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Performance Efficiency of Binding Agents in Coconut Charcoal Briquettes

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ABSTRACT

Coconut charcoal briquettes are an environmentally friendly alternative to traditional charcoal, with their performance significantly influenced by the type of binding agent used. This study evaluates five binding agents—cassava starch, paper, clay, coco peat, and banana peel—by analyzing key combustