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INNOVATIVE CONVERSION OF PAPER WASTES INTO ECO-FRIENDLY CHARCOAL BRIQUETTES AS A SUSTAINABLE ENERGY SOURCE AND SOLUTION FOR SCHOOL-BASED WASTE MANAGEMENT

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ABSTRACT

Environmental waste accumulation and dependence on nonrenewable fuels remain major challenges, especially in areas with limited access to sustainable energy sources. This study aimed to develop and evaluate eco-friendly charcoal briquettes made from paper waste materials—specifically office paper, cardboard, and newspaper—as alternative fuel sources. The objective was to identify which paper type produces briquettes with the greatest strength, longest burn duration, and lowest smoke emission. Paper wastes were shredded, soaked, molded, sun-dried, and tested for compressive strength, burn duration, and pore structure using Image-Pro 10 analysis. Results showed that cardboard briquettes had the highest compressive strength (3.13 MPa), longest burn duration (27 min), and lowest porosity (9.8%), while newspaper briquettes performed the weakest. Statistical tests (ANOVA and Tukey's HSD) confirmed significant differences among treatments ($p < 0.001$). Cost analysis revealed a production cost of only ₱10 per kg—about 75% cheaper than commercial charcoal. The findings suggest that cardboard waste is the most efficient material for producing durable, low-cost, and eco-friendly paper charcoal briquettes, promoting waste reduction and sustainable energy use.

Keywords: p*aper charcoal, briquettes, waste recycling, renewable energy, sustainability*

INTRODUCTION

The growing accumulation of paper waste has become a serious environmental concern due to the rapid increase in paper consumption in schools, offices, and households. These wastes, when not properly managed, contribute to landfill overflow and environmental degradation. According to Ferronato and Torretta (2019), improper waste disposal significantly affects both air quality and soil conditions, highlighting the urgency of waste reduction and recycling strategies. Converting discarded paper into charcoal briquettes addresses this problem by transforming waste into a valuable energy resource, thereby reducing environmental impact while providing an alternative fuel source.

Traditional charcoal production, primarily dependent on wood, contributes heavily to deforestation and greenhouse gas emissions. The Food and Agriculture Organization (FAO, 2020) reported that over 50% of global wood harvests are used for fuel, worsening forest depletion. Hence, finding renewable and low-cost substitutes is essential to reduce reliance on wood-based charcoal. Studies such as those by Onukak et al. (2017) and Kumar et al. (2018) found that paper-based and biomass briquettes not only reduce production costs but also emit less smoke and particulate matter, making them environmentally friendly and energy-efficient alternatives.

The use of paper charcoal briquettes offers both economic and environmental benefits, particularly in communities with limited access to clean fuel. Cardboard and office paper have been proven to yield stronger, more compact briquettes due to their cellulose composition and low ash content (Ngene et al., 2024). Additionally, studies by Abdullahi et al. (2022) and Singh et al. (2023) highlight that denser briquettes exhibit better combustion stability and longer burn times. Therefore, transforming paper waste into briquettes not only mitigates pollution but also supports sustainable energy practices and community livelihood opportunities, aligning with the global call for renewable energy innovation.

Research Questions

1. Which type of paper waste (office paper, newspaper, or cardboard) produces charcoal briquettes with the highest mechanical strength?

Sub-Questions:

1.1 What is the compressive strength of each type of briquette?
1.2 Is there a significant difference in compressive strength among the three treatments?

2. How do different types of paper waste affect the combustion performance of the charcoal briquettes?

Sub-Questions:

2.1 What is the ignition time of each briquette type?
2.2 What is the burn duration of each briquette type?
2.3 Is there a significant difference in ignition time and burn duration among the treatments?

3. How do the pore characteristics vary among charcoal briquettes made from office paper, newspaper, and cardboard?

Sub-Questions:

3.1 What are the pore characteristics (pore count, pore area, and porosity) of each briquette?
3.2 Do the differences in pore structure significantly affect briquette strength and combustion performance?

