RASĀYAN *J. Chem.*
Vol. 18 | No. 3 |1822-1830| July-September | 2025
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

PHYSICOCHEMICAL CHARACTERISTICS AND FUEL POTENTIAL OF CHARCOAL BRIQUETTES FROM CANDLENUT AND PEANUT SHELL MIXTURES

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ABSTRACT

The exhaustion of fossil fuel reserves has heightened the demand for alternative and renewable energy sources. Biomass-derived charcoal briquettes represent a viable alternative, providing a sustainable approach to transform agricultural waste into effective fuel. This study examines the physicochemical features of charcoal briquettes produced from different mixing ratios of candlenut shells and peanut shells—specifically 60:30, 45:45, and 30:60 by weight. The briquettes were assessed for moisture content (3.429%–5.073%), ash content (9.574%–13.645%), volatile matter (8.929%–13.459%), and fixed carbon (67.823%–78.068%). The physical characteristics assessed included density (0.609–0.678 g/cm³), calorific value (2651.210–3039.258 cal/g), and combustion duration (15–19 minutes). The results demonstrate that the briquettes predominantly conform to specified quality criteria, except for calorific value, which is marginally below optimal levels. These findings validate the viability of utilising candlenut and peanut shells as feedstock for charcoal briquettes, offering an environmentally sustainable substitute for fossil fuels while contributing to the mitigation of agricultural waste. The study endorses Sustainable Development Goal (SDG) 7: Affordable and Clean Energy, by advocating for the advancement of renewable biofuel derived from locally accessible biomass resources. In addition, the results can serve as instructional material for thermochemistry, particularly in calorimetric calculations, thereby supporting both energy sustainability and science education.

Keywords: Alternative Energy, Biomass Briquettes, Candlenut Shell, Peanut Shell, Renewable Energy, Charcoal Characteristics.

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INTRODUCTION

The overexploitation of fossil-based energy resources has led to a rapid decline in their availability. In Indonesia, this dependency on fossil fuels has significantly contributed to a sharp reduction in domestic oil production. This decline is primarily attributed to the expansion of industrial activities and population growth. To address the depletion of these non-renewable resources, there is an urgent need to develop alternative energy sources that are not only renewable and widely available but also economically accessible to the general public.[1] Researchers have proposed several strategies to reduce reliance on finite energy supplies, with one promising approach being the use of renewable biomass. Biomass energy can be harnessed through various conversion technologies, one of which involves transforming it into briquettes. Briquetting is a method of compressing and shaping biomass into uniform, solid fuel forms with enhanced calorific efficiency. Among the various types of biomass residues, candlenut shells have emerged as a viable feedstock for briquette production due to their rigid structure. This physical robustness is attributed to their chemical composition, which includes approximately 25.77% cellulose, 28.73% hemicellulose, and 36.02% lignin.[2] The relatively high lignin content plays a critical role in binding the material during briquette formation and contributes to a higher energy yield when combusted. Alternative fuels can address waste management issues and serve as a substitute for kerosene through their conversion into charcoal briquettes; however, optimization is needed to enhance the effectiveness and efficiency of these alternative raw materials.[3] Therefore it is necessary to mix with other biomass in the manufacture of candlenut shell briquettes with the expectation that optimal characteristics will be produced and can overcome other biomass wastes. Apart from candlenut shells, one of the most abundant biomass wastes is peanut shell

http://doi.org/10.31788/RJC.2025.1839366

waste. As we know, these two materials are only used for the seeds, while the shell and skin are wasted. Peanut skin itself has a chemical content such as 63.5% cellulose, 13.2% lignin, 9.5% water, 8.4% protein, 3.6% ash, and 1.8% fat.[2] Peanut shell waste also holds significant potential for use in charcoal briquette production due to its relatively high cellulose and lignin content. Several researchers have previously made briquettes from a mixture of candlenut shells and empty palm fruit bunches[4], peanut shells and corn cobs[5], and several other biomasses. However, there has been no research on briquettes made from a mixture of candlenut shells and peanut shells, so the chemical and physical characteristics of charcoal briquettes from a mixture of these two raw materials are unknown. Therefore, this study focuses on the development of briquettes derived from a combination of candlenut shells and peanut shells, with the objective of examining their physical and chemical properties and identifying the optimal composition based on the resulting characteristics. Therefore, this study aims to analyze the physical and chemical properties of charcoal briquettes made from different ratios of candlenut shells and peanut shells, and to determine the optimal mixture that yields the best performance. The research addresses the existing gap by investigating a previously unexamined biomass combination. Furthermore, this study contributes directly to the achievement of Sustainable Development Goal (SDG) 7: Affordable and Clean Energy, which emphasizes access to reliable, sustainable, and modern energy for all.[6] The utilization of biomass waste to produce renewable energy aligns with the SDG 7 target to increase substantially the share of renewable energy in the global energy mix. According to[7], the sustainable use of bioenergy from agricultural residues not only reduces greenhouse gas emissions but also provides energy solutions that are inclusive and adaptable for rural and underserved communities. Hence, innovations such as these briquettes offer both environmental and socio-economic benefits.

EXPERIMENTAL

Charcoal Making

Candlenut shells and peanut shells were dried in the sun for 5 days for candlenut shells and 3 days for peanut shells. After that, it was carbonized manually using an old tin that had a hole punched at the bottom. The charcoal making of candlenut shells and peanut shells is done separately. After the place for making is ready, the candlenut shells and dried peanut shells are put into each biscuit tin and then burned. Following the carbonization process, the candlenut and peanut shells are extracted from the container and allowed to cool to ambient temperature. Once cooled, the resulting charcoal is ground using a stone mortar and subsequently passed through a 60-mesh sieve to produce fine charcoal powder.

Briquettes Charcoal Making

Charcoal briquettes are made by mixing candlenut shell charcoal flour (TK), peanut shells (KK), and tapioca flour adhesive. The adhesive is made by cooking 30 g of tapioca flour with 200 mL of water. This mixture is heated until it forms a gel, indicated by a color change from white to clear. The finished tapioca adhesive is then mixed with charcoal flour according to the mixture composition variations presented in Table-1.

Table-1: Variations in the Composition of a Mixture of Candlenut Shells (TK) and Peanut Shells (KK)

Sample	Composition TK: KK	Tapioca flour
A	60%: 30%	10%
B	45%: 45%	
C	30%: 60%	

The briquette dough that has been mixed evenly is then printed using a cylindrical mold, and manual pressing is carried out. The finished printed briquettes are then dried in the sun. After obtaining the results of dry briquettes, a characteristic test is carried out according to the parameters tested.

Chemical and Physical Characterization of Charcoal Briquettes

The present study assessed the chemical and physical characteristics of charcoal briquettes, focusing on several key parameters. The chemical properties analyzed included moisture content, ash content, volatile matter, and fixed carbon content. The physical properties evaluated comprised density, calorific value, and combustion performance.

Water Content

The moisture content was determined by oven-drying briquette samples at 105°C until a constant weight was achieved. The percentage of moisture was then calculated using the following equation:

$$\textit{Water content (\%)} = \frac{W_2 - W_3}{W_1} \times 100\ \%$$

Ash Content

To determine ash content, the samples were incinerated in a muffle furnace at a temperature of 600°C for a duration of three hours. The percentage of ash was calculated using the formula:

$$\textit{Ash content (\%)} = \frac{W_3 - W_1}{W_2} \times 100\ \%$$

Volatile Matter Content

Determination of volatile matter content is carried out by heating the briquette samples using a furnace at 950ºC for 3 hours. Volatile matter levels are calculated using the formula:

$$\textit{Volatile matter content} = \frac{W_1 - W_2}{W_1} \times 100\%$$

Bonded Carbon Content

The fixed carbon content was calculated by referencing the SNI 01-6235-2000 standard. It was obtained indirectly by subtracting the combined percentages of moisture, ash, and volatile matter from 100%, according to the equation:

carbon content = 100 % - (water content + ash content + volatile matter content)

Density

Density was measured by calculating the ratio of the mass of the briquette to its volume, expressed using the equation:

$$p = \frac{m}{V}$$

Calorific Value

The calorific value, representing the energy released per unit mass upon complete combustion, was determined using a bomb calorimeter. The energy value was calculated as:

$$GE = \frac{(T_2 - T_1) \times 1.325{,}605}{\text{sample weight}}$$

T_1 = initial temperature (°C)
T_2 = final temperature (°C)
He = ekuivalen hidrotermal (Cal/°C)

Burn Ability

The determination of burn ability is done by calculating the length of time it takes to boil water with a volume of 1 liter of water.[8] Testing the burn ability of briquettes was carried out by weighing ± 165 g of briquettes and then placing them in a briquette stove and burning them. After that, calculate the time it takes to boil 1 liter of water using a stopwatch.

RESULTS AND DISCUSSION

The findings of this study are based on the analysis of the chemical and physical properties of briquettes produced from a mixture of candlenut shell charcoal and peanut shells, as presented in Table-2.

Table-2: Characterization Results of Briquettes Composed of Mixed Candlenut Shells and Peanut Shells Include the Evaluation of Their Impact on the Corrosion Rate of Iron Plates

Sample	Mixed composition briquette TK: KK (%)	Chemical characteristics				Physical characteristics		
		Water content (%)	Ash content (%)	Volatile matter (%)	Bounded carbon content (%)	Density (g/cm^3)	Calorific value (cal/g)	Burn ability (minute)
A	60: 30	3,429	9,574	8,929	78,068	0,678	3039,258	15
B	45: 45	4,604	13,196	12,357	69,843	0,633	2804,986	17
C	30: 60	5,085	13,645	13,459	67,823	0,609	2651,210	19

This analysis not only contributes to the technical understanding of biomass briquettes but also directly supports Sustainable Development Goal (SDG) 7: Affordable and Clean Energy, by demonstrating the viability of low-cost, renewable energy derived from agricultural waste.

Characteristics of Charcoal Briquettes

Water Content

Moisture content refers to the proportion of water present in briquettes, expressed as a percentage. This parameter plays a critical role in determining the overall quality and performance of charcoal briquettes. According to[9]Moisture content significantly influences the calorific value of briquettes. Elevated moisture levels tend to lower the energy yield, as a portion of the generated heat is initially consumed in evaporating the water before contributing to effective combustion. The distribution of moisture content across different briquette mixture variations is presented in Table-1, with the corresponding graphical representation shown in Fig.-1.

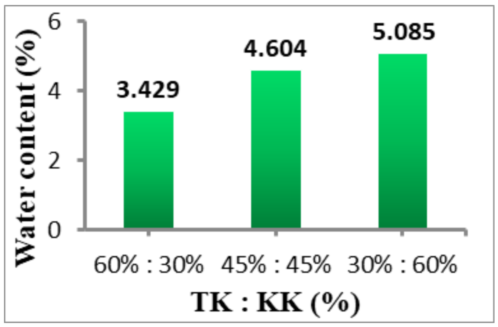

Fig.-1: Graph of Water Content in Each Variation of Briquette Mix

The moisture content of the briquettes produced in this study ranged from 3.429% to 5.085%, all of which fall within the acceptable limits established by various national standards for briquette quality. The highest moisture content (5.085%) was observed in the mixture containing 30% candlenut shell (TK) and 60% peanut shell (KK), whereas the lowest value (3.429%) was recorded in the composition with 60% TK and 30% KK. An increasing proportion of peanut shell charcoal in the mixture was found to correspond with an increase in the briquettes' moisture content, while higher candlenut shell content resulted in lower moisture levels. These differences can be attributed to the intrinsic chemical composition of the raw materials, particularly their cellulose and lignin content. According to[2]Candlenut shells contain 25.77% cellulose and 36.02% lignin, whereas peanut shells have a significantly higher cellulose content (63.5%) and lower lignin content (13.2%) (Ministry of Agriculture, 2008). As noted by[10] Higher cellulose content increases water absorption due to hydrogen bonding with the hydroxyl (–OH) groups present in cellulose. Conversely, lignin acts as a binder that provides structural rigidity and hydrophobic characteristics to the material. Therefore, raw materials with higher lignin concentrations tend to yield briquettes with lower moisture content.

Ash Content

Ash refers to the inorganic residue left after the combustion process, which no longer contains carbon elements. Silica is the primary component of ash, and its presence negatively impacts the calorific value of the briquettes. As the ash content increases, the quality of the briquettes decreases, as higher ash levels can lead to a reduction in the heating value.[11] The distribution of ash content across different briquette mixture variations is presented in Table-1, with the corresponding graphical representation shown in Fig.-2.

