table 1 as an initial overview of the quality of the produced biobriquettes prior to a more detailed discussion of each parameter.

Table 1. Proximate Analysis and Calorific Value of Water Hyacinth Char Briquettes

Parameter	Result (%) / (cal/g)	National and International Standards
Moisture Content	12.233 %	Ministry of Energy and Mineral Resources Regulation (<15 %)
Ash Content	18.315 %	SNI 01-6235-2000 (<8 %); Japanese Briquette Standard (<10 %)
Volatile Matter	50.900 %	SNI 01-6235-2000 (<15 %); USA Briquette Standard (<15 %)
Fixed Carbon	18.552 %	Japanese Briquette Standard (80–85 %); British Briquette Standard (>50 %)
Calorific Value	4,049.097 cal/g	SNI 01-6235-2000 (>5,000 cal/g); Japanese Briquette Standard (>7,000 cal/g)

The results of moisture content testing of water hyacinth charcoal briquettes for each experimental repetition are presented in Table 2.

Table 2. Moisture Content Measurement Results of Water Hyacinth Char Briquettes

Treatment	Moisture Content (%)
A1	12,200
A2	12,650
A3	11,850
Average	12,233

The moisture content test results of water hyacinth charcoal briquettes showed variations across each experimental repetition. Treatment A1 exhibited a moisture content of 12.200%, A2 showed 12.650%, and A3 recorded 11.850%, with an average value of 12.233%.

Moisture content is a critical parameter in evaluating charcoal briquette quality, as it affects ignition ease, combustion stability, and calorific value. The moisture content of water hyacinth charcoal briquettes obtained in this study remained below the maximum limit specified by the Regulation of the Ministry of Energy and Mineral Resources (<15%), indicating general compliance with solid fuel requirements. However, when compared with international quality standards, the observed moisture content can be considered relatively high and may reduce combustion efficiency, as a portion of the thermal energy is consumed to evaporate water during the initial combustion stage [16,20].

The relatively high moisture content of water hyacinth charcoal briquettes can be attributed to the inherent characteristics of water hyacinth, which naturally contains a very high moisture level. In addition, the use of natural sun-drying methods is strongly influenced by weather conditions and ambient humidity, allowing residual moisture to remain trapped within the briquette pores. This condition may lead to a reduction in effective calorific value and slow down the initial ignition process [21,22].
Therefore, optimization of the drying process, both before and after briquette molding, is highly necessary to further reduce moisture content. Lower moisture levels are expected to improve combustion efficiency, accelerate ignition, and enhance the overall quality of water hyacinth charcoal biobriquettes as a locally sourced biomass-based alternative fuel.

The results of ash content measurements of the briquettes are presented in Table 3.

Table 3. Ash Content Measurement Results of Water Hyacinth Char Briquettes

Treatment	Ash Content (%)
A1	Ash Content (%)
A2	Ash Content (%)
A3	Ash Content (%)
Average	Ash Content (%)

Based on the test results, the ash content of water hyacinth charcoal briquettes exhibited relatively high and consistent values across all experimental repetitions. Treatment A1 recorded an ash content of 18.445%, A2 showed 17.950%, and A3 reached 18.550%, with an average value of 18.315%. The relatively small variation in ash content among repetitions indicates consistency in both raw material characteristics and the briquette production process.
Ash content is an indicator of the amount of inorganic residue remaining after complete combustion and directly affects combustion efficiency and calorific value. The ash content values of the water hyacinth charcoal briquettes obtained in this study are considered high when compared with national and international charcoal briquette quality standards. According to SNI 01-6235-2000, the ash content of charcoal briquettes is required to be less than 8%, while the Japanese briquette standard specifies an ash content of less than 10%. Therefore, the ash content of the water hyacinth charcoal briquettes produced in this study does not meet these quality standards.
The high ash content is closely related to the characteristics of water hyacinth as an aquatic plant with the ability to absorb various mineral elements and metals from the surrounding water and sediment. During the carbonization process, organic compounds decompose and burn, whereas non-combustible inorganic components remain as ash. This condition results in a relatively high ash fraction in the briquettes [15].
High ash content negatively affects briquette quality because ash is inert and does not contribute to heat generation, thereby reducing the calorific value and combustion efficiency. In addition, excessive ash residue may reduce user convenience by leaving a large amount of combustion residue [22]. Nevertheless, for local-scale and household applications, water hyacinth charcoal briquettes still show potential for use, provided that quality improvement efforts are undertaken, such as optimizing the carbonization process or blending with low-ash biomass to reduce the ash fraction [24].

The results of volatile matter content testing of water hyacinth charcoal briquettes for each experimental repetition are presented in Table 4.

Table 4. Volatile Matter Measurement Results of Water Hyacinth Char Briquettes

Treatment	Volatile Matter Content (%)
A1	50,650
A2	50,650
A3	51,400
Average	50,900

Based on the test results, the volatile matter content of water hyacinth charcoal briquettes exhibited very high and relatively uniform values across all experimental repetitions. Treatments A1 and A2 each showed a volatile matter content of 50.650%, while treatment A3 presented a slightly higher value of 51.400%. The average volatile matter content obtained was 50.900%, indicating that a large fraction of the material still consisted of easily volatilized organic compounds.

Volatile matter refers to components that vaporize when the briquette is heated, including gases, tar, and light hydrocarbon compounds. A high volatile matter content can facilitate initial ignition; however, it generally has a negative impact on combustion quality by increasing smoke formation and reducing flame stability (18). The volatile matter content of water hyacinth charcoal briquettes observed in this study far exceeds the limits specified by charcoal briquette quality standards, both under SNI 01-6235-2000 and international standards such as those of Japan and the United States, which generally require volatile matter contents below 15%.

The high volatile matter content obtained indicates that the carbonization process was not yet optimal. Carbonization conducted using a simple method without precise control of temperature and duration resulted in incomplete decomposition of organic compounds, causing a substantial portion of volatile matter to remain trapped within the charcoal structure (4,26). This finding is consistent with previous studies reporting that increasing carbonization temperature and duration can effectively reduce volatile matter content while increasing fixed carbon content in biomass briquettes (11).

In addition to process-related factors, the characteristics of water hyacinth as a raw material—rich in cellulose and hemicellulose—also contribute to the high volatile matter content. These components decompose readily at relatively low temperatures and generate high volatile fractions when carbonization is not carried out optimally (26). The elevated volatile matter content directly contributes to the low fixed carbon content and calorific value of the briquettes, highlighting the need for carbonization process optimization to improve the quality of water hyacinth charcoal biobriquettes as an alternative fuel.

The results of calorific value testing of water hyacinth charcoal biobriquettes for each experimental repetition are presented in Table 5.

Table 5. Calorific Value Measurement Results of Water Hyacinth Char Briquettes

Treatment	Calorific Value (cal/g)
A1	3725,072
A2	4240,276
A3	4181,943
Average	4049,097

The test results indicate that the calorific value of water hyacinth charcoal biobriquettes varied across experimental repetitions. Treatment A1 exhibited a calorific value of 3725.072 cal/g, A2 recorded 4240.276 cal/g, and A3 showed 4181.943 cal/g, with an average value of

4049.097 cal/g. The relatively small variation in calorific value among repetitions indicates consistency in the biobriquette production process.

Calorific value is a primary parameter in evaluating the quality of biobriquettes as alternative fuels, as it represents the amount of thermal energy released during combustion. The average calorific value of the water hyacinth charcoal biobriquettes obtained in this study remains below the quality standards specified by SNI 01-6235-2000, which require values greater than 5,000 cal/g, as well as the Japanese briquette standard that mandates calorific values exceeding 7,000 cal/g. Therefore, the produced water hyacinth charcoal biobriquettes do not yet meet energy quality standards for commercial applications.

The low calorific value of the water hyacinth charcoal biobriquettes is closely associated with the obtained proximate characteristics, particularly the high moisture content, ash content, and volatile matter content, as well as the low fixed carbon content. High moisture content causes a portion of the released thermal energy to be consumed for water evaporation, while high ash content reduces the fraction of combustible material. Moreover, elevated volatile matter content indicates a suboptimal carbonization process, resulting in low fixed carbon content as the primary source of thermal energy [(12)].

These results are consistent with previous studies reporting that improvements in biomass biobriquette quality, particularly in terms of calorific value, are strongly influenced by optimization of the carbonization process, including control of heating temperature and duration [(4,11,26)]. Accordingly, enhancement of the calorific value of water hyacinth charcoal biobriquettes may be achieved through improvements in drying methods, the use of carbonization furnaces with better temperature control, and increased compaction pressure during molding to produce briquettes with higher density.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of proximate analysis and quality assessment, it can be concluded that charcoal biobriquettes produced from pure water hyacinth have the potential to be developed as a local biomass-based alternative fuel, although their quality characteristics have not yet fully met national and international standards. The moisture content of the biobriquettes remains within an acceptable range; however, the high ash and volatile matter contents contribute to low fixed carbon content and calorific value. These conditions indicate that the utilization of water hyacinth biobriquettes is more suitable for local-scale applications with relatively low energy demand, while simultaneously serving as a strategy for controlling aquatic weeds and utilizing biomass waste.

The findings of this study provide practical implications as a basis for the development of water hyacinth processing technologies into higher-value alternative energy products. For future research, optimization of the production process is required, particularly in terms of controlling carbonization temperature and duration to reduce volatile matter content and increase fixed carbon, as well as regulating compaction pressure during briquette molding to obtain higher density and calorific value. Such improvements are expected to enhance product quality and bring it closer to the applicable solid fuel quality standards.

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