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ABDIMAS TALENTA
Jurnal Pengabdian Kepada Masyarakat
Journal homepage: https://talenta.usu.ac.id/abdimas

Potential of Dry Leaf Waste as A Raw Material for Charcoal Briquettes Preparation as an Alternative Fuel

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ARTICLE INFO
Article history:
Received : 30 June 2024
Revised : 07 July 2024
Accepted : 26 September 2024
Available online: 17 November 2024

E-ISSN: 2549-418X
P-ISSN: 2549-4341

How to cite:
Sontang, M., Sudiati., Aisyah, D. (2024). Potential of Dry Leaf Waste as A Raw Material for Charcoal Briquettes Preparation as an Alternative Fuel. ABDIMAS TALENTA: Jurnal Pengabdian Kepada Masyarakat, 9(2), 121-131.

http://doi.org/10.32734/abdimastalenta.v9i2.17774

ABSTRACT
This research was motivated by the large potential of dry leaf waste in the campus environment of the University of North Sumatra and the awareness of the importance of appropriate innovation in the use of dry leaf waste as an environmentally friendly alternative fuel. The aim of this research was to determine the potential of leaf waste in the campus environment as a raw material for making environmentally friendly charcoal briquettes. The research method was observation, conducted in the campus environment of the University of North Sumatra, followed by calculating the amount of leaf waste produced per day, and testing continued with the production of dry leaf briquettes. The test results of the three combustions with different mixtures of raw materials in each combustion resulted in solid dry leaf briquettes that could ignite well. This study produced briquettes with proximate and ultimate tests that met SNI No.01-6235-2000 standards with a moisture content test of 4.35%, ash content test of 5.65%, carbon content test of 78.68%, calorific value of 6115 cal/g, and a burning rate of 1.5 grams/minute. Briquettes that meet SNI standards can become an environmentally friendly alternative energy source, a source of livelihood, and will certainly have a positive impact on waste management on the campus of the University of North Sumatra.

Keyword: Briquettes, Fuel, Innovation, Leaf Waste, Sustainable Energy

1. Introduction

The University of North Sumatra is a campus with an area of 116 hectares, which is densely populated with large and shady trees. Every day, these trees produce a large amount of dry leaves and twigs. These leaves come from dozens of tree species that grow throughout the campus. Most of the produced leaf and twig waste is collected and ends up in the Final Disposal Site (TPA), indicating that there is no proper form of organic waste management at the University of North Sumatera. The presence of waste in the city of Medan is a complex problem faced by the community and city managers, especially in terms of providing facilities and infrastructure. With a population of nearly three million people, the amount of waste produced each day reaches 2.000 tons. Specifically, 48% is organic waste and 52% is inorganic waste. This amount of waste is estimated to continue increasing at a growth rate of 4% [1]. Piles of waste that disturb health and environmental beauty are a type of pollution that can be classified as social environmental degradation [2].

The solution that can be provided is to utilize biomass energy from organic waste in innovative products. In waste utilization, the University of North Sumatra has processed waste into compost [2]. To date, people are only familiar with the use of waste for composting, but due to the relatively long and complicated processing process, most people are reluctant to make compost [3]. Finally, the waste is left to pile up in the trash and rot or is burned into ashes. Another alternative presented in this research is that waste can also be used as fuel for charcoal briquettes, which will explain the process starting by calculating the potential of waste in the compaction process using hydraulic press pressure [4]. The raw material used in this study was organic waste originating from the University of North Sumatra campus environment, consisting of dry leaves and small twigs. Community-based processing of organic and non-organic waste into economically valuable products includes processing organic waste into compost, making eco-bricks, animal waste in the form of biogas, and organic waste from dry leaves/twigs into charcoal briquettes (bio-briquettes)[5].

Utilizing waste into fuel can solve fuel problems at the household level because people can make their own fuel using alternative materials, thereby reducing household expenses and increasing their income by selling charcoal briquettes [6]. The government has previously promoted the use of coal-derived fuel called coal briquettes [7]. However, in reality, the availability of coal briquettes in the market is difficult for people to obtain sustainably [6]. This is influenced by the limitations of coal as a raw material [8], and the need for alternative alternatives to replace coal briquettes obtained from organic waste, namely dry leaves around the USU campus. Briquettes are potential and reliable alternative energy sources for households. In principle, the process of making charcoal briquettes from organic waste consists of burning, sieving, mixing ingredients, molding, and drying [8]. The process of making briquettes in other countries is no different from the process of making briquettes in Indonesia, only the materials used are different. For example, the material for briquette production in Thailand comes from Eucalyptus wood, which has a calorific value of 3779.98 cal/g [9].

Every leaf or grass contains various chemical elements, one of which is carbon (C) and water (H). Young leaves contain large amounts of water. However, when the leaves start to turn yellow, then dry and fall, the water content in the leaves decreases, making it easier to burn and charcoal [7]. From this leaf charcoal, a solid fuel resembling coal briquettes was obtained. This alternative fuel is called a leaf briquette because it is made from leaves. Seeing the abundance of raw materials around the community (especially at the University of North Sumatra), including natural raw materials from plants, so they are easily renewable, it is hoped that the emissions produced by Bio Briquettes from leaves will be relatively lower compared to fossil fuels (nonrenewable) such as kerosene [7].

The utilization of natural resources can be discussed in environmental physics, which studies various natural phenomena related to physical and mathematical aspects [10] as a response of living organisms to their environment within the framework of environmental physics processes and issues [1]. Physics is a fundamental science that includes the science of living beings and physical sciences (astronomy, chemistry, mathematics, physics itself). Essentially, physics discusses matter and energy, which are the roots of every field of science and underpin all phenomena. This requires measuring the physical variables involved in environmental issues and linking them to biological and sociological responses [1]. One environmental issue related to physical variables is the presence of waste or garbage. According to the Dictionary of Environmental Terms (1994), waste is a material that has no value or is useless for ordinary or primary purposes, in the use of damaged or defective goods in manufacturing, or surplus, rejected, or discarded materials. According to Rasyastuti (1996), waste is a resource that is not ready for use. The term "waste" for management [3] refers to a material discarded from its source as a result of human activities or natural processes that have no economic value. Based on its nature, waste is divided into three types: organic, inorganic, and hazardous and toxic (B3) [11].

Waste is the final product in the form of residual material from washing, decontamination, or body metabolism processes, which can be in liquid or semi-solid form [10]. Collected waste can accumulate and rot, significantly disrupting health and the environment, and affecting aesthetic quality [12]. Therefore, waste is also considered a public issue, and its management can be linked to public management science. Public management directs human abilities to manage the environment in an environmentally friendly manner through planning, organizing, implementing, controlling, evaluating, and reporting [13]. Law Number 23 of 1997 on environmental management explains how to manage the environment (including waste) using a management approach [14]. The best way to manage waste is to reduce it to zero while producing innovative products that are beneficial to the public [11].

Innovation in the public sector is a breakthrough type of service, original creative ideas, and/or modifications that provide benefits to society, whether in the form of new discoveries or new contextual and accountable approaches. Many breakthrough innovations have been carried out in research, especially innovations in waste as a raw material for producing renewable energy sources as a substitute for non-renewable energy such as oil, coal, and gas, which have had a negative impact on the earth [15,16]. Renewable energy is the amount of energy sources available to humans that can be processed [17]. As reserves of non-renewable energy sources become increasingly depleted, the cost of mining them will increase, impacting the increase in selling prices to the public. Moreover, non-renewable energy releases carbon emissions into the atmosphere, which is a major contributor to global warming [14].

Currently, the world is trying to reduce carbon emissions from fossil fuels using biomass as an alternative energy source amounting to 10 - 15% of the world's energy needs [12,18]. Developed Currently, the world is trying to reduce carbon emissions from fossil fuels using biomass as an alternative energy source amounting to 10 - 15% of the world's energy needs. Developed countries use biomass to meet 9 - 14% of their energy needs. The BP Statistical Review of World Energy 2021 reported that China has the highest consumption of biomass energy in the world. The country's renewable energy consumption reaches 7.79 exajoules or 24.6% of the total world consumption, but in developing countries, almost 20 - 35% of the energy needs are met by biomass. When biomass is burned or converted into other forms of fuel, the carbon in the biomass reacts with the oxygen in the air to form carbon dioxide, which is exposed to the atmosphere. This means that carbon dioxide is not added to the atmosphere, so biomass can be seen as an energy source that does not produce carbon dioxide emissions [12,18]. Charcoal briquettes or charcoal are processed charcoal/charcoal that is formed using a pressing system and adhesive material in the form of briquettes. It is produced through a compression and pressure process, and a small amount of smoke [18]. The composition of the briquettes increased the specific gravity of the wood and the density of the charcoal briquettes. The resulting density is between 0.45 - 1.03 g/cm^3 and the heating value is between 7290-7456 cal/g. The calorific value of combustion indicates the heat energy per unit mass of the fuel. The heating value was measured using a bomb calorimeter [9]. The test parameters used to assess the quality of the briquettes included density, water content, compressive strength, volatile matter content, ash content, bound carbon content, and heating value. Data analysis used a Factorial Experiment with a basic design of Completely Randomized Design (CRD) and further testing of the average value using the Least Significant Difference (LSD) test [19].

Currently, existing waste is a complicated problem faced by almost all parties in big cities in Indonesia, including Medan. Currently, waste is collected collectively from the community, which is then transported and stored to a temporary disposal site (TPS), which is then disposed of in a final disposal site (TPA), which is quite far away and is generally processed in the form of a landfill. The Ministry of Environment reports that by 2022, Indonesia will produce 69.2 million tons of waste, which will increase by 2 - 4% per year. The most dominant waste composition was food waste (40.2%), followed by wood/twigs/leaves (13.1%), and paper (11.3%) [12,18]. Several studies on the production of biobriquettes (biomass) have been conducted, particularly on the Asian continent [12]. Biobriquette research is increasingly developing, and it is necessary to examine the technology, variables, and materials used to differentiate previous research from current research. In this study, considerations for making bio briquettes are fundamental aspects that must be discussed. This is related to the benefits obtained and the comparison of this study with previous studies. The research was carried out using a furnace-burning medium rather than a stove. The use of a furnace was chosen because in this study, an investigation was carried out on the combustion characteristics (ignition time, heating value, and emissions) that, if conducted in a stove, would have other aspects that influence it (fluid mechanics). The gas analyzer TPI 708 flue gas Control Box, thermocouple 2, thermocouple1 [18].

Carbonization is the process of heating organic waste to certain temperatures with a limited air supply. Carbonization was carried out to release several organic chemicals and leave a residue consisting of pure carbon. At a temperature of 50 - 150 ºC, only pure water is released, at a temperature of 200 - 400 ºC the carbonization process begins, namely decomposition or partial rot [18,20]. Charcoal is the result of the carbonization of waste and can be used as a raw material for briquettes, household fuel, or activated charcoal, and side products include methane gas, hydrogen gas, and ammonia. In the carbonization process, the volume or weight of the waste is reduced by up to 20% of the original amount [19,18]. In the carbonization process, smoke gas from the carbonization furnace can be carried to distillation equipment to obtain waste distilled oil for certain purposes. The gases produced during carbonization can be further processed to produce chemicals.

2. Implementation Method

This research was conducted in the Campus Environment of the Universitas Sumatera Utara (USU), Medan, Indonesia. The research was conducted for six months by conducting field observations and discussing the objects observed in the Universitas Sumatera Utara environment.

2.1 Data Collection Techniques

Data collection was performed using primary and secondary sources. For the primary data collection, various techniques were used, including in-depth interviews with key informants and observations. Secondary data were obtained by triangulation and used as a basis for data analysis and additional information. The data source in this Study also comes from reference books and other notes that support observations and are related to the title of the case study idea. This step aimed to obtain a theoretical basis for supporting this report.

2.2 Data Processing and Data Analysis Techniques

Key informant data processing and the data obtained were analyzed using Microsoft Excel. A descriptive analysis method based on data was obtained from an analysis of the mathematical calculation results. Information from the interviews was processed to support the findings from the questionnaire data analysis. In addition to these methods, observation methods at the research location were also used to strengthen the research findings.

