Journal of Sylva Indonesiana Vol.07, No.02 (2024) 76–88

talenta PUBLISHER

Journal of Sylva Indonesiana

Journal homepage: https://talenta.usu.ac.id/jsi

Utilization of Three Species of Mangrove Wood Branches for Briquettes and Its Preference as Alternative Solid Biofuel

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ARTICLE INFO

Article history:
Received June 2nd, 2023
Revised February 7th, 2024
Accepted March 19th, 2024
Available online August 26th, 2024

E-ISSN: 2622-5093
P-ISSN: 2622-5158

How to cite:
H. Tambunan, A. Nuryawan, A. H. Iswanto, M. Basyuni, I. Risnasari, A. Hermawan and B. Jeong, "Utilization of three species of mangrove wood branches for briquettes and its preference as alternative solid biofuel" *Journal of Sylva Indonesiana*, vol. 07, no. 02, pp. 76-88. Aug. 2024, doi: 10.32734/jsi.v7i02.12184

http://doi.org/ 10.32734/jsi.v7i02.12184

ABSTRACT

Wood briquettes - one of the biomass energies - were produced from three species of mangrove wood branches, namely mata buaya (*Bruguiera sexangula*), buta-buta (*Excoecaria agallocha*), and bakau minyak (*Rhizophora apiculata*) using three types of starch adhesives made from tapioca, maize, and potato. This study aimed to evaluate user preferences for the kind of fuel, and responses to acceptance of the use of briquettes, and to analyze the effect of attributes on interest in using wood briquettes from mangrove wood branches. Cylindrical briquettes were produced in dimensions of 3 cm diameter and 4 cm thickness. After obtaining all the data, variance analysis and chi-square analysis were conducted. Before conducting the preference survey, evaluations of calorific value and color performance were carried out. The wood briquettes of this study have a calorific value that has met the ISO 17225-3:2-2020 standard of class A2. Even though the three types of wood briquettes differ in their L* (brightness), a* (red/green), and b* (blue/yellow) values, each briquette has a neutral color. A survey was conducted on 60 respondents using a questionnaire to evaluate user preferences for the type of fuel, responses to acceptance of the use of briquettes, and the effect of attributes on interest in using wood briquettes from mangrove wood branches. The results showed that gas is still the most preferred fuel by respondents, with as many as 35 people (58.33%). Meanwhile, 54 respondents (90%) stated they would use wood briquettes. Wood briquettes made of Bakau minyak wood species were the most preferred, with as many as 28 people (46.67%). The chi-square analysis results suggested no relationship between the preference for using wood briquettes from mangrove wood branches and fuel attributes. Based on this study, wood briquettes of mangrove wood branches have the potential to be an alternative fuel as long as their availability is easy to obtain.

Keyword: Biomass Energy, Mangrove, Preference, Survey, Wood Briquettes

1. Introduction

Energy is an important part of human life. Energy is used for various purposes, ranging from cooking and heating to operating equipment, operating industrial machinery, and transportation. Global energy demand is quickly expanding as a result of rising population and economic growth, particularly in developing countries, which will account for 90% of the energy demand increase through 2035. Fossil fuels are the most widely used energy source today and will remain predominant in 2035 [1]. The reliance on fossil fuels as the main energy source has led to significant environmental harm, including global warming and air pollution. The consequences of air pollution have led to numerous health problems delivering negative impacts on society and the economy. Additionally, fossil fuels are energy sources that are not renewable, with reserves dwindling and eventually being depleted [2]. Therefore, renewable energy as an alternative to fossil fuels is an effort that must be made to overcome these unbeneficial impacts.

Biomass energy is a widely available renewable resource with untapped potential. Bio-energy represents a valuable renewable energy option with the potential to boost energy security [3] and can reduce the negative impact of using fossil fuels because it is carbon neutral [4]. Biomass encompasses all organic material generated through the process of photosynthesis, which includes plants and vegetation on land and in water. Biomass is harvested from forests as wood biomass, as well as from various types of waste, including municipal solid waste, forestry and agricultural residues, and specific industrial by-products [5]. Indonesia is one of the countries focused on advancing renewable energy, with a particular emphasis on bioenergy.

Indonesia has forest resources as a producer of wood biomass. Indonesia has great potential to develop a source of biomass energy. Energy obtained from wood biomass is still a choice for Indonesian people, especially those in society who live around forests that are used for cooking purposes. Mangrove is one of the forest resources in Indonesia. It provides various benefits, such as a source of energy, a building material, and both the absorption and storage of carbon [6]. However, the utilization of mangrove forests is still prioritized for ecological functions, reducing the disadvantages of natural disasters such as tsunamis and hurricanes [7], producing food and beverage products processed from mangrove leaves and fruits [8]–[10], sources of pharmaceuticals [11]–[12], and natural dyes derived from mangrove biomass [13]. Meanwhile, mangroves as an energy source have not been employed optimally. Communities generally use mangrove wood biomass, which is harvested directly for firewood [14].

That certainly has a drawback impact on the mangrove ecosystem, as dependence on fuel wood from harvesting directly causes mangrove forests to degrade [15]. In addition, burning firewood creates a lot of smoke, which is hazardous to health [16]. Hence, using mangrove wood biomass from non-main stems, such as branches, as an alternative biomass energy source to replace fossil fuels used as raw materials for making wood briquettes is an effort that can be implemented to overcome this problem. Briquetting is the process of compacting woody biomass into a solid material that can be used as fuel [17]. Wood briquettes are environmentally friendly solid fuels that help reduce pollution, contribute to environmental sustainability, and are light, economical, and easy to transport [18].

The use of wood briquettes as a fuel source is still rare among the community. There are many factors contributing to this, including the lack of public awareness about bioenergy, insufficient implementation of regulations, subsidized fossil fuel energy, etc. Despite the diverse potential benefits of bioenergy in social, economic, and environmental aspects. Wood briquettes as bioenergy have the potential to diversify the energy sector by utilizing locally sourced raw materials [19]. In this regard, a survey on the preferences for fuel types and public acceptance of wood briquettes as a renewable energy source needs to be conducted.

This study focused on producing wood briquettes from branches of three mangrove species, namely mata buaya (*Bruguiera sexangula*), buta-buta (*Excoecaria agallocha*), and bakau minyak (*Rhizophora apiculata*), and applying three different starch adhesives: tapioca, maize, and potato. This study aims to evaluate the basic characteristics of wood briquettes, including calorific value and color performance, and subsequently to complete a survey using a questionnaire containing user preferences for the type of fuel, responding to the acceptability of wood briquettes as fuel, and analyzing the effect of attributes on interest in using wood briquettes from mangrove wood branches.

2. Materials and Methods

2.1 Materials

Prototypes of wood briquettes made from mangrove wood branches comprised of mata buaya (*B. sexangula*), buta-buta (*E. agallocha*), and bakau minyak (*R. apiculata*). The woods were obtained from Lubuk Kertang, a village university partner, which is located at 04º 02' 34.25" - 04º 05' 27.11" North Latitude and 98º 14' 57.92" - 98º 18' 37.87" East Longitude. It lies in West Brandan District, Langkat Regency, Province of North Sumatra, Indonesia (Figure 1).

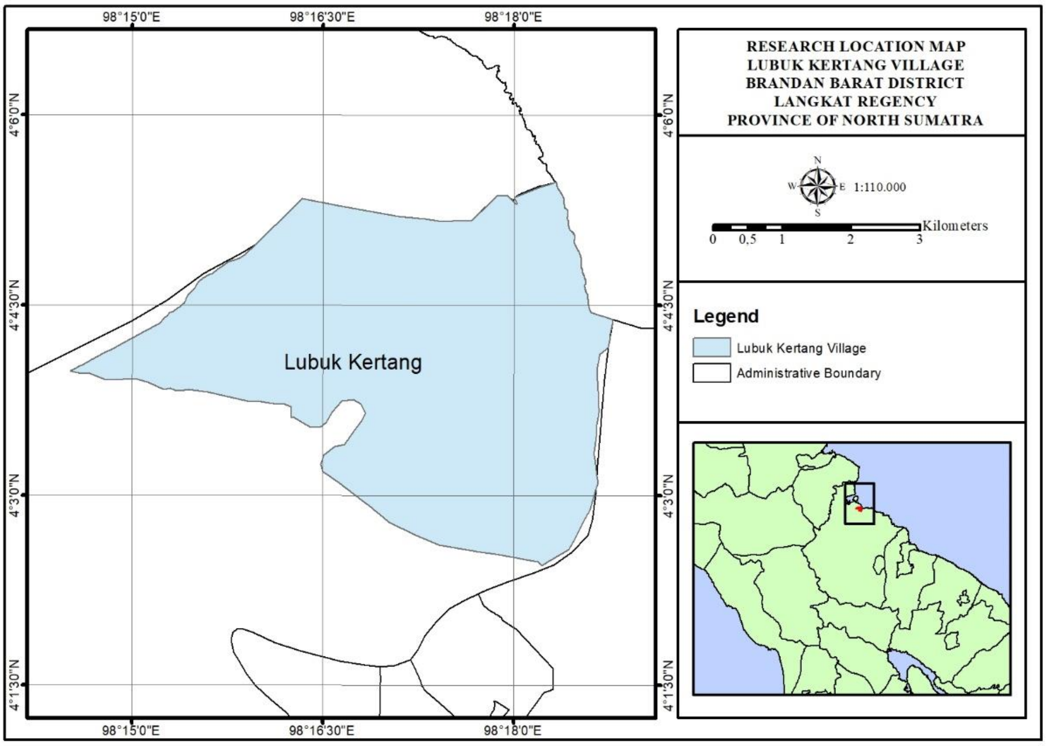
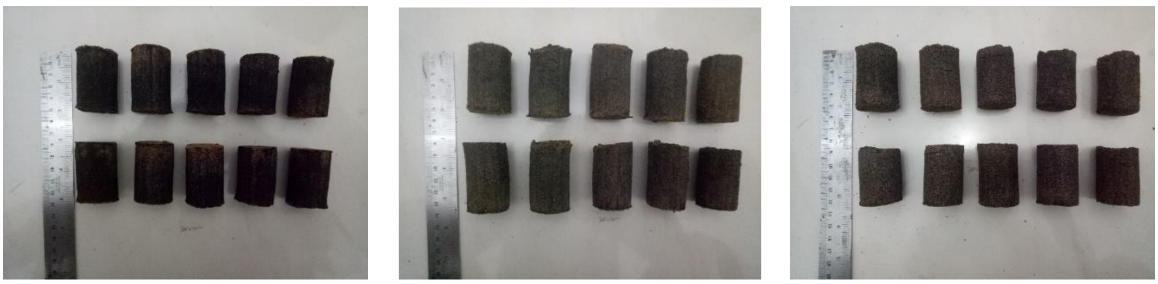


Figure 1. Research location map

The survey was conducted using a questionnaire. Determination of the minimum number of respondents using the rules of thumb, that is, using a ratio of 1:10 of the number of independent variables used. There were four independent variable attributes, namely price, availability (easy to obtain), calorific value (heat) produced, and ease of combustion. In this study, 60 respondents were obtained because they represented the number of male and female respondents.

2.2 Procedure for Making Wood Briquettes

Wood briquettes were made semi-manually by utilizing three branches of mangrove wood. It has been converted into 40-mesh powder, to empower the community around the mangrove forest. In this study, 5% starch adhesive was used from tapioca, maize, and potato based on the oven-dry weight of mangrove branch sawdust. The process of mixing the three types of starch adhesives was conducted by first diluting the starch with a ratio of starch and water of 1:10 (w/w) and then heating it at a temperature of 85° C. The determination of the target density of 0.9 g/cm^3 follows the procedure for making particleboard, except that the dimensions are cylindrical. Pressing was carried out using a briquette-making tool [20]. Then it was combined using a press machine with a pressure of 30 kgf/cm^2 by cold pressing for 5 minutes. The wood briquettes were subsequently dried in direct sunlight for 3 days. Then the wood briquettes are stored in airtight plastic bags to be stored, tested, or used as fuel. The prototype of wood briquettes produced in this study is presented in Figure 2.



(a) (b) (c)

Figure 2. Wood briquettes (a) mata buaya (*B. sexangula*), (b) buta-buta (*E. agallocha*), and (c) bakau minyak (*R. apiculata*)

2.3 Determination of Calorific Value

The calorific value of wood briquettes was evaluated in a bomb calorimeter using a Parr Bomb Calorimeter 6400 (Parr Instrument Company) by combusting wood briquettes in a high-pressure oxygen atmosphere in a bomb calorimeter. The calorific value was determined referring the ASTM D5865-10a standard [21].

2.4 Analysis of Statistics

2.4.1 Color quantification

Before the survey was conducted, the color of wood briquettes was quantified using a colorimeter (CHNSpec CS-10) to measure the L* (brightness), a* (red/green), and b* (blue/yellow) values. The color difference (ΔE) of sawdust raw material and wood briquettes is calculated using formula (1). The effect of different ΔE values is classified based on Table 1.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

Table 1. Effect of different ΔE values

Value of ΔE	Effect
<0.2	Not seen
0.2 – 1.0	Very little
1.0 – 3.0	Little
3.0 – 6.0	Moderate
>6.0	High

Furthermore, the data was analyzed using an experimental design to evaluate the effect of the mangrove wood species and starch adhesive type. This analysis used a factorial completely randomized design (CRD) with two factors: (A) mangrove wood species, including *mata buaya* (*B. sexangula*), *buta-buta* (*E. agallocha*), and *bakau minyak* (*R. apiculata*) and (B) types of starch adhesives; such as tapioca starch, maize starch, and potato starch. If the analysis of variance shows the treatment has a significant effect and to determine the difference between levels, it would be continued using the DMRT (Duncan Multiple Range Test). The statistical model of this design is presented in equation (2).

$$Yijk = \mu + \alpha i + \beta j + (\alpha\beta)ij + \Sigma ijk \quad (2)$$

Where: Yijk is the observed value in the treatment of the i^{th} mangrove wood species, the j^{th} is type of starch adhesive, and the k^{th} is repetition, μ is the population mean, αi is the effect of the i^{th} mangrove wood species, βj is the effect of the j^{th} type of starch adhesive, (αβ)ij is the interaction effect of the i^{th} mangrove wood species and j^{th} type of starch adhesive, Σijk is the random effect (error) on the i^{th} mangrove wood species, j^{th} is type of starch adhesive, and k^{th} is repetition.

2.4.2 Analysis of Chi-square

Chi-square analysis evaluated the relationship between preference in using wood briquettes of mangrove wood branches and fuel attributes. The formula of chi-square analysis is presented in equations (3) and (4) as follows.

$$X^2 = \sum_{i=1}^{k}\left[\frac{(fo-fe)^2}{fe}\right] \quad (3)$$

$$fe = \frac{ri\ x\ ci}{\sum ri} \quad (4)$$

Where: X2 is the chi-square, fo is observed frequency, fe is the expected frequency, i is 1, 2, …, k is the fuel attribute categories, ri is the number of row i, ci is the number of column i, and ∑ri is the observation number of i.

The hypothesis used is H0, which means there was no relationship between preference for using wood briquettes of mangrove wood branches and fuel attributes. H1 means there was a relationship between preference in using wood briquettes of mangrove wood branches to fuel attributes. The test was carried out at a 95% confidence interval with the following test criteria; a) If X2 count > X2 table, then H0 is rejected and b) If X2 count < X2 table, then H0 is accepted.

2.4.3 Likert scale

The decision to choose a fuel source is influenced by several attributes of the fuel product. Four attributes of fuel products were analyzed, namely price, availability (easy to obtain), calorific value (heat) produced, and ease of combustion. Respondents were asked to rate the attributes of the fuel on a scale from strongly disagree to strongly agree. The analysis used a Likert scale to facilitate data processing, where each attribute was given a score of 1-5 from strongly disagree to strongly agree (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly disagree). A simple statistical analysis was carried out using the mean (average) value. Then the average value of each fuel attribute is obtained which is used to determine the effect of these attributes on the respondent's decision when selecting a fuel source.

3. Result and Discussion

3.1 Calorific Value

The calorific value is the main factor that must be considered for wood briquettes as a fuel source. The wood briquettes produced in this study had a calorific value ranging from 3740.45 to 3872.66 cal/g, as depicted in Figure 3. The wood briquettes produced from mata buaya wood species with maize starch adhesive exhibited the highest calorific value. The lowest calorific value was observed in briquettes made from *buta-buta* wood species using potato starch adhesive. The calorific value was influenced by the moisture content, volatile matter, ash content, and fixed carbon. All of these parameters have been recorded [20]. Generally, the higher the ash and moisture content of the wood briquettes, the lower the calorific value [22].

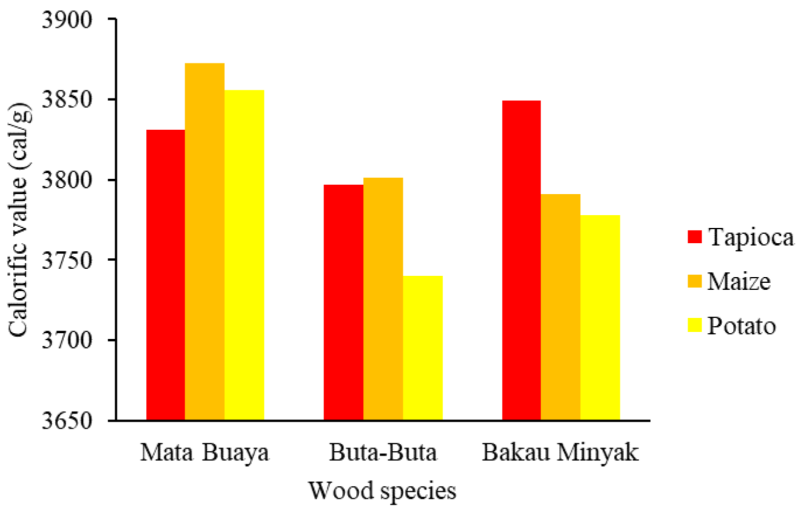


Figure 3. The calorific value of wood briquettes

Furthermore, the calorific value of the wood briquettes is also affected by the wood's chemical components, including cellulose, hemicellulose, and lignin. Lignin is the chemical component that plays the most role in increasing the calorific value of briquette fuel. The calorific value of lignin is higher than that of cellulose and hemicellulose because of its higher carbon content [23, 24]. The calorific value of wood briquettes in this study met the ISO 17225-3:2-2020 class A2 standard [25], which required a minimum calorific value of 3439 cal/g. This indicates that mangrove wood branch briquettes are a viable alternative to fossil fuels as a renewable energy source. The wood briquettes in this study have a lower calorific value compared to *Prosopis juliflora* (Karuvelam tree) wood briquettes of 4374.044 cal/g [26]. However, the wood briquettes in this study, particularly those from the *mata buaya* type, had a higher calorific value compared to those of *Ceiba pentandra* as a result of research by Antwi-Boasiako and Acheampong [27], with a calorific value of 3823.92 cal/g.

3.2 Color Quantification Value of Wood Briquettes

Quantification of the color of wood briquettes was conducted using a colorimeter before asking the respondents to choose their preference for wood briquettes. The results of the color quantification are presented in Table 2. Based on the data obtained, the three types of wood briquettes were categorized as neutral (shades of brown), neutral (a mixture of orange and brown), and neutral (pale yellow-green), according to color matching with the color list of paint products from Nippon Paint. The three types of wood briquettes in this study generally have a dark color. This color was similar to the solid biofuel color of *Salix viminalis* and *Quercus robur* types with torrefaction treatment as a result of research by Dragusanu et al. [28]. The color of wood briquettes is primarily influenced by the raw material used, chemical composition, characteristics, and treatment of the raw material. Although color is not a parameter for assessing the quality of solid biofuel, both market trends and consumer preferences are greatly influenced by it because the two can be directly observed [29]. The analysis of variance indicated that the interaction between mangrove wood species and starch adhesive types significantly impacted the L* values (brightness), a* values (red/green), and b* values (blue/yellow).

Table 2. Color quantification value (values accompanied by the same letters do not differ significantly according to the DMRT test at a 5% significance level)

Species	Sawdust L*	Sawdust a*	Sawdust b*	Type	Briquettes L*	Briquettes a*	Briquettes b*	ΔE	Effect
MB	55.92 ± 1.54	9.66 ± 0.80	20.75 ± 0.55	MBT	26.55 ± 2.98ab	2.75 ± 2.30cd	10.33 ± 2.32ab	31.98 ± 4.05	High
				MBM	25.54 ± 1.09a	0.98 ± 0.30a	9.21 ± 0.46a	33.64 ± 2.38	High
				MBK	27.94 ± 1.55ab	2.53 ± 1.37bcd	10.01 ± 1.47ab	30.83 ± 3.22	High
BB	54.33 ± 0.25	4.64 ± 0.25	20.79 ± 0.23	BBT	33.41 ± 1.36de	1.42 ± 0.51abc	12.04 ± 0.51cd	22.92 ± 1.49	High
				BBM	31.70 ± 1.18cd	1.11 ± 0.37ab	11.34 ± 0.46bc	24.79 ± 1.47	High
				BBK	29.70 ± 2.80bc	0.31 ± 0.22a	9.93 ± 0.88ab	27.27 ± 2.66	High
BM	52.84 ± 0.73	6.14 ± 0.11	19.73 ± 0.34	BMT	33.83 ± 2.23def	3.28 ± 1.27d	12.10 ± 1.28cd	20.72 ± 2.31	High
				BMM	36.99 ± 3.76f	3.52 ± 1.10d	13.64 ± 0.97d	17.20 ± 4.34	High
				BMK	36.13 ± 2.65ef	2.89 ± 0.64cd	12.97 ± 0.81d	18.33 ± 2.75	High

Remarks: MBT= Mata buaya tapioca; MBM= Mata buaya maize; MBK= Mata buaya potato; BBT= Buta-buta tapioca; BBM= Buta-buta maize; BBK= Buta-buta potato; BMT= Bakau minyak tapioca; BMM= Bakau minyak maize; BMK= Bakau minyak potato

DMRT test results indicated that the L* (brightness) value of wood briquettes made from *bakau minyak* species with maize starch adhesive, which had the highest value, was not significantly different from that of briquettes of the same type using tapioca or potato starch adhesive. However, it differed significantly from the wood briquettes made from mata buaya and buta-buta wood species using all three types of starch adhesives. For the a* (red/green) value, the wood briquettes made from *bakau minyak* wood species with the three types of starch adhesives did not show significant differences from each other, but they were significantly different from all the wood briquettes made from buta-buta wood species. In terms of the b* (blue/yellow) value, the wood briquettes from *bakau minyak* wood species with the three types of starch adhesives showed no significant differences among themselves but were significantly different from all briquettes made from mata buaya wood species. This indicates that, generally, wood briquettes made from *bakau minyak* wood species exhibit different L* (brightness), a* (red/green), and b* (blue/yellow) values compared to those made from mata buaya and buta-buta wood species when using the three types of starch adhesives [30].

Furthermore, when compared to the base color of the raw material for making wood briquettes, the difference (ΔE) is high, ranging from 17.20 to 33.64. This difference is caused by the process of making briquettes, which involves starch adhesive, and the drying process of the finished briquettes [30].

3.3 Sociodemographic Characteristics of Respondents

Table 3 displays the sociodemographic details of the respondents, including their gender, age range, educational background, and income level. Dongzagla and Adams [31] stated that socioeconomic and demographic factors significantly influence fuel preferences. From Table 3, it is known that the gender of the respondents was the same, consisting of 30 men and 30 women. Hou et al. [32] stated that gender influences the decision to choose fuel. Men and women perceive fuel consumption differently. Men are responsible for household finance; they may want to reduce spending on fuel [33]. Meanwhile, Adeyemi and Adereleye [34] stated that women are more actively engaged in obtaining fuel and cooking within the household.

People's tastes and product preferences can be influenced by their age. Age is a factor related to the life cycle that influences behavior in purchasing and using a product [35]. Table 3 presents the age group of the respondents, and it is known that the respondents with the highest number were in the age group 22–31 years, namely 40 people. This age group is the middle adult and tends to be more mature in thinking and acting for choosing a product, particularly fuel. The adults decide to choose a fuel source for cooking in the household [34].

The level of education also plays a significant role in influencing a person's decision to purchase a desired product. This is because the higher one's level of education, the better their ability to think about and perceive the product that will be used. Fazrina et al. [36] stated that education affects a person's choice of desired product because a person's education level will affect the values adopted, ways of thinking, perspective, and even knowledge of the product consumed. The education factor can also determine the quality and quantity of the product consumed.

The highest number of respondents was at the higher education level (bachelor degree), up to 35 people. Concerning fuel choices, education has a very significant impact. People with higher education are more informed about and aware of the harmful impacts of using firewood on both human health and the environment, which encourages them to choose cleaner and safer fuels [37].

Table 3. Sociodemographic characteristics of respondents

Variable	Number of respondents	Percentage
Gender		
Men	30	50%
Women	30	50%
Age group (years)		
14 - 17	-	
18 - 21	18	30%
22 - 31	40	66.67%
32 - 41	2	3.33%
>41	-	-
Level of education		
Elementary school	-	-
Junior high school	-	-
Senior high school	25	41.67%
Bachelor degree	35	58.33%
Postgraduate	-	-
Income level		
< IDR 1,500,000	35	58.33%
IDR 1,500,000 - IDR 2,500,000	7	11.67%
IDR 2,500,000 - IDR 3,500,000	8	13.33%
>IDR 3,500,000	10	16.67%

Income level is one of the factors that affects a person's product selection. Someone with a high income tends to buy products with good quality, convenience, more efficiency, etc. Table 3 shows that the highest number of respondents with an income level of < IDR 1,500,000 are classified as having low-income levels [38]. An increase in income is linked to the shift towards using modern fuels as a preferred energy source. Households with higher incomes tend not to use traditional fuels as the main fuel for cooking. They prefer to use modern fuels [39], such as gas and electricity. Higher-income enables them to purchase gas and cooking appliances that are more convenient and efficient compared to firewood and charcoal, which have numerous adverse effects associated with their use [40].

3.4 Respondents' Preference for Fuel

Figure 4 presents the types of energy and fuel sources chosen by the respondents. The kind of gas is the most preferred as a fuel source (35 people). On the other hand, charcoal fuel is the least preferred, with only 2 respondents choosing it. Wood briquettes were the second most preferred after gas, with 10 respondents. However, the number of respondents who preferred wood briquettes as their fuel source was relatively small compared to gas. Some respondents had used and chosen wood briquettes as their fuel source, while most had not and did not choose wood briquettes.

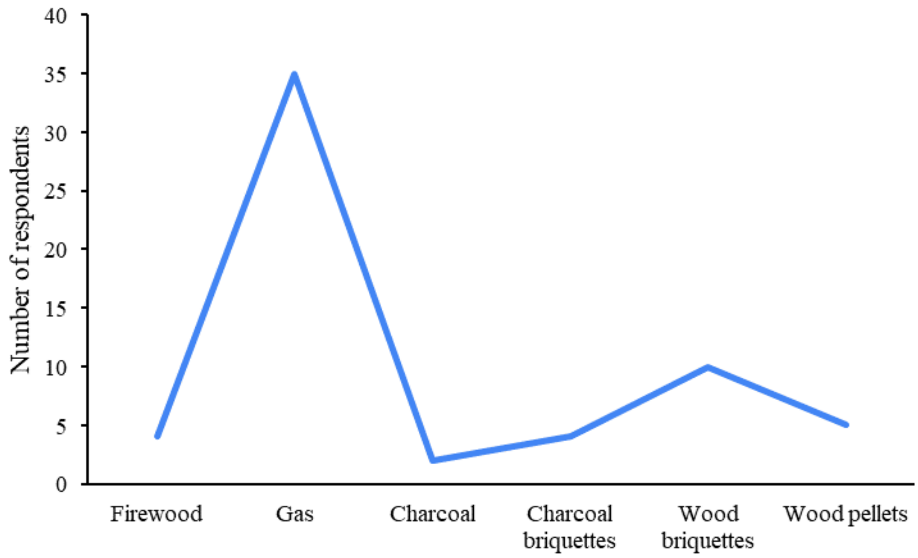


Figure 4. Respondents' preferences for the type of fuel

According to Njenga and Mendum [41], briquettes are a promising alternative fuel for cooking and heating that are cheaper and cleaner. Therefore, wood briquettes are more popular among low-income populations. There are 54 respondents (90%), stated that they were willing to use wood briquettes as an alternative fuel source to replace fossil fuels, while the rest (6 respondents or 10%) were vice versa.

3.5 Prototype of Wood briquettes from Mangrove Wood Branches

Based on the survey data that has been conducted, it is known that the type of wood briquettes is most preferred by respondents, as shown in Figure 5. Wood briquettes from Bakau minyak wood species with the use of all three types of starch adhesives are the most preferred wood briquettes by respondents, up to 28 people. Wood briquettes from mata buaya wood species are the second most popular, selected by 22 people, while those from buta-buta wood species are the least preferred. The majority of respondents stated that they liked the color, shape, and size of the three types of wood briquettes and were interested in using them as fuel and recommending them to their family or closest people. The color of the wood briquettes can influence respondents' perceptions of the quality or attractiveness of the product. The calorific value, which indicates the energy content of briquettes, is essential for assessing their efficiency and effectiveness as a fuel source. Respondents' preferences can be influenced by visual aspects (such as color) and practical considerations (such as calorific value) when selecting or evaluating wood briquettes [29]. Mugabi and Kisakye [15] stated that the shape affects respondents' preference for briquettes. Briquettes with a cylindrical or rod shape are preferred by respondents due to the consistent heat produced and their uniform size.

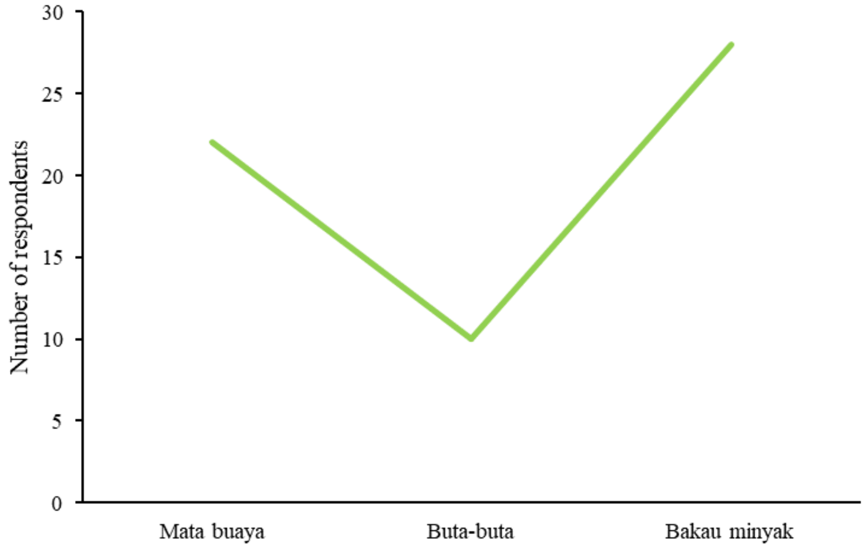


Figure 5. Respondents' preference of wood briquettes of mangrove branches

3.6 Attributes of the Fuel

Table 4 shows the Likert scale, which applied to several attributes and consumer attitudes, while Table 5 shows the effect of these attributes on the respondents' decisions. Analysis of the mean value of the four fuel attributes showed that the value is greater than 3. This indicates that these attributes have quite an effect on respondents' preferences in choosing a fuel source. The selection and use of fuel are impacted by the combination of economic and non-economic factors. Economic factors include the market price of fuel, while non-economic factors include distance and access to fuel sources [42]. Table 5 shows that availability (easy to obtain) is the most influential attribute, with a mean (average) value of 3.92, while the attribute of calorific value (heat) produced is the least influential attribute, with a mean (average) value of 3.60.

Table 4. Assessment of fuel attributes

Attributes	Number of respondents					Total
	1	2	3	4	5	
Price	1	4	18	31	6	60
Availability (easy to obtain)	1	1	11	36	11	60
Calorific value (heat) produced	1	4	20	28	7	60
Ease of combustion	0	1	15	36	8	60

Table 5. Analysis of the mean value of the fuel attribute

Attributes	Mean value	Rating
Price	3.62	III
Availability (easy to obtain)	3.92	I
Calorific value (heat) produced	3.60	IV
Ease of combustion	3.85	II

The availability attribute (easy to obtain) is the most influential in choosing a fuel source because people prefer to use fuels that are widely available and easy to find around them. Gupta and Köhlin [43] stated that availability is a very important factor in the decision-making process when choosing a fuel source. Policies on the use of gas and increasing its availability, thereby reducing the availability of other fuels such as kerosene and the use of gas by the public continue to increase. This is following the results obtained from the survey, that the majority of respondents use gas as a fuel source (Figure 4).

3.7 Analysis of Chi-square

A chi-square analysis was carried out to determine whether fuel attributes influenced respondents' interest in using wood briquettes from mangrove wood branches. The results is presented in Table 6.

Table 6. The results of the chi-square analysis of the relationship between interest and fuel attributes

Chi-square analysis	X^2 count	X^2 table	Df	Asymp. Sig.	Information
Relationship of interest to fuel attributes	7.728	12.592	6	0.259	There is no relationship

Table 6 shows the results of the chi-square analysis of the relationship between interest in using wood briquettes from mangrove wood branches and fuel attributes. Table 6 informs the X2 count value is 7.728, which is less than the X2 table value of 12.592, or the asymptote sig. of 0.259, which is greater than 0.05. Therefore, hypothesis H0 is accepted. There is no relationship between interest in using wood briquettes from mangrove wood branches and fuel attributes. It can also be seen from the mean value of the respondents' choice of fuel attribute, namely that the mean (average) value of each fuel attribute does not differ much. Thus the interest in using briquettes from mangrove wood branches is not influenced by fuel attributes. According to Kiobia et al. [44], factors affecting the purchase of briquette products can be grouped into three categories: performance, attractiveness, and personal capacity. Furthermore, the price aspect of buying briquettes as a sustainable energy source is not regarded as a barrier to their utilization.

The lack of a relationship between interest in using wood briquettes and fuel attributes can be attributed to knowledge or information about briquette fuel and habits of using previously used fuels, so respondents have their own choices in determining the type of fuel and do not rely on attributes. Lack of understanding or awareness of the benefits or advantages of the wood briquettes may make them less interested. Respondents tend to choose fuels that they are already familiar with or have used before, even if there are more efficient or environmentally friendly options. Existing habits and preferences can be strong factors in decision-making. Bujdosó et al. [45] state that knowledge and awareness can be considerations in community acceptance of renewable energy sources. Furthermore, acceptance and interest in a particular type of fuel are highly influenced by habits because they have been used for a long time and have formed cooking habits [46].

4. Conclusion

The calorific value of the wood briquettes in this study met the ISO 17225-3:2-2020 class A2 standard, where wood briquettes made from mata buaya with maize starch adhesive have the highest calorific value. The three types of wood briquettes have a neutral color with a high difference (ΔE) between the color of the raw material for making wood briquettes and the color of the wood briquettes. Most respondents used gas (58.33%) of the total respondents, while only 16.67% used wood briquettes. As many as 54 respondents (90%) stated they would use wood briquettes as an alternative fuel or energy source to replace fossil fuels. Among the three types of wood briquettes made from mangrove wood branches, those from Bakau Minyak wood species, using any of the three starch adhesives, are the most preferred by 28 people (46.67%). On the contrary, the wood briquettes from buta-buta wood species are the least favored. The results of the mean value analysis show that the attribute that has the most influence on respondents' preference is availability (easy to obtain), with a mean value of 3.92. The least influential attribute is the calorific value (heat) produced, with a mean value of 3.60. Meanwhile, based on the results of the chi-square analysis, it is known that the X2 count value is 7.728, which is less than the X2 table value of 12.592, or the asymptote value. Sig. of 0.259, which is greater than 0.05. This means no relationship between interest in using wood briquettes from mangrove wood branches and fuel attributes. The fuel attribute in this case did not affect the respondents' interest in using wood briquettes from mangrove wood branches.

Acknowledgements

This paper is an additional output of the research activity of Center of Excellence for Mangrove (PUI Mangrove) entitle Morphological and Acoustical Properties of Charcoal Briquette Made of Branches Wood of Mangroves funded by Equity Project to MB through scheme of special assignment number 4921/UN5.1.R/SK/PPM/2023 dated December 23rd, 2023.

References

[1] T. Hassan, H. Song, Y. Khan, and D. Kirikkaleli, "Energy efficiency a source of low carbon energy sources? Evidence from 16 high-income OECD economies", *Energy*, vol. 243, p. 123063, Mar. 2022. https://doi.org/10.1016/j.energy.2021.123063

[2] F. Martins, C. Felgueiras, M. Smitkova, and N. Caetano, “Analysis of fossil fuel energy consumption and environmental impacts in European countries”, *Energies*, vol. 12, no. 6, p. 964, Mar. 2019. https://doi.org/10.3390/en12060964

[3] C. Field, J. Campbell, and D. Lobell, “Biomass Energy: The scale of the Potential Resource,” *Trends in Ecology & Evolution*, vol. 23, no. 2, pp. 65–72, Feb. 2008. https://doi.org/10.1016/j.tree.2007.12.001

[4] H. C. Butterman and M. J. Castaldi, “CO_2 as a carbon neutral fuel source via enhanced biomass gasification,” *Environmental Science & Technology*, vol. 43, no. 23, pp. 9030–9037, Nov. 2009. https://doi.org/10.1021/es901509n

[5] S. Khan, V. Paliwal, V. V. Pandey, and V. Kumar, “Biomass as Renewable Energy,” *International Advanced Research Journal in Science, Engineering and Technology* (IARJSET), vol. 2, no. 1, pp. 301–304, 2015. https://doi.org/10.17148/IARJSET

[6] Untari, R. Darma, P. Betaubun, and A. A. Arief, “Review of the use of mangrove forests in supporting the socioeconomic life of fishing communities,” *IOP Conference Series: Earth and Environmental Science*, vol. 575, no. 1, p. 012042, June 2020. https://doi.org/10.1088/1755-1315/575/1/012042

[7] J. Kumar, V. M. E. Kumar, K. Rajanna, K. Naik, and A. Pandey, “Ecological benefits of mangrove,” *Life Sciences Leaflets*, vol. 48, pp. 85-88, 2014.

[8] R. Rajis, D. Desmelati, and T. Leksono, “Utilization of Pedada Fruit (*Sonneratia caseolaris*) of Mangrove for Syrup Production towards Costumer Acceptance,” *Jurnal Perikanan dan Kelautan*, vol. 22, no. 1, pp. 51-50, 2017.

[9] M. Basyuni, Y. S. Siagian, B. Slamet, N. Sulistiyono, L. A. Putri, E. Yusraini, and I. Lesmana, “Leaf nutrition content and organoleptic of Jeruju (*Acanthus ilicifolius* L) and processed products in Lubuk Kertang Village, North Sumatera,” *IOP Conference Series: Earth and Environmental Science*, vol. 374, no. 1, p. 012052, November 2019. https://doi.org/10.1088/1755-1315/374/1/012052

[10] M. Basyuni, S. M. Situmeang, L. A. Putri, E. Yusraini, and I. Lesmana, “Financial Analysis of pidada syrup (*Sonneratia caseolaris*),” *IOP Conference Series: Earth and Environmental Science*, vol. 454, no. 1, p. 012112, Feb. 2020. https://doi.org/10.1088/1755-1315/454/1/012112

[11] Supriyanto, Indriyanti, and A. Bintoro, “Medicinal Plant Species Inventory on Mangrove Forest at Margasari Village Labuhan Maringgai District, East Lampung,” *Jurnal Sylva Lestari*, vol. 2, no. 1, pp. 67–76, Apr. 2014. http://dx.doi.org/10.23960/jsl1267-76

[12] L. A. Genilar, E. Kurniawaty, R. A. M, Mokhtar, and K. A. Audah, “Mangroves and their medicinal benefit: A mini review,” *Annals of the Romanian Society for Cell Biology*, pp. 695-709, 2021.

[13] I. R. Risnasari, Deni Elfiati, Arif Nuryawan, Harisyah Manurung, Mohammad Basyuni, Apri Heri Iswanto, Erman Munir, Bejo Slamet, and Arida Susilowati, “Workshop on processing of mangrove plants residues as natural dyes on ecoprinting products at Lubuk Kertang Village, Langkat Regency, North Sumatra,” *Sarwahita*, vol. 18, no. 01, pp. 70–83, Jul. 2021. https://doi.org/10.21009/sarwahita.181.7

[14] C. Kusmana and S. Sukristijiono, “Mangrove resource uses by local community in Indonesia,” *Journal of Natural Resources and Environmental Management*, vol. 6, no. 2, pp. 217–224, Dec. 2016. https://doi.org/10.19081/jpsl.2016.6.2.217

[15] P. Mugabi and D. B. Kisakye, “Status of production, distribution and determinants of biomass briquette acceptability in Kampala city, Uganda,” *Maderas. Ciencia y tecnología*, vol. 23, pp. 1–8, Dec. 2020. https://doi.org/10.4067/S0718-221X2021000100413

[16] A. Pallegedara and A. S. Kumara, “Impacts of firewood burning for cooking on respiratory health and healthcare utilisation: Empirical evidence from Sri Lankan micro-data,” *The International Journal of Health Planning and Management*, vol. 37, no. 1, pp. 465–485, Oct. 2021. https://doi.org/10.1002/hpm.3350

[17] T. Kebede, D. T. Berhe, and Y. Zergaw, “Combustion characteristics of briquette fuel produced from biomass residues and binding materials,” *Journal of Energy*, vol. 2022, pp. 1–10, Mar. 2022. https://doi.org/10.1155/2022/4222205

[18] N. Kanagaraj, C. Sekhar, M. Tilak, and B. Palanikumaran, “Cost and returns of briquette production in Tamil Nadu, India,” *International Journal of Current Microbiology and Applied Sciences*, vol. 6, no. 7, pp. 1238–1242, Jul. 2017. https://doi.org/10.20546/ijcmas.2017.607.149

[19] C. S. Galik, M. E. Benedum, M. Kauffman, dan D. R. Becker, "Opportunities and barriers to forest biomass energy: A case study of four U.S. states." *Biomass and Bioenergy*, vol. 148, no. 106035, pp. 1-11, Feb. 2021. https://doi.org/10.1016/j.biombioe.2021.106035

[20] H. Tambunan and A. Nuryawan, "Simple briquette-making tool," Simple patent in the process of patent registration, 2023.

[21] ASTM D 5865-10a, Standard Test Method for Gross Calorific Value of Coal and Coke, *American Society for Testing and Material*, 2010.

[22] R. Bachmid, H. Halim, S. P. Yudha, and A. Halim, "Effect Pressing Briquettes Merbau Waste (Spinach Wood) With Tapioaka Adhesive," *Journal of Chemical Process Engineering*, vol. 5, no. 2, pp. 56–61, 2020. https://doi.org/10.33536/jcpe.v5i2.659

[23] A. Demirbas, "Higher heating values of lignin types from wood and non-wood lignocellulosic biomasses," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol. 39, no. 5, pp. 592-598, Mar. 2017. https://doi.org/10.1080/15567036.2016.1248798

[24] D. S. Nawawi, A. Carolina, T. Saskia, D. Darmawan, S. L. Gusvina, N. J. Wistara, R. K. Sari, and W. Syafii, "Karakteristik Kimia Biomassa untuk Energi (Chemical Characteristics of Biomass for Energy)," *Jurnal Ilmu dan Teknologi Kayu Tropis*, vol. 16, no. 1, pp. 44-51, Jan. 2018.

[25] ISO 17225-3, Solid biofuels — Fuel specifications and classes— Part 3: Graded wood briquettes, *International Organization for Standardization*, 2020.