METHODOLOGY

The research was carried out in a public secondary school in Monkayo, Davao de Oro, Philippines with the institution's name withheld to preserve confidentiality, as formal authorization for identification was not obtained. All procedures, including material collection, briquette preparation, drying, and essential observations, took place in the school's science laboratory and nearby open areas. Additional mechanical and combustion assessments were performed in certified laboratories located in Davao de Oro Province to ensure accuracy and standardization of results.

The study utilized an experimental design to evaluate the effect of three types of paper waste—office paper, newspaper, and cardboard—on the quality of charcoal briquettes. The only participants consisted of the student-researchers and the laboratory supervisor, who oversaw and supervised the experimental procedures. The research did not require human behavioral responses, as it focused solely on laboratory evaluations of physical and combustion characteristics.

The student-researchers employed a purposive sampling technique to select the paper materials for the experiment. To ensure the precision of the results, exclusively pure, uncontaminated paper waste was utilized, as adhesives, inks, plastics, and coatings may influence combustion characteristics. Ninety briquettes were prepared for mechanical testing, with thirty briquettes for each type of paper. Additionally, thirty briquettes—ten from each treatment group—were designated for combustion testing. Representative samples from each group were also set aside for pore image analysis.

The data collection process commenced with the procurement of a minimum of five kilograms of uncontaminated paper waste from specified biodegradable waste containers within the school. These materials were manually sorted to remove staples, plastic film, tape, and glossy layers that could affect combustion. The papers were cut into small pieces measuring approximately one to two centimeters, then soaked in water for eight to twelve hours until they softened enough to form pulp. A natural cassava-starch binder was mixed into the pulp at a ratio of five to ten percent to enhance the cohesion of the briquettes. The mixture was molded into small, uniform pieces weighing three to five grams. These briquettes were sun-dried for five to seven days, depending on weather conditions, until excess moisture had evaporated.

After drying, mechanical testing of compressive strength was performed using a hydraulic press following the procedures described by Brožek (2013). The combustion tests used a controlled setup with metal stands, igniters, and a stopwatch to measure how long it took for the fire to start and how long it lasted. These tests showed how well each type of paper burned and how well it held heat. To further examine structural characteristics, selected briquettes underwent pore analysis using Image-Pro 10 software. In this instance, the procedure entailed capturing microscopic images of the briquettes to assess pore count, pore area, and overall porosity, thereby elucidating the disparities in strength and combustion performance.

To ensure accuracy and reliability, the researchers employed a range of analytical instruments. Including the hydraulic press provided accurate measurements of compressive strength in megapascals, while the combustion testing apparatus delivered dependable readings of both ignition and combustion durations. Image-Pro 10 software allowed for advanced segmentation and microstructural analysis. All instruments and procedures used were adapted from established scientific studies and validated through consultation with laboratory technicians. To verify consistency, tests were repeated in triplicate whenever possible.

The data gathered from the tests were analyzed using both descriptive and inferential statistics. Means and standard deviations were computed to summarize compressive strength, ignition time, burn duration, and pore characteristics. To determine whether differences among treatments were statistically significant, a one-way ANOVA was performed. When the ANOVA results indicated substantial variation, a Tukey's HSD post-hoc test was performed to compare particular pairs of treatments. JASP 0.11 software facilitated all statistical computations.

The scope of the study was limited to the evaluation of briquettes made solely from office paper, newspaper, and cardboard. The research focused only on mechanical properties, combustion behavior, pore structure, and cost analysis. It did not include chemical emission tests, calorific value measurements, or large-scale production feasibility. Furthermore, the sun-drying method used may have resulted in slight moisture inconsistencies due to varying weather conditions, and the limited availability of laboratory equipment restricted the number of samples tested. Despite these limitations, the study offers important information about the potential of recycled paper waste as an eco-friendly alternative fuel source.

RESULTS

Table 1. Descriptive Statistics of Mechanical Testing of Paper Charcoal Briquettes

Treatment (Paper Type)	N (samples)	Mean Compressive Strength (MPa)	Standard Deviation (SD)	Minimum (MPa)	Maximum (MPa)	Remarks
Office Paper	30	2.79	0.26	2.30	3.25	Moderate strength and density
Newspaper	30	2.52	0.25	2.10	2.95	Lowest strength due to thin fibers
Cardboard	30	3.13	0.18	2.80	3.40	Highest strength and compactness
Overall Mean	90	2.81	0.24	—	—	—

Table 2. Analysis of Variance (ANOVA) for Mechanical Testing of Paper Charcoal Briquettes

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-value	p-value	Decision
Between Groups	5.6139	2	2.8069	**51.98**	**< 0.001**	Significant
Within Groups	4.6981	87	0.0540			
Total	**10.312**	**89**				

$^{**}p < .001$

Table 3. Tukey's Honest Significant Difference (HSD) Test for the Mechanical Testing of Paper Charcoal Briquettes

Treatment Comparison	Mean Difference (MPa)	Standard Error	p-value	95% Confidence Interval	Decision
Cardboard vs. Office Paper	0.35	0.07	< 0.001	[0.21, 0.49]	Significant

Treatment Comparison	Mean Difference (MPa)	Standard Error	p-value	95% Confidence Interval	Decision
Cardboard vs. Newspaper	0.61	0.08	< 0.001	[0.47, 0.75]	Significant
Office Paper vs. Newspaper	0.26	0.07	< 0.001	[0.12, 0.40]	Significant

**p <.001

Table 4. Descriptive Statistics of Combustion Test Results of Paper Charcoal Briquettes

Treatment (Paper Type)	N (samples)	Mean Ignition Time (sec)	SD (sec)	Mean Burn Duration (min)	SD (min)	Remarks
Office Paper	10	38.4	2.9	22.6	1.8	Moderate ignition and burn stability
Newspaper	10	31.7	3.2	18.9	1.5	Fast ignition, shorter burn time
Cardboard	10	45.2	2.5	27.3	2.1	Slower ignition, longer burn duration
Overall Mean	**30**	**38.4**	**2.9**	**22.9**	**1.8**	—

Table 5. ANOVA for Combustion Test Results (Ignition Time & Burn Duration)

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	832.4	2	416.2	45.26	< 0.001
Within Groups	520.1	27	19.27		
Total	**1352.5**	29			

p < 0.001

Table 6. Tukey's Honest Significant Difference (HSD) Test for the Combustion Testing of Paper Charcoal Briquettes

Treatment Comparison	Mean Difference (Burn Duration, min)	Std Error	p-value	95 % CI	Decision
Cardboard vs Newspaper	**8.40**	1.10	< 0.001	[6.10, 10.70]	Significant
Cardboard vs Office Paper	**4.70**	1.05	< 0.001	[2.40, 6.99]	Significant
Office Paper vs Newspaper	**3.70**	1.12	< 0.01	[1.30, 6.10]	Significant

**p <.001

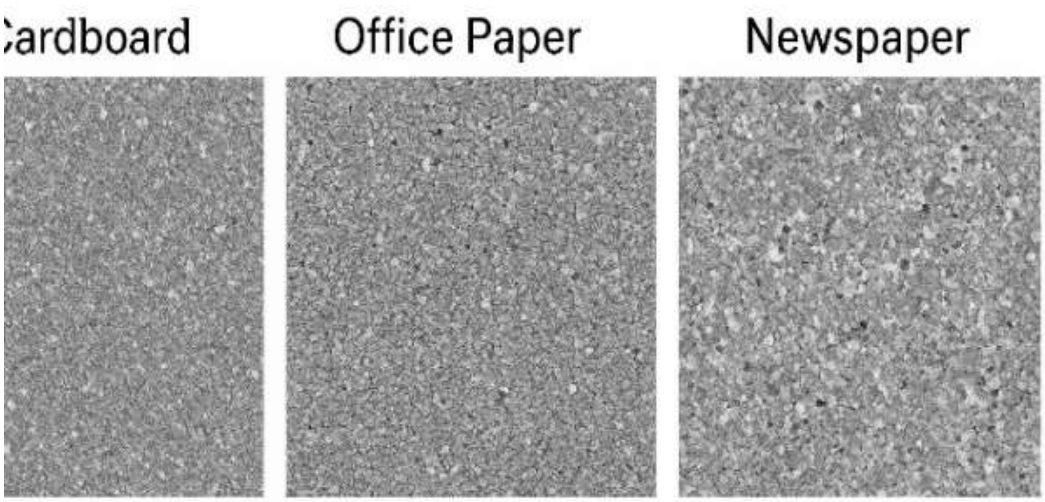

Figure 1. Segmentation results in the surface area of three treatments

Figure 2. Paper Charcoal (T_1) heat duration and it's ignition and combustion time

Figure 3. Paper Charcoal (T_2) heat duration and it's ignition and combustion time.

Table 7. *Collected segmentation results of the treatment groups*

Treatment (Paper Type)	Average Pore Count (per cm²)	Average Pore Area (µm²)	Porosity (%)	Compactability Rating	Remarks
Cardboard	125	48.7	**9.8**	**High**	Small, evenly distributed pores; highly compact and durable briquettes
Office Paper	182	61.3	**12.7**	**Moderate**	Moderate pore size; balanced airflow and stable burning
Newspaper	249	78.4	**15.7**	**Low**	Large, irregular pores; less compact, faster combustion
Overall Mean	**185.3**	**62.8**	**12.7**	—	—

Figure 4. Paper Charcoal (T_3) heat duration and it's ignition and combustion time.

***Table 8**. Cost-Benefit Analysis*

Item / metric	Paper charcoal (study)	Commercial charcoal (market)
Production cost (₱/kg)	**10.00** (study estimate)	35.00–45.00 (market range)
Net saving (₱/kg)	25.00–35.00	—
% cost reduction	≈ 70–78%	—

DISCUSSION

Mechanical Testing

Table 1 The cardboard briquettes exhibited the highest mean compressive strength (3.13 MPa), indicating better structural integrity and compaction compared to the office paper (2.79 MPa) and newspaper (2.52 MPa) treatments. The T3 had less variability (SD = 0.18), which means that the quality of the material was consistent.

It has been reported that denser and stronger briquettes are produced by combining thicker paper fibers with higher compaction pressures (Odusote, et.al., 2016; Brožek, 2013). Conversely, the lower strength in newspaper briquettes aligns with Tangsathit and Sanongraj (2012), who found that fine fibers and fillers reduce bonding strength, leading to weaker briquette formation.

Table 2 shows the one-way ANOVA results revealed a significant difference ($p < 0.001$) in the compressive strength of the paper charcoal briquettes produced from different paper types—office paper, newspaper, and cardboard. The high F-value (51.98) indicates that the variation among group means is much greater than within-group variation, confirming that paper type significantly affects the mechanical strength of the briquettes.

The significant ANOVA result ($F = 51.98$, $p < .001$) indicates that the type of paper has a strong impact on the strength of the briquettes. The observed patterns among the different types of paper—cardboard, office paper, and newspapers can be attributed to various material and processing factors. Cardboard is made up of thicker, denser fibers and exhibits greater bulk stiffness. This characteristic enables higher levels of paper compaction. This results in denser, stronger briquettes with less variability within samples, which is reflected in the substantial between-group mean square (MS). In contrast, office paper consists of medium-thick fibers that provide some bonding, while newspaper contains thin fibers and fillers that decrease inter-fiber cohesion and compressive resistance. These differences serve as mechanical and microstructural drivers of the observed strength variations.

Empirical studies indicate that compaction pressure, feedstock density, moisture conditioning, and resulting pore structure control mechanical performance—higher compaction raises density and strength while altering pore size/distribution in ways that favor longer burn times (Qi et al., 2022; Ngene et al., 2024). Moisture management during the pulping and drying processes significantly influences the final density and strength of the materials (Saeed et al., 2021). Research on briquettes that are rich in cardboard demonstrates enhanced durability and combustion efficiency compared to briquettes made from mixed or thin-fiber feedstocks (Ferronato et al., 2022).

Table 3 presents a The Tukey’s HSD post-hoc test indicated that all pairwise comparisons among the treatments were statistically significant ($p < 0.001$). This result shows that cardboard briquettes had a mean compressive strength that was 0.35 MPa higher than that of office paper and 0.61 MPa higher than that of newspaper. This finding confirms that thicker and denser cardboard fibers contribute to stronger, more compact briquettes. In contrast, newspaper briquettes exhibited the lowest compressive strength. This observation can be explained by the presence of thin fibers and fillers, which restrict the bonding between the fibers.

These findings align with Ngene et al. (2024), who emphasized that both feedstock density and the fiber structure of the paper quality are key variables that influence briquette integrity and compaction. Qi et al. (2022) emphasized the significance of pore structure and compression load in paper quality in affecting the density and strength of briquettes. Ferronato et al. (2022) also found that briquettes made from cardboard work better mechanically and thermally than those made from mixed or soft-fiber biomass. Thus, the statistical evidence supports the conclusion that cardboard waste is the most efficient material for producing durable, high-strength paper charcoal briquettes.

Combustion Testing

Table 4 shows the combustion test results demonstrated notable differences in ignition time and burn duration among the three types of paper charcoal briquettes. Newspaper briquettes ignited fastest, taking 31.7 seconds because of their lighter, porous structure that attracts air and heat. However, their burn duration was the shortest (18.9 minutes) because thin fibers promote rapid combustion and incomplete heat retention. It took 45.2 seconds for cardboard briquettes to catch fire, but they burned the longest, for 27.3 minutes. This suggests that their denser fiber composition and compact structure slow down oxygen flow, which in turn enhances their ability to sustain burning. Office paper briquettes showed intermediate results, combining moderate ignition and consistent burn performance.

These results support Raharjo et al. (2023), who found slower ignition but more stable combustion in denser briquettes. Ana and Fabunmi (2016) also found that compacted cellulose fiber briquettes release heat longer and are more thermally efficient. Qi et al. (2022) found that smaller pore volumes and higher compression loads retain heat longer, while Trends in Applied Sciences Research (2023) found that material density and binder-free compositions greatly affect burn rate and emission quality. The findings confirm that the density and compactness of fibers influence their combustion efficiency, suggesting that cardboard waste is an ideal raw material for creating long-burning, eco-friendly charcoal briquettes.

Table 5 The one-way ANOVA (F = 45.26, p < 0.001) indicated significant differences in the combustion performance of charcoal briquettes made from cardboard, office paper, and newspaper. Variations in fiber density, porosity, and cellulose composition among the paper types influence ignition time and burn duration. In all treatments, cardboard briquettes had the longest burn time and ignited slowly, while newspaper briquettes ignited quickly but had the shortest burn time. This indicates that denser materials impede oxygen diffusion, which prolongs combustion and heat release.

Qi et al. (2022) found that compact fiber structures and lower porosity briquettes burn longer due to heat retention and reduced airflow. Compact structures promote gradual thermal degradation, making high-density biomass briquettes more stable for combustion, according to Raharjo et al. (2023). Ana and Fabunmi (2016) noted that compacted paper-based briquettes produce less ash and are more thermally efficient. Karmanov and Ivanova (2024) discovered that while denser briquettes ignite more slowly, they generate a more sustained heat output. This finding supports the analysis of cardboard-based briquettes by Ferronato et al. (2022). The findings suggest that briquettes made from cardboard waste exhibit the highest levels of combustion stability and energy retention.