2.3 Block Diagrams in the Design Process

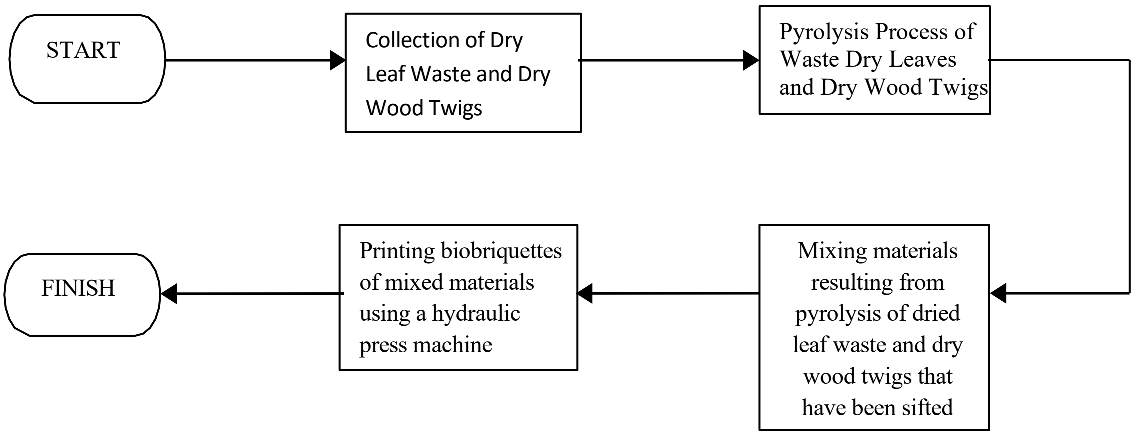

Figure 1. Block Diagram of the Design Process

2.4 Utilization of USU Dried Leaf Waste into Briquettes

Based the leaf waste profile USU, leaf waste experiments on making leaf briquettes were carried out on a large scale at the Marendal Medan Briquette House Factory, which produces briquettes from leaf waste and wood. This study was conducted based on direct experiments coupled with the experience of factory owners. The leaves and twigs that would be burned were washed with running water and then dried in the sun again so that the leaves and twigs were clean and not damp.

1. Combustion Process
   The collected dry waste leaves and twigs were placed in the pyrolysis tank. Then, the tank was closed tightly so that the smoke condensed into liquid smoke. Burning leaves and twigs cannot be compacted because they require air spaces, so ripening or burning can obtain maximum results. The time required for the pyrolysis of leaves and twigs is almost the same as that for coconut shells, namely 3 – 5 h, but for wood, it is approximately 5 – 7 h.
   Burning is carried out using a pyrolysis barrel with a capacity of 100 kg, but the maximum amount of leaf raw material that can be burned is only approximately 30 kg. After consulting the factory owner, the experiment in making leaf briquettes was combined with small twigs to produce more solid briquettes. The combustion experiments were performed three times.
   - The first trial was on 23/09/22, the first burning results were less than optimal, with a composition of 17.3 kg of dry leaves and 4.2 kg of dry twigs with a full cylinder condition and a burning time of 4 hours. This is because the pyrolysis burning barrel cannot be filled with too dense material, and it must have an air cavity; as a result, the leaves and twigs are not completely burned (half-cooked) with a result weighing 9.7 kg.
   - The second trial on 24/09/22, burning was carried out with a composition of 4.3 kg of leaves and 4.4 kg of twigs (total 8.7 kg). Then, the leaves and twigs from the previous burning were added (9.7 kg) by alternately arranging them in the tube; namely, the twigs were inserted first at a height of 15 cm in

the tube, and then the leaves were inserted at a height of 15 cm. The results of this second burning were quite good, burning approximately 11.4 kg of leaves and twigs.
- The 3rd burning trial on the following day with a composition of 6.3 kg leaves + 5.3 kg twigs with the tubes full (alternating 15 cm twigs + 15 cm leaves) with a longer burning time of around 5 - 6 hours. The results were very good, and the colors of the leaves and twigs were black and brittle. With burnt results of 6.9 kg.

2. Siege Process
   After undergoing the burning process or pyrolysis process, the powdered leaves and small twigs turn black with a brittle texture and are then crushed and ground like flour using a disk mill.

3. Sifting Process
   The charcoal flour resulting from pyrolysis was sieved to produce a soft and smooth texture with a size of 50 mesh. Approximately 24 kg of charcoal was produced in this study.

4. Gluing Process
   The charcoal flour that had passed through the filter (24 kg) was then mixed with water and starch, with a composition of 2 kg starch and 2 liters of water. Previously, starch was cooked with water. The mixture was then mixed until it was evenly mixed using a mixer machine, where the starch functioned as an adhesive.