The ash content of the briquettes analyzed in this study ranged from 9.574% to 13.645%. These values surpass the maximum ash content specified by Indonesian briquette standards (8%) and those of Japan, which generally fall between 3% and 6%. Nevertheless, Sample A conforms to the British standard, which allows ash contents between 8% and 10%, while the remaining samples remain within the limit of the American standard, which permits up to 18%. The highest ash content, 13.645%, was observed in the briquette composed of 30% candlenut shell (TK) and 60% peanut shell (KK), whereas the lowest, 9.574%, was found in the mixture containing 60% TK and 30% KK. This trend indicates that increasing the proportion of peanut shell charcoal leads to higher ash content, likely due to its elevated silica concentration. Moreover, the higher lignin content in candlenut shells (36.02%) compared to peanut shells (13.2%) contributes to a more efficient carbonization process. This results in higher-quality charcoal with lower residual ash content.[12]

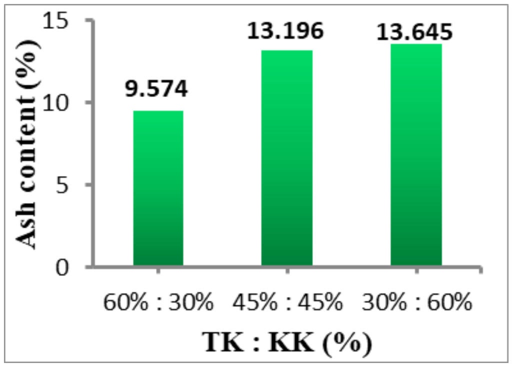

Fig.-2: Graph of Ash Content in Each Variation of Briquette Mix

Volatile Matter Content

Volatile matter is a substance that can evaporate as a result of the decomposition of compounds in charcoal, other than water, ash, and carbon. Volatile substances consist of the elements hydrogen, C2-C4 hydrocarbons, methane, and carbon monoxide. The volatile matter content for each briquette composition is detailed in Table-1, while its graphical illustration is provided in Fig.-3.

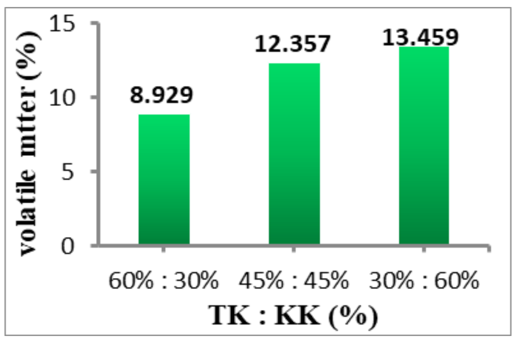

Fig.-3: Graph of Volatile Matter Content in Each Variation of Briquette Mix

The volatile matter content of the charcoal briquettes produced in this study ranged from 8.929% to 13.459%, all within the acceptable limits set by several international standards. These include the Indonesian standard (maximum 15%), the Japanese standard (15–30%), the British standard (16%), and the American standard (up to 19%). The data inform practical strategies to optimize fuel blends, thereby making clean-burning briquettes more accessible and environmentally acceptable, a contribution toward sustainable modern energy services (SDG 7.1 and 7.2). The highest volatile matter content, 13.459%, was recorded in the mixture comprising 30% candlenut shell (TK) and 60% peanut shell (KK), while the lowest value, 8.929%, was observed in the composition with 60% TK and 30% KK. A trend was identified in which increasing the proportion of peanut shell charcoal corresponded to higher volatile matter content, while increasing the candlenut shell content led to a reduction in volatiles. This can be attributed to the nature of peanut shell charcoal, which generally contains a greater amount of volatile hydrocarbons. These compounds, due to the larger surface area of peanut shell particles, are more susceptible to degradation. The elevated presence of hydrocarbons contributes significantly to the volatile fraction. Consequently, mixtures with higher peanut shell content tend to release more smoke upon ignition, primarily due to combustion reactions involving carbon monoxide (CO) and alcohol-based volatile compounds.[13]

Bonded Carbon Content

Fixed carbon content refers to the portion of carbon that remains within the charcoal structure after the exclusion of moisture, volatile matter, and ash components. This parameter represents the amount of carbon that is chemically bound and contributes directly to the energy content of solid fuels such as charcoal.[14] The fixed carbon content for each briquette formulation is detailed in Table-1, with its corresponding graphical representation provided in Fig.-4.

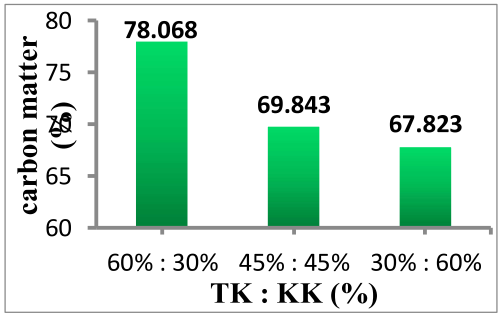

Fig.-4: Graph of Bonded Carbon Content in Each Variation of Briquette Mix

The fixed carbon content of the charcoal briquettes produced in this study ranged from 78.068% to 67.823%. These values fall within the acceptable limits set by Indonesian standards, which specify a maximum of 80%, and also align with international standards such as those of Japan (60–80%) and the United Kingdom (minimum 75%). The highest fixed carbon content (78.068%) was observed in the briquette composed of 60% candlenut shell (TK) and 30% peanut shell (KK), while the lowest value (67.823%) occurred in the mixture with 30% TK and 60% KK. A clear inverse relationship was noted between the proportion of peanut shell charcoal and the fixed carbon content; higher peanut shell content corresponded to lower fixed carbon values. This trend is attributed to the inherent differences in the physicochemical composition of the raw materials, particularly in terms of moisture, ash, and volatile matter. Candlenut shell charcoal, which typically has lower levels of these components, contributes to a higher fixed carbon yield. Briquettes with elevated fixed carbon content are generally considered to possess superior fuel quality, as this component directly enhances the calorific value. The energy released during combustion primarily results from the oxidation of carbon, producing heat.[4]

Density

Briquette density is a physical characteristic that influences the heat output and burn duration of the briquettes. The density values for each variation of the briquette mixture are presented in Table-1, with the corresponding graphical representation shown in Fig.-5.

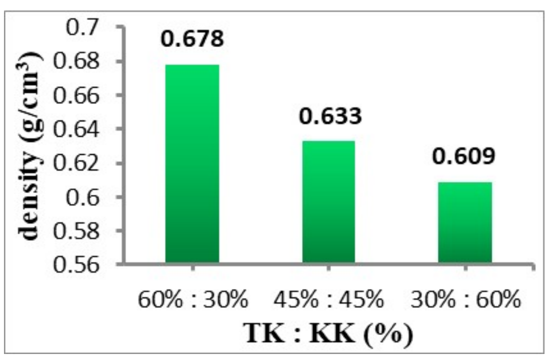

Fig.-5: Graph of Density in Each Variation of Briquette Mix

The density of the charcoal briquettes produced in this study ranged from 0.678 to 0.609 g/cm³, aligning with the standard density requirements for briquettes in several countries. The highest density value (0.678 g/cm³) was recorded in the briquette mixture consisting of 60% candlenut shell (TK) and 30% peanut shell (KK), while the lowest density (0.609 g/cm³) was observed in the composition containing 30% TK and 60% KK. Density is a critical parameter in determining briquette quality, as higher density is generally associated with improved calorific value. According to[13]Briquette density is influenced by both the particle size and the uniformity of the charcoal materials used in the mixture. Higher density briquettes tend to burn longer and produce more consistent heat, offering a viable and affordable energy source, especially for low-income and rural communities, directly supporting inclusive energy access under SDG 7.[8]

Calorific Value

The calorific values for each variation of the briquette mixture are presented in Table-1, with the corresponding graphical representation shown in Fig.-6.