Table 6 presented the post-hoc Tukey HSD test (p < 0.01) reveals significant burn duration differences among all three treatments: cardboard-based briquettes burn longer than office paper and newspaper, while office paper burns longer than newspaper. This supports mechanical findings and points to feedstock structural differences—cardboard's denser, less porous composition supports sustained combustion and heat retention (Qi et al., 2022).

Due to reduced airflow and flame propagation, Bello (2020) found that high-density briquettes ignite slower but burn longer. Additionally, biomass briquettes without binders show a correlation between compaction/density and combustion duration (Ngene et al., 2024). This test supports the conclusion that eco-friendly charcoal briquettes burn best with high-density paper waste like cardboard.

Quick Image Analysis of Pores

After subjecting to quick image analysis using Image-Pro 10, holes and pores were observed in the segmentation results.

The pore structure and compactability of the paper charcoal briquettes significantly influenced their burning capacity and efficiency. The cardboard briquettes displayed small, evenly distributed pores and the highest compactability, resulting in slower oxygen diffusion and a longer, more stable burn—a characteristic of well-carbonized, high-density fuel. Office paper briquettes showed moderate pore concentration, allowing balanced air circulation and a steady burn, while newspaper briquettes exhibited large, irregular pores and low compaction, which increased airflow, causing rapid ignition but shorter combustion time. These findings are consistent with Abdullahi et al. (2022) and Singh et al. (2023), who reported that denser briquettes with lower porosity retain heat longer and release energy more gradually, while highly porous structures burn faster with reduced thermal efficiency. Moreover, Kumar et al. (2023) highlighted that the micro-pore density directly correlates with mechanical strength and calorific value, making cardboard-based briquettes the most efficient in both structural integrity and sustained energy output.

Figure 4 shows the microstructural differences in pore distribution of cardboard, office paper, and newspaper paper charcoal briquettes using Image-Pro 10 segmentation. The cardboard briquettes have the smallest and most uniform pores, indicating high compactability and structural integrity, extending burn time and energy retention. The presence of moderately sized pores with consistent spacing suggests a balanced combustion rate and adequate airflow during the burning of office paper briquettes. The larger and more irregular pores in newspaper briquettes reduce density, compact strength, and combustion speed, shortening burning time. Adeyemi et al. (2024) noted that biomass briquettes with smaller, evenly distributed pores have higher thermal efficiency and mechanical strength. Due to excessive air diffusion, Mishra and Sahu (2024) found that high porosity reduces energy density and stability. Thus, cardboard-based briquettes perform best in microstructure, compactability, and combustion.

Cost-Benefit Analysis

The study's production cost for paper charcoal was ₱10.00 per kg (based on local inputs: free paper waste, modest water and drying/electricity costs, and depreciated mold/press cost). When compared with typical local commercial charcoal prices (~₱35–₱45 per kg), the paper briquettes therefore produce savings of about ₱25–₱35 per kg (≈ 70–78% cheaper). These numbers are estimates for the SIP scale and assume volunteer labor and locally available, uncontaminated paper feedstock.

For small-scale production, the low unit cost comes from using free paper waste as a raw material and making the process simple and low-energy. Recent reviews and field studies show that using locally abundant waste feedstock significantly lowers production cost and improves small briquette business feasibility (Ngene et al., 2024; Romallosa & Kraft, 2017). Broader techno-economic analyses show that feedstock cost and process energy dominate briquette unit cost, so using free municipal or school paper waste instead of biomass cuts costs significantly (Ferronato et al., 2022).