5. Printing Process
   Next, charcoal flour, which has been mixed with starch, is molded into a solid cylinder shape (without cavities), or the shape can be adjusted to market demand.

6. Drying Process
   The drying process can be performed using an oven at 650 °C for 4 h or in direct sunlight, depending on the heat of the sun.

3. Results and Discussion

3.1 Profile of Dry Leaf Waste in USU's Environment

The potential for dry leaf waste in the USU environment is very large, as seen from the following:
1. From a number of leaves collected by the cleaning staff.
2. From seeing scattered leaves piling up unmanaged by the cleaning staff.

From the results of interviews with several cleaning staff members, information was obtained regarding the division of outdoor sweeping officers into two areas:

1. Roadside area from door 1 to door 4.
   - Starting work from 7 to 11 in each area/anca, but after the lunch break, around 1 pm, cleaning is carried out again in the area determined by the foreman/supervisor until 4 pm.
   - With a total of ± 21 officers, every day they can clean around 10 – 15 small sacks (10 kg) of rubbish. Four to six medium-sized sacks (30 kg/50 kg) were obtained from different sources. The trash consisted of both dry leaves and branches.
   - Garbage collected in sacks is picked up and transported by transport vehicles that continue to circulate at irregular times between morning and evening. After transportation, it is thrown into the TPS at gate 4.
   - The average salary for officers who work in areas outside the faculty is still below the minimum wage, and some officers have complained about employee reductions, which has had an impact on areas/threats that were previously worked by around four people, now down to two people, but this does not reduce the loyalty of the officers, which can be seen based on the average period of work between five and ten years; some have even worked for ± 27 years, such as Mrs. Nuraidah and Mrs. Sujiah for 23 years.
2. Faculty and Unit Areas.
   - The number of officers in each faculty is different, such as the engineering faculty that employs 19 people (in door 14 people, out door 5 people), in contrast to the social sciences, which employs only nine people (eight door 8 people and one door 1 person). Fak Ekonomi employs 14 people (8 people in the door and 3 people in the door).

- Information from officers and rubbish is collected in the rubbish bins of each faculty; however, transportation to the TPS at gate 4 is carried out only once every few days. Thus, officers often burn accumulated rubbish. This condition can be observed at several locations.

The data below are a calculation of the amount of rubbish every day in the USU environment, data taken from interviews with several cleaning staff on duty in roadside areas, parks, parking lots, as well as in the yards of several faculties, as follows:

- The USU's potential for dry leaf waste by area/faculty reached 750 kg/day (see Figure 1). The five areas with the highest amount of dry leaf waste were Library, FKG, Social Sciences, MIPA, and Auditorium.
- The data above does not include several areas/regions where dry leaf waste is accumulated which is not always covered, so it has the potential to increase the volume of waste by up to 1 ton/day, and there are several areas/regions where there is still visible accumulation of waste which has been covered by weeds. Large piles of leaf waste show great potential for leaf waste at the University of North Sumatra.

Areas or points where parks/yards are often not covered are only cleaned if there is grass cutting and are handled in mutual cooperation, such as the courtyard of the pavilion/Pancasila building, the parking lot, next to road gate 1 or TPS, and several points in other places. Likewise, in several areas in the faculty yard, areas that were not TPS were also found, but there was a buildup of household waste as well as dry leaf waste, twigs, and even tree trunk waste from the results of cutting down mountains of trees. This can also increase the volume of dry leaves and twig waste that can be managed.

3.2 Figures Graph of Waste Composition by Waste Type in 2023

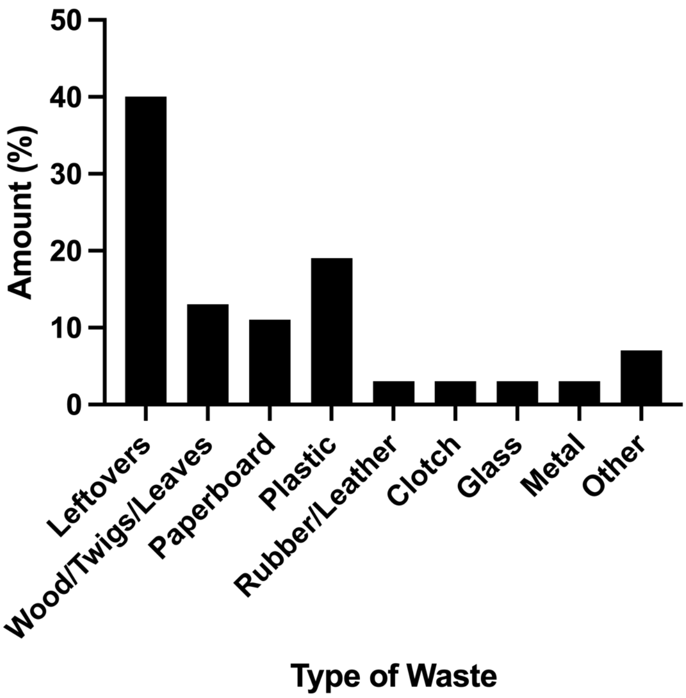

Figure 2. Indonesia's Waste Potential 2023 (source: sipsn.menlhk.go.id)

Figure 2 shows the composition of waste by type. Food waste dominates the waste composition with the largest portion, namely 40.7% of the total waste. This food waste includes food that is not consumed, expired food, or food scraps that are not used when cooking. Wood, branches, and leaves account for 11.6% of the total waste, usually originating from tree pruning, garden cleaning, or gardening activities. Paper and cardboard make up 11.1% of the total waste, including used paper, cardboard boxes, and paper packaging. Plastic waste comprises 11.0% of the total waste, including plastic bottles, plastic bags, plastic packaging, and various other plastic products. Rubber and leather waste make up 6.6% of the total waste, including products such as used tires and discarded leather goods. Fabric waste accounts for 4.2% of the total waste, originating from used clothing, fabric scraps, or other unused textiles. Glass waste constitutes 3.1% of the total waste, including glass bottles, glass shards, and other glass products. Metal waste comprises 1.9% of the total waste, including cans, used metal tools, and other metal objects. Finally, the "others" category accounts for 6.6% of the total waste that is not included in the above categories, consisting of various other types of waste that cannot be specifically categorized. With an understanding of this waste composition, more effective and efficient waste management strategies can be developed to reduce environmental impact and enhance recycling and waste processing. Especially dry leaves waste can be turned into charcoal briquettes for alternative fuel.

Figure 3. Types of Leaves in the USU Environment and Their Collection Containers

Based on observations that have been made, it is found that in the environment of the University of North Sumatra (USU), there are various types of leaves that can be found. This diversity reflects the rich biodiversity around the campus, which not only provides natural aesthetics but also serves as a natural laboratory for students and researchers. Each type of leaf has unique characteristics that can be studied further for academic and practical purposes. The types of leaves in the USU environment vary from the leaves of tamarind trees, handkerchief flower trees, ebony or blackwood trees, bisbul trees, eucalyptus trees, ketapang trees, mahogany and trembesi trees, to leaves from shrubs and bushes. Mahogany leaves, known for their large size and slightly rough texture. Meanwhile, trembesi leaves are smoother and often have a smaller size.

The management of fallen leaves is also an important concern in the USU environment. To maintain the cleanliness and aesthetics of the campus, leaf collection containers have been provided at various strategic points, and also provided by street sweeping workers in the USU environment. These containers are usually made of weather-resistant materials and placed near areas with dense trees. The leaf collection process not only helps maintain cleanliness, but also supports the composting and recycling programs run by the university. Leaf collection containers are usually differentiated based on the type of material to be collected. There are special containers for dry leaves that will be composted, as well as containers for fresh leaves that can be used for further research. With this organized collection system, the USU campus environment can remain clean and green, while supporting sustainable academic and research activities. The existence of various types of leaves in the USU environment with proper management of these leaves into biobriquettes shows the commitment of researchers in maintaining the balance of nature while supporting green economy activities. In this way, USU is not only a comfortable place to study but also contributes to environmental conservation and wise management of natural resources and can make biobriquette products as an alternative fuel in the household.

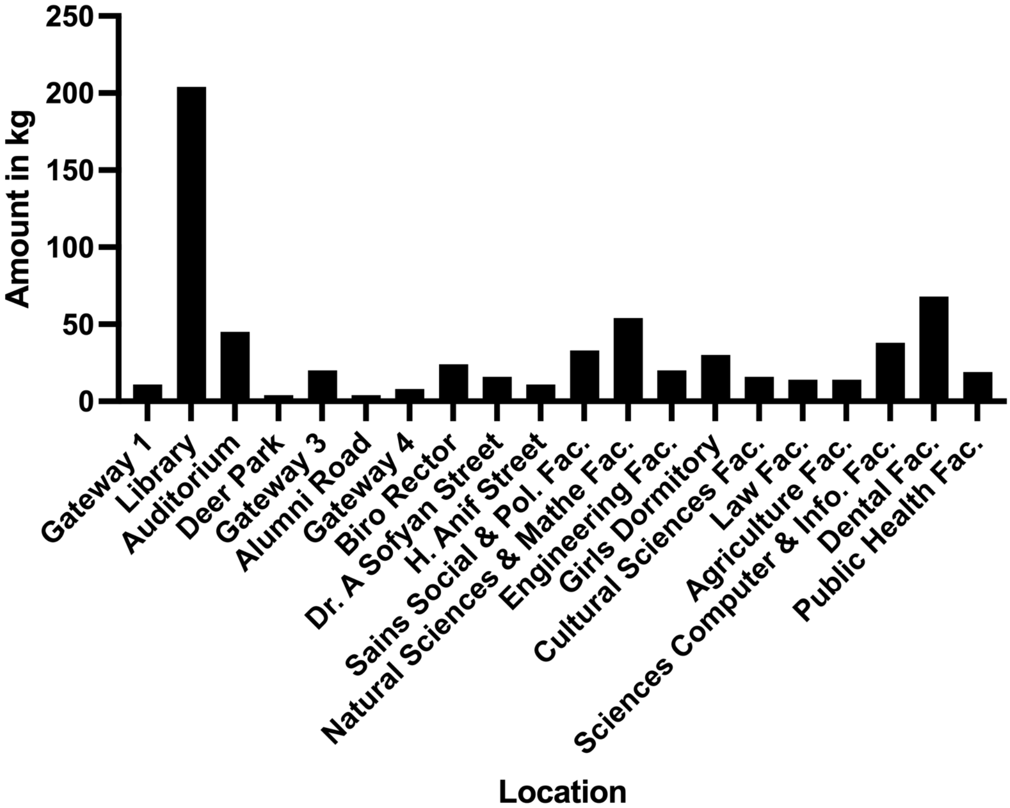

Figure 4. Graph of Potential Leaf Waste in the USU Environment

Based on Figure 4, it is found that the Library area has the largest amount of leaf waste in the USU environment. From this potential, it will be processed into product innovations such as briquettes that can be applied in replacing LPG fuel. Based on the results of our observations, there are 28 officers who clean the streets around the who clean the street area around the faculty, where there are casual and honorary workers working every day, and then after the garbage is collected in sacks and then transported to the TPS. And will be transported by the garbage hauler from the City Government which will be disposed of outside the USU environment. Where based on information that each faculty has 2 - 5 cleaning employees to clean the faculty environment. Based on their information, quite a lot of leaf waste is obtained from the faculty environment, usually the waste is burned in the afternoon or transported in the morning by the waste transportation officer and then taken to the TPS, the amount of waste is 7 - 10 sacks per day in each faculty. Potential USU dry leaf waste by area/faculty (see Figure 4). The five areas with the most dry leaf waste and dry wood branches are Library, FKG, FISIP, FMIPA, and Auditorium.

The results of the research obtained proximate and ultimate values on dry leaf charcoal briquettes and dry wood twigs in Table 1.

Table 1. Results of proximate and ultimate tests on dry leaf charcoal briquettes and dry wood twigs

Composition of dry leaf charcoal and dry wood twig briquettes	Water Content (%)	Ash Content (%)	Carbon Content (%)	Calorific Value (cal/g)	Burning Rate (gr/min)
6.3 kg of leaves + 5.3 kg of dry wood twigs	4.35	5.65	78.68	6115	1.5
4.3 kg leaves + 4.4 kg dry wood twigs	5.78	6.15	67.09	5722	1.8

Table 1 shows the results of proximate and ultimate tests on charcoal briquettes made from a mixture of dry leaves and dry wood branches. The proximate tests include measurements of moisture content, ash content, and carbon content, while the ultimate tests include measurements of heating value and burning rate. From this table, we can see how variations in raw material composition affect the physical and chemical properties of the resulting charcoal briquettes. In the first composition, where 6.3 kg of dry leaves were mixed with 5.3 kg of dry wood twigs, the results showed that the briquettes had a moisture content of 4.35%, ash content of 5.65%, carbon content of 78.68%, calorific value of 6115 cal/g, and burning rate of 1.5 g/min. This composition shows good quality with high carbon content and high calorific value, although the burning rate is moderate.

In the second composition, which consisted of 4.3 kg of dried leaves and 4.4 kg of dried wood twigs, the test results showed an increase in moisture content to 5.78% and ash content to 6.15%, but the carbon content decreased to 67.09%. The heating value was also lower than the first composition, at 5722 cal/g, with a higher burning rate of 1.8 g/min. This difference shows that decreasing the proportion of dry leaves and increasing the proportion of dry wood twigs tends to increase the moisture and ash content, and decrease the carbon content and calorific value. However, the higher burning rate of the second composition suggests that these briquettes may burn out more quickly, which could be a drawback in household applications. In general, for household use and cooking, a slightly lower burning rate is preferable as it provides stability and a longer burning duration. Overall, the briquettes with 6.3 kg of dry leaves and 5.3 kg of dry wood twigs produced the best composition of briquettes, in that they produced heat more steadily and lasted longer, which is ideal for applications such as long-term cooking or heating that requires stability. This analysis is important to understand how variations in feedstock affect the performance of charcoal briquettes in terms of energy efficiency and burning speed.

Figure 5. Dry leaf charcoal briquettes

Figure 5 shows the charcoal briquettes of dry leaves and dry wood branches produced in this study. The charcoal briquettes in the figure have a uniform cylindrical shape. This shape is commonly used because it is easy to produce and provides even heat distribution when burned. The briquettes appear to be uniform in size, both in height and diameter. The consistent size helps in predicting the burning time and heat generated more accurately. The surface of the briquettes looks smooth and dense, indicating that they were produced under high pressure which ensures compactness and high density. The smooth surface also indicates that there are not many loose particles or debris that can cause excessive dust. The deep black color of the briquettes indicates that they have undergone a good carbonization process, where most of the organic matter has been converted into pure carbon. This is important to ensure that the briquettes have a high calorific value. Dense briquettes tend to have a higher energy value and burn longer. High density also reduces the empty space inside the briquette, which means more fuel per unit of volume.

Figure 6. USU Research Team at the Charcoal Briquette Factory

Figure 6 shows the research team from the University of North Sumatra (USU) at the charcoal briquette plant. This study not only showcases the research team from USU but also emphasizes the importance of research and development in the charcoal briquette industry to achieve environmental and economic sustainability.

4. Conclusions

This study found that the potential for dry leaves around the USU campus was between 750 kg and 1 ton per day. The trial using dry leaf waste succeeded in producing a solid charcoal briquette product that could burn well. This study on the use of dry leaves in charcoal briquette products is very useful for increasing science and knowledge among students and the community at the University of North Sumatra, especially cleaning staff. Students and cleaning staff who knew about the alternative of processing dry leaves to make charcoal briquettes were very enthusiastic because they had entrepreneurial ideas. The results of using briquettes in households can help the government reduce the use of petroleum, the availability of which is becoming increasingly low. In future research, researchers will conduct in-depth scientific tests (xrf analysis and sem eds) to make briquettes more measurable and of higher quality. According to the market, the best quality is biocharcoal briquette products, which have a high calorific value and optimal water content. Next, researchers will hold training outreach on dry leaf waste management for community groups or students so that they have additional skills and knowledge as a basis for entrepreneurship. This study produced briquettes with proximate and ultimate tests that met SNI No.01-6235-2000 standards with a moisture content test of 4.35%, ash content test of 5.65%, carbon content test of 78.68%, calorific value of 6115 cal/g, and a burning rate of 1.5 grams/minute with the best composition in the composition of 6.3 kg of dry leaves and 5.3 kg of dry wood twigs.

5. Acknowledgment

We thank the University of North Sumatra Research Institute for providing funding and opportunities for the applied research. We also thank the USU cleaning staff for providing information and collecting leaf waste to be processed into charcoal briquettes in the context of research activities and outreach on the use of leaf waste to create innovative leaf briquette charcoal products on the USU Medan Campus.

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