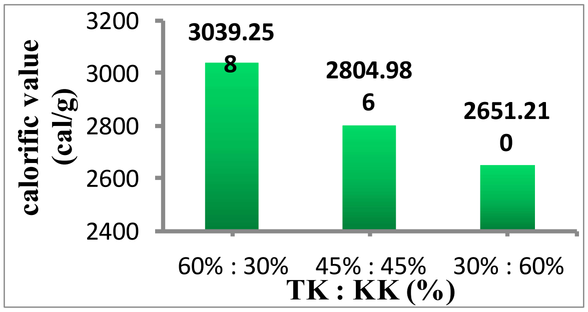

Fig.-6: Graph of Calorific Value in Each Variation of Briquette Mix

The calorific value of the charcoal briquettes produced in this study ranged from 3039.258 cal/g to 2651.210 cal/g. These values are considerably lower than the calorific values specified in various international standards, such as the Indonesian standard for briquettes (5000 cal/g), British briquettes (around 6500 cal/g), Japanese briquettes (approximately 6000-7000 cal/g), and American briquettes (around 7000 cal/g). The lower calorific values observed in this study are likely attributable to the relatively high ash content. High ash content often correlates with elevated volatile matter levels, which in turn leads to a reduction in the bound carbon content, thereby negatively affecting the overall calorific value. Another possible contributing factor to the low calorific values could be the testing procedure itself, as the sample was not formed into capsules or pellets prior to testing. Instead, it was directly placed into the Bomb Calorimeter, which may have resulted in a lower testing temperature, thereby compromising the efficiency of the combustion process and leading to suboptimal burning conditions. However, utilizing this biomass waste has the potential to produce alternative energy, which aligns with SDG 7.2, namely, substantially increasing the share of renewable energy in the global energy mix.[15]

Burn Ability

The burn ability for each variation of the briquette mixture is presented in Table-1, with the corresponding graphical representation shown in Fig.-7.

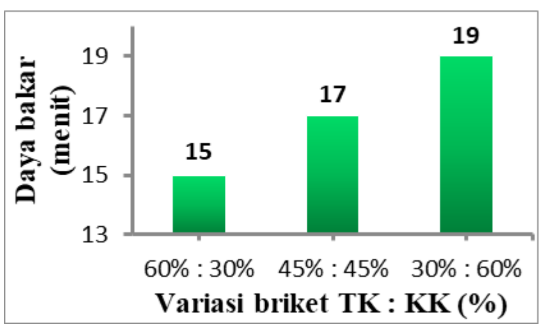

Fig.-7: Graph of Burn Ability in Each Variation of Briquette Mix

The burn ability of the briquettes was assessed by measuring the time required to boil 1 liter of water.[3] This test helps evaluate the briquettes' effectiveness as fuel. The fastest time to boil water was recorded for the briquettes with a composition of 60% candlenut shell (TK) and 30% peanut shell (KK), which took 15 minutes. In contrast, the longest boiling time was observed in the briquettes with a composition of 30% TK and 60% KK, taking 19 minutes. This practical outcome demonstrates that simple biomass blends can produce functional household fuel, supporting clean cooking solutions as emphasized in SDG 7.1.2.[16] The boiling time decreased as the proportion of candlenut shell charcoal increased and the proportion of peanut shell charcoal decreased. This is attributed to the higher calorific value of the mixture with more candlenut shell charcoal, which is influenced by its lower water content and higher carbon content. The reduced water content in the briquettes accelerates the ignition process and minimizes smoke production, leading to a more efficient and optimal combustion.[17] Additionally, the amount of bonded carbon in the briquettes significantly affects the combustion process, as carbon is required to react with oxygen to generate heat. Therefore, a higher bonded carbon content leads to improved combustion efficiency.

CONCLUSION

The examination of the chemical and physical properties of charcoal briquettes composed of a blend of candlenut shell and peanut shell indicated that the water content varied from 3.429% to 5.073%, ash content from 9.574% to 13.645%, volatile matter from 8.929% to 13.459%, fixed carbon from 67.823% to 78.068%, density from 0.609 to 0.678 g/cm³, calorific value from 2651.210 to 3039.258 cal/g, and burn duration between 15 to 19 minutes. Of the three composition variants evaluated, Sample A, comprising 60% candlenut shell charcoal and 30% peanut shell charcoal, demonstrated the most advantageous overall properties. This formulation yielded briquettes exhibiting the maximum fixed carbon concentration, minimal moisture content, and enhanced density and combustion efficiency. Although the water content, volatile matter, fixed carbon, and density of Sample A comply with the Indonesian National acceptable (SNI), its ash content and calorific value fall somewhat short of the acceptable standards. Nevertheless, the composition demonstrates significant potential as a sustainable and locally accessible biofuel source, particularly in alignment with initiatives to advance renewable energy solutions under Sustainable Development Goal (SDG) 7: Affordable and Clean Energy. In addition, the results of this study can be utilized as instructional material for thermochemistry, particularly in calorimetric calculations.

ACKNOWLEDGMENTS

The author would like to thank Tadulako University profusely for providing laboratory facilities and equipment so that this research could be carried out. Thank you and sincere appreciation to all those who have helped either directly or indirectly.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interest

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-7: Affordable and Clean Energy*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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