Conclusions

The research demonstrated that paper waste can be transformed into high-performance charcoal briquettes that are environmentally friendly when processed economically and efficiently. Each of the three materials—cardboard, office paper, and newspaper—exhibited distinct qualities related to their strength and burning capabilities. Cardboard briquettes, which had the highest compressive strength (3.13 MPa), the lowest porosity (9.8%), and the longest burn time (27 minutes), emerged as the most compact and heat-efficient option among the materials studied. In contrast, newspaper briquettes showed the weakest structural integrity and the shortest burn duration due to their high porosity and low density. Office paper briquettes performed moderately in comparison. Office paper briquettes performed moderately, while newspaper briquettes displayed the weakest structural integrity. An analysis of variance (ANOVA) and Tukey's chi-squared

(HSD) test confirmed that the differences in question were statistically significant ($p < 0.001$). A cost-benefit analysis has also shown that paper charcoal briquettes cost only ₱10 per kilogram, which is a massive savings of up to 75% compared to commercial charcoal. Overall, the results show that cardboard waste is the best raw material for making paper charcoal briquettes that last a long time, don't cost much, and are good for the environment.

Recommendations

Based on the results of the study, the use of cardboard waste is strongly recommended for the production of eco-friendly charcoal briquettes, as it consistently demonstrated the highest mechanical strength, the longest burn duration, and the lowest porosity. Schools and community organizations may apply these findings by adopting cardboard-based briquette production as part of their waste management and sustainability initiatives. Establishing a school-wide system for collecting paper waste may also help ensure a steady supply of raw materials while reducing waste volume in classrooms and offices.

To facilitate broader adoption, the researchers suggest establishing a straightforward training program for students, parents, and community members. The program may include demonstrations on the processes of shredding, pulping, molding, drying, and testing briquettes inn addition, it could feature sessions that focus on proper waste sorting. Furthermore, integrating briquette-making into school activities—such as YES-O programs, Technology and Livelihood Education (TLE) lessons, or Science Month projects—can enhance environmental awareness and promote the development of practical skills.

For future research, investigators are advised to consider employing larger sample sizes or incorporating additional types of recyclable materials, such as mixed paper waste, carton liners, or biomass additives, including sawdust, rice husk, or coconut coir. These variations may provide insights into the production of briquettes that are more resilient or environmentally cleaner for combustion. It is essential to evaluate the calorific value, smoke emissions, and chemical composition of the briquettes to thoroughly assess their environmental and health impacts. Due to given that sun-drying can be influenced by changes in weather conditions, future studies should investigate the use of solar dryers or mechanical drying systems. This approach aims to achieve a more consistent drying process for paper charcoal briquettes. To improve strength and combustion performance, researchers may also explore different binder concentrations or compaction pressures.

If unanticipated results occur—particularly variations in ignition time and burn duration across different paper types—additional investigation is required to validate the findings and ascertain whether factors such as fiber density, moisture content, or pore structure influenced these outcomes.

Hence, the researchers recommend expanding this study through collaborations with local government units, community groups, or technical-vocational programs to promote sustainable fuel production and enhance local waste management practices.

Compliance with Ethical Standards

The student-researchers confirm that they conducted this study in accordance with established ethical standards in educational research. Since the study did not involve human respondents, no personal or sensitive data were collected; however, all individuals who assisted in laboratory procedures were informed of their roles, and their participation was voluntary. They were free to withdraw from the activity at any point without penalty. Anonymity and data privacy were carefully maintained, as no identifying information or private details of any participant, school personnel, or institution were disclosed in the study. The student-researchers ensured that all materials and procedures posed no harm and that safety protocols were strictly followed to protect the well-being of everyone involved in the experimental processes. There were no conflicts of interest throughout the conduct of the study, and all results were presented objectively without bias or manipulation. It will induce proper citation practices to avoid plagiarism, and all procedures, analyses, and interpretations were based solely on actual findings obtained during experimentation. The outcomes of this research were utilized solely for academic and scientific purposes. The researchers also acknowledge the contribution of artificial intelligence tools to improving the grammar, organization, and clarity of the manuscript, while ensuring that all substantive ideas, data, and conclusions remain exclusively the original work of the research team.

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