[26] J. A. Kumar, K. V. Kumar, M. Petchimuthu, S. Iyahraja, and D. V. Kumar, "Comparative analysis of briquettes obtained from biomass and charcoal," *Materials Today: Proceedings*, vol. 45, no. 2, pp. 857-86, 2021. https://doi.org/10.1016/j.matpr.2020.02.918

[27] C. Antwi-Boasiako and B. B. Acheampong, "Strength properties and calorific values of sawdust-briquettes as wood-residue energy generation source from tropical hardwoods of different densities," *Biomass and Bioenergy*, vol. 85, pp. 144-152, Feb. 2016. https://doi.org/10.1016/j.biombioe.2015.12.006

[28] V. Dragusanu, A. Lunguleasa, C. Spirchez, and C. Scriba, "Some Properties of Briquettes and Pellets Obtained from the Biomass of Energetic Willow (Salix viminalis L.) in Comparison with Those from Oak (Quercus robur)," *Forests*, vol. 14, no. 6, pp. 1-20, May 2023. https://doi.org/10.3390/f14061134

[29] A. Sgarbossa, C. Costa, P. Manesatti, F. Antonucci, F. Pallottino, M. Zanetti, S. Grigolato, and R. Cavalli, "Colorimetric patterns of wood pellets and their relations with quality and energy parameters," *Fuel*, vol. 137, pp. 70-76, Dec. 2014. https://doi.org/10.1016/j.fuel.2014.07.080

[30] H. Tambunan, A. Nuryawan, A. H. Iswanto, I. Risnasari, M. Basyuni, and W. Fatriasari, "Briquettes Made of Branches Wood of Three Mangrove Species Bonded by Starch Adhesive," *Materials*, vol. 16, no. 15, pp. 1-22, Jul. 2023. https://doi.org/10.3390/ma16155266

[31] A. Dongzagla and A. M. Adams, "Determinants of urban household choice of cooking fuel in Ghana: Do socioeconomic and demographic factors matter?," *Energy*, vol. 256, p. 124613, Oct. 2022. https://doi.org/10.1016/j.energy.2022.124613

[32] B. Hou, H. Liao, and J. Huang, "Household cooking fuel choice and economic poverty: Evidence from a nationwide survey in China," *Energy and Buildings*, vol. 166, pp. 319–329, May 2018. https://doi.org/10.1016/j.enbuild.2018.02.012

[33] B. Acharya and K. Marhold, "Determinants of household energy use and fuel switching behavior in Nepal," *Energy*, vol. 169, pp. 1132–1138, February 2019.; https://doi.org/10.1016/j.energy.2018.12.109

[34] P. A., Adeyemi and A. Adereleye, "Determinants of household choice of cooking energy in Ondo state, Nigeria," *Journal of Economics and Sustainable Development*, vol. 7, no. 9, pp. 131-142, 2016.

[35] M. Slabá, "The impact of age on the customers buying behaviour and attitude to price," *Littera Scripta*, Jan. 2020. https://doi.org/10.36708/Littera_Scripta2019/2/11

[36] R. Fazrina, I. Marsaulina, and E. Naria, "The Correlation of The Characteristics and The Knowledge of Environmental Health with The Consumers Descision in Purchasing The Organic Vegetables at Carrefour Medan Fair Plaza in Year 2013," *Lingkungan dan Kesehatan Kerja*, vol. 2, no. 3, pp. 1-9, 2013.

[37] F. O. Ogwumike, U. M. Ozughalu, and G. A. Abiona, "Household energy use and determinants: Evidence from Nigeria," *International Journal of Energy Economics and Policy*, vol. 4, no. 2, pp. 248-262, 2014.

[38] E. Indrianawati and Y. Soesatyo, "Influence of the Income Level and the Economics Knowledge of Consumption Level in Post Graduate Students Universitas Negeri Surabaya," *Jurnal Ekonomi Pendidikan dan Kewirausahaan*, vol. 3, no. 2, pp. 214–226, Mar. 2017. https://doi.org/10.26740/jepk.v3n2.p214-226

[39] J. U. Okonkwo, "Gender, energy expenditure and household cooking fuel choice in Nigeria," *The Energy Journal*, vol. 44, no. 5, pp. 1–37, 2020. http://dx.doi.org/10.2139/ssrn.3890003

[40] O. O. Olugbire, F. J. Aremu, O. H. Opute, C. A. Ojedokun, O. O. Olawale, and A. Adisa, "Determinants of Household Cooking Energy Choice in Oyo State, Nigeria," *Russian Journal of Agricultural and Socio-Economic Sciences*, vol. 52, no. 4, pp. 28–36, Apr. 2016. http://dx.doi.org/10.18551/rjoas.2016-04.04

[41] M. Njenga and R. Mendum, "Fuel briquettes: an affordable and cleaner cooking and heating fuel," *Urban Agriculture Magazine*, vol. 32, pp. 36-38, 2017.

[42] A. H. Danlami, R. Islam, and S. D. Applanaidu, "An Analysis of the Determinants of Households' Energy Choice: A Search for Conceptual Framework," *International Journal of Energy Economics and Policy*, vol. 5, no. 1, pp. 197-205, 2015.

[43] G. Gupta and G. Köhlin, "Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India," *Ecological Economics*, vol. 57, no. 1, pp. 107–121, Apr. 2006. https://doi.org/10.1016/j.ecolecon.2005.03.010

[44] D. O. Kiobia, Y. M. Yustas, W. M. Tarimo, S. A. Mbacho, N. R. Makange, A. T. Kashaija, E. B. Mukama, and F. R. Silungwe, "Classification of Briquettes Selection Criteria Using Principal Components Analysis Approach," *Journal of Power and Energy Engineering*, vol. 10, no. 6, pp. 14-26, June 2022. https://doi.org/10.4236/jpee.2022.106002

[45] Z. Bujdosó, C. Patkós, T. Kovács, Z. Radics, and Z. Baros, "The Social Aspects and Public Acceptance of Biomass Giving the Example of a Hungarian Region," *Int. Journal of Renewable Energy Development (IJRED)*, vol. 1, no. 2, pp. 39-43, June 2020. https://doi.org/10.14710/ijred.1.2.39-43

[46] M. Emily, "Socio-Economic Factors Influencing Adoption of Improved Biomass Energy Technologies in Rural and Urban Households in Kitui," M. S. thesis, Univ. of Nairobi, Nairobi, Kenya, 2015.