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Research Article

Environmental remediation through briquettes making from waste papers and latex

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Abstract. This project is dedicated to mitigating the challenges associated with paper and glove waste disposal by introducing an environmentally conscious solution—carbonized briquettes designed for use as sustainable fuel. The methodology involves the meticulous combination of waste paper and gloves, followed by compression into briquettes and carbonization through pyrolysis. A thorough analysis was conducted to assess the quality of the resulting briquettes, focusing on combustion and physical properties. Noteworthy findings include approximately 11% volatile matters, 30 ppm of carbon monoxide, 0.56% moisture content, and over 76% fixed carbon. Physical properties exhibited 0.03% bulk density, 0.9% shattered index, and 0.81% tumbling test. Importantly, the experimental data attests to the project's minimal environmental impact, contributing positively to the overall well-being of the planet. The study's significance extends to environmental sustainability and remediation. It also sets the stage for future research endeavors, highlighting the need to optimize the briquette-making process, consider the glove-to-paper ratio, and develop effective glove cleaning methods to enhance safety for both users and makers. These refinements aim to fortify the project's potential for positive environmental and health outcomes. In summary, this project champions the conversion of paper and glove waste into eco-friendly fuel sources, offering a sustainable and promising solution to waste management challenges. The findings underscore its potential for widespread adoption, aligning with the principles of environmental sustainability and fostering a healthier planet for future generations.

Keywords: carbonized briquettes, environmental sustainability, remediation.

1. Introduction

In recent years, escalating waste generation has led to environmental degradation, presenting a critical challenge to public health and the environment. The study by Lamba et al. (2022) underscores the importance of sustainable waste management, identifying briquettes as a promising solution. Waste paper and gloves, abundant in various sectors, offer a recyclable source for creating briquettes, reducing landfill waste and providing a cost-effective, sustainable fuel (Lamba et al., 2022).

Briquettes, formed through carbonizing waste papers and gloves, not only diminish waste volume but also convert volatile components into a stable form, aligning with environmental sustainability. This eco-friendly alternative contrasts with traditional fuels like coal and firewood, known contributors to deforestation and air pollution (P Wilaipon, 2007; Caban et al., 2021). The environmental ramifications of deforestation and air pollution have been well-documented, emphasizing the urgency for greener alternatives (P Wilaipon, 2007; Caban et al., 2021).

The ecological advantage of briquettes extends to their carbon-neutral nature, releasing the same amount of carbon dioxide during combustion as absorbed during plant growth (Rominiyi et al., 2017; P Wilaipon, 2007). This project addresses a critical gap in waste management, particularly the improper disposal of paper and gloves, contributing to environmental degradation and health hazards. Unlike existing briquette production methods, which may rely on specific waste types and energy-centric goals, this project focuses on creating carbonized briquettes from waste papers and gloves, emphasizing environmental remediation alongside energy production.

Hypothesizing that briquettes from waste papers and latex can minimize greenhouse gas emissions and offer sustainable fuel sources, the research question centers on their effectiveness in environmental remediation. The main objective is to investigate the feasibility and environmental impact of these briquettes, with specific goals of production, quality analysis, and environmental impact assessment. The significance of this study lies in its potential to revolutionize waste management, creating environmentally friendly products, generating employment, and reducing dependence on imported fuels. The challenges, including the need for specialized equipment, underscore the practical considerations essential for successful implementation. This project is aims to make carbonized briquettes from a mixture of waste papers and latex (gloves) referred in this project as waste management for to reduce the amount of waste sent to landfills and promote the effective management of waste, and as energy generation for the production of a fuel source with a high energy content that can be used for heating and cooking, reducing dependence on traditional fossil fuels. It hwlps to develop a sustainable solution to these problems by making carbonized briquettes, with the goal of converting waste materials into a useful and environmentally friendly fuel source that can be used for heating and cooking, while also reducing the amount of waste sent to landfills. By doing so, the project aims to promote sustainable development, reduce greenhouse gas emissions, and contribute to a cleaner and healthier environment.

2. Method

2.1. Production of Briquettes

The methodology for producing carbonized briquettes involves the following steps including such as the material collection and sorting by collecting 2.1 kg of waste paper and 0.9 kg of gloves, ensuring they are cleaned and free of contaminants. Secondly, the shredding and pulverization which involves to shred the 2.1 kg of waste paper and 0.9 kg of gloves collected into small pieces for easier handling and mixing.

The third step involves homogeneous mixing the shredded waste paper and pulverized gloves in a ratio of 2.1:0.9 to create a homogenous mixture. And add binder by taking 3 kg of the shredded material with a binding agent, such as 0.3 kg of cassava flour, to enhance briquette cohesion. The molding and drying consists of molding the mixture into briquettes using a pump and allow them to dry in sunlight. The finals step is carbonization in which the briquettes are put in a furnace at 380°C for 20 minutes in a low-oxygen environment. The final stage is of drying by allowing the carbonized briquettes to dry further in the oven to enhance burning efficiency and reduce smoke production.

Figure 1. Cut waste papers and soaked them into water

Figure 2. Grind the waste papers and reduce the amount of water

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2.2 Making non-carbonized briquettes from a mixture of waste papers and latex (gloves)

The process involves the steps such as Collection and Preparation, Mixing, Mixing with Binding Agent, Briquetting, Drying, and Packaging.

Figure 3. Compact briquettes and give them desired size

2.3 Making carbonized briquettes from waste papers

This process involves the following steps such as collecting and shredding of 3 kg of waste paper to reduce its moisture content, mix the shredded papers with a binding agent (0.3 kg of cassava flour) to hold the briquette together. Then after, continue with compressing the mixture into the desired size and shape by using pump, and, carbonize the briquettes in a furnace by heating them in an oxygen-free environment, typically using furnace or oven at 380 ^{0}C in 20 minutes, to remove any remaining organic material and to produce a clean, high-carbon fuel., and finally, Cool the carbonized briquettes and pack the carbonized briquettes for storage and use. The carbonized briquettes can then be burned as a fuel source, producing heat and ash. The ash can be used as a fertilizer, while the carbonized briquettes can be burned again to produce more heat (Bhattacharya et al., 2009).

2.4 Making non-carbonized briquettes from waste papers

The methodology of making non-carbonized briquettes from a mixture of waste paper and gloves involves the following steps such as collection and preparation which is done by collecting 2.1kg of waste paper and 0.9 kg of gloves and shred them into small pieces, and mixing the shredded 2.1kg of waste paper and 0.9kg of gloves in a suitable ratio to create a homogenous mixture. Then, the addition of binding agent is done using the shredded paper and gloves which are mixed with a binding agent of 0.3kg of cassava flour to help hold the briquette together, and the Briquetting where it is required to compress the mixture into desired size and shape by using pump, followed by drying where the briquettes are put under sun light. The final step is packaging which involves storing the dried briquettes in a suitable place for later use as fuel.

Note: The exact ratio and compression pressure used will vary depending on the specific waste paper and gloves used, as well as the desired characteristics of the briquettes.

Figure 4. Allow briquettes to dry to oven

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2.5 Measurement of Percentage Moisture Content (%MC)

To measure the moisture content of waste paper briquettes, you will need to follow these steps including weighing of the sample of briquettes and record the weight as the wet weight, followed by drying it in an oven at 105°C for one hour, and repeat the process until it reaches a constant weight. This means that the weight of the sample does not change even with further drying. Weigh the sample again after drying and record the weight as the dry weight.
The moisture content of waste paper briquettes can be determined by using the following formula of:

Moisture Content = ((Wet Weight - Dry Weight) / Dry Weight) x 100%

Where we weight of the mass of briquette before drying, and the mass of the briquette after drying to a constant weight.

2.6 Determining Ash Content in Waste Paper Briquettes

Ash content of briquettes refers to the amount of inorganic residue that remains after the briquette has been burned or combusted. It can be an important parameter to measure because it can affect the combustion efficiency of briquette. Research conducted by (Onukak et al., 2017) showed that percentage of ash content was determined by taking residual samples obtained after volatile matter determination (W1) that were heated gradually in a muffle furnace at 700 ±50°C and weighed after cooling to get the ash weight (W2). You need to follow these steps by weighing the initial sample of the waste paper briquette, burn the sample in a furnace until all the organic matter is completely burned off, and after allowed the furnace to cool down and then weigh the ash residue. The percentage of ash content was determined using the following equation of:

Ash content%= (W1/W2)*100%

2.7 Measurement of percentage fixed carbon (%FC)

(Onukak et al., 2017) defined Fixed carbon of briquettes as the portion of carbon that remains in the briquette after volatile matters have been removed during the carbonization process. It indicates the quality and energy density of the briquette. Higher fixed carbon content generally means a higher energy density and better combustion efficiency, resulting in more heat generated per unit of briquette. The percentage of fixed carbon was calculated by subtracting the sum of Moisture content, volatile matter (VM), and ash content (AC) from 100% using the following equation:
Fixed carbon: 100% - (MC+VM+AC)

Figure 5. Furnace machine used to carbonize briquettes

2.8 Determination of Ignition Time

According to a study of (Onukak et al., 2017), Ignition time of briquettes refers to the amount of time it takes for the briquette to start burning when exposed to a flame or heat source. It is an important parameter to measure because it can affect the ease of use and handling of the briquette, as well as its combustion efficiency. The briquette samples were ignited at the edge of their bases with a Bunsen burner. The time taken for each briquette to catch fire was recorded as the ignition time using a stopwatch according to. The ignition time was calculated using the following equation:

Ignition time: t1-t0

According to studies of (Zhang et al., 2015) and (Economics & Library, n.d.) Showed that carbonized briquettes generated from waste papers and agricultural wastes had a high heating value and may be used as a sustainable energy source. Several studies have also looked into how waste papers and gloves are turned into carbonized briquettes. For example, a study conducted by (Gupta et al., 2019) used a hydrothermal carbonization technique to create briquettes from used gloves, while a study by (Moreno et al., 2016) used a pyrolysis process to create briquettes from waste papers.

3. Result and Discussion

3.1. Quality Analysis of Briquette Produced and Its Evaluation

3.1.1. Determination of Combustion Properties

The defining attributes of combustion include the release of heat and light. The point at which a material begins to ignite is referred to as its ignition temperature. A substance will not ignite or undergo combustion if its temperature remains below this threshold. Additionally, the presence of oxygen is essential for combustion to occur, as it is a vital element in the process. The combustion properties measured are Moisture Content, Ash Content, Volatile Matters, Fixed Carbon, Carbon Monoxide, and Smoke, were analyzed for different types of briquettes.

3.1.2. Combustion Properties

Table 1. Environmental Parameters at Three Research Stations

Station	Research	Coordinate Point	Environmental Parameters
1	Carbonized Waste Paper	6° 54'46.6"S 110° 29'08.9"E	32, 7.4, 3.28, 5.52
2	Carbonized Waste Paper	6° 55'25.0"S 110° 28'44.1"E	31.87, 7.4, 3.44, 5.41
3	Carbonized Waste Paper	6° 55'13.6"S 110° 29'01.2"E	31.93, 7.8, 3.52, 5.78

The "Coordinate Point" in the table refers to the geographical coordinates of the research stations where the environmental parameters were measured. It has to include the latitude and longitude of each station (Domingo J. et al., 2018). The format used for expressing these coordinates is degrees, minutes, and seconds for both latitude (N/S) and longitude (E/W). The first station site of our research has 32 degree celcius, 7.4 minutes, 3.28 as latitude and 5.52 as longitudinal coordinates. The second station is on 31.87 degree celcius, 7.4minutes, 3.44 as latitude and 5.41 as longitudinal coordinates points. The third station is on 31.93 degree celcius, 7.8 minutes, 3.52 and 5.78 as latitude and longitudinal coordinates points respectively.

3.2 Quality of Moisture Content (Mc) Analysis

A p-value below 0.05 indicates that there is a statistically significant difference in the moisture content of the briquettes. In general, briquettes with a moisture content of around 10-15% are considered to be suitable for combustion because it is too low for optimal burning efficiency and environmental impact (Aliyu M. et al., 2020). Based on the obtained p-value being less than 0.05 that is the evidence which strongly support the hypothesis that waste paper and gloves briquettes are viable and sustainable, w1 being the residual samples mass obtained after volatile matter determination and w2, the weight (mass) of the smple after cooling (ash weight).

Table 2. Moisture content of tested samples

Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.730	4.933	0.000809	0.395	1.064	0.395	1.064
W1	2.99	108.232	2.49E-15	2.936808	3.062	2.936	3.062
W2	-3.021	-95.013	8.04E-15	-3.09375	-2.949	-3.093	-2.94

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3.3 Ash Content Analysis

During the experimental analysis, the ash content of the briquettes was measured and the results showed a p-value below 0.05, indicating that the ash content was significantly low. Based on this finding, it can be concluded that the briquettes are suitable for use as they contain a relatively low amount of ash content. This is an important finding because high ash content in fuel can cause several problems, such as reducing the heating value, increasing the emission of pollutants, and affecting the combustion efficiency. Therefore, the low ash content of the briquettes indicates that they are environmentally friendly and can contribute to sustainable energy production (Olorunnisola, A. O., 2007). Overall, the results of this study suggest that briquettes made from the tested materials can be a viable alternative to conventional fossil fuels, particularly in areas where sustainable energy sources are in high demand, W3 being the mass of sample wighted and put into the furnace for 3-4 hours until all organic matter has been burned off and w4 is the mass of the crucible after it is cooled down in a desiccator (Chandra R. et al., 2012). Thus, the low ash content indicates environmental friendliness and suitability for sustainable energy production.

Table 3. Quamtity of ash of tested samples

Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	10.5753	11.468	1.13E-06	8.489	12.661	8.489	12.661
W3	3.047	43.305	9.32E-12	2.888	3.207	2.888	3.207
W4	-3.40914	-44.1625	7.82E-12	-3.583	-3.234	-3.583	-3.234

3.4 Fixed Carbon Analysis

During experimental analysis, the fixed carbon content of the briquettes obtained had p-value below 0.05 which can conclude that the briquettes contain a significant amount of fixed carbon and are suitable for use as a fuel source. Fixed carbon is an important component of solid fuel, it is responsible for producing heat during combustion. Therefore, the high fixed carbon content in the briquettes indicates that they are capable of producing more energy when burned (Lubwama M. et al., 2020). This makes the briquettes an attractive alternative to traditional fossil fuels, as they offer a sustainable and environmentally friendly solution for energy production (Young, P., 2003). The significant fixed carbon content indicates suitability as a fuel source, offering a sustainable alternative to traditional fossil fuels.

Tabale 4. Quantity of fixed carbon analysis

Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	100	7.52E+15	6.6E-140	100	100	100	100
Volatile Matters	-1	-4.6E+14	6E-129	-1	-1	-1	-1
Ash Content	-1	-3.7E+14	3.8E-128	-1	-1	-1	-1

3.5 Analyze Impact of Produced Briquettes on the Environment

3.5.1. Evaluation of Volatile Matters as a Quality Indicator of Briquettes

The findings suggest that the briquettes made from waste papers and gloves have a positive impact on environmental remediation by reducing the number of volatile matters, as the p-value obtained from our experiment is below 0.05. So, the statistical evidence supports our hypothesis that the briquettes made from waste papers and gloves are an efficient means of environmental remediation. Thus, the p-value below 0.05 supports the hypothesis that waste paper and gloves briquettes efficiently reduce volatile matters, contributing to environmental remediation (Kaliyan N. et al., 2009).

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Table 5. Evaluation of volatile matters as quantity indicator of briquettes results

Coefficients	Standard Error	t Stats	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	8.1047	9.77431	4.33E-06	6.229	9.980	6.229	9.980
W2	2.698	59.113	5.72E-13	2.594	2.801	2.5948	2.801
W3	-2.933	-44.205	7.75E-12	-3.083	-2.783	-3.083	-2.783

3.5.2 Carbon Monoxide Analysis

During the experimental analysis of the waste papers and gloves, measured the carbon monoxide (CO) produced during burning and found it to be equal to 31 ppm. This result suggests that the briquettes contain relatively low levels of carbon monoxide, making them safe and suitable for burning. According to safety regulations, briquettes that produce CO levels above 56 ppm are not permitted to burn due to the health risks associated with high levels of this toxic gas. Therefore, the low levels of CO produced by the waste papers and gloves indicate that they can be safely burned without posing a risk to human health. These findings support the use of these briquettes as a sustainable and environmentally friendly fuel source.

3.6 Burning Process

The experimental analysis conclusively demonstrates that waste paper briquettes provide a reliable and clean source of energy during burning. The evidence presented in the above photo clearly shows that waste paper and gloves briquettes are an effective and sustainable alternative to traditional charcoal, providing a high-quality fuel source for a variety of applications. Through careful analysis of all the data collected, it is clear that waste paper and gloves briquettes are an excellent choice for those seeking a renewable source of energy, providing both environmental benefits and reliable performance.

3.7 Analysis of Physical Properties of Briquettes

The experimental analysis was also conducted on physical properties of briquettes included Bulk density, shattered index and tumbling test. The result showed that the briquettes produce approximately 11% of volatile matters, 30 ppm of carbon monoxide; 0.56% of Moisture content and above 76% of fixed carbon, 0.03% of bulk density, 0.9% of shattered index and 0.81% of tumbling test. The experimental data confirms that project could not have negative environmental impacts so that it could promote good health and sustainability of well-being of organisms on the planet. Future studies should prioritize optimizing the briquette-making process by considering the glove-to-paper ratio and developing effective glove cleaning methods to ensure safety for both users and makers.

3.7.1. Shattered Index Analysis

The resistance to the shattered index was consistently above 80%, indicating high durability and suitability for transportation and storage. In the experimental analysis, we obtained a resistance to the shattered index of all briquettes were above 80%. Based on this result, we can conclude that the briquettes contain a high resistance to shattered index, which were beneficial in several ways. Firstly, high resistance to shattered index briquettes is better able to resist transport, reducing the likelihood of breakage or damage during shipping. Additionally, high resistance to shattered index briquettes is also more durable, which is an important factor when considering their suitability for long-term storage. In conclusion, our results demonstrate that the briquettes possess a high resistance to shattered index, making them a robust and reliable fuel source that is resistant to transport and has a high level of durability.

3.7.2. Tumbling Test Analysis

Consistently above 80%, the resistance to the tumbling test implies high durability and suitability for transportation, storage, and long-lasting use. During the experimental analysis of the briquettes, we observed a resistance to tumbling test that was consistently above 80%. This result indicates that the briquettes possess a high resistance to tumbling, which in turn suggests that they have a strong ability to withstand transport and handling. Furthermore, this high resistance to tumbling implies that the briquettes have a high level of durability, meaning they can withstand wear and tear over time. Overall, these findings suggest that the briquettes produced in this study have desirable qualities that make them suitable for transportation and storage, as well as for use as a long-lasting fuel source.

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4. Conclusion

In conclusion, the experimental analysis conducted for this has provided promising results that highlight the potential benefits of this project for Rwanda's sustainable development and environmental protection. The briquettes made from waste papers and gloves have shown to have high fixed carbon content, low moisture content, and resistance to water penetration, making them a suitable alternative to traditional charcoal. Moreover, the low carbon monoxide and smoke emissions suggest that the briquettes are less harmful to the environment and human health, further supporting their use.

The production of these briquettes from waste materials not only provides an eco-friendly solution to the problem of charcoal wood usage but also offers an opportunity for waste reduction and environmental remediation. This project has the potential to create new job opportunities and support local businesses, while simultaneously reducing deforestation and protecting the environment. Overall, the project has significant potential to promote sustainable development and environmental protection in Rwanda while also providing economic and social benefits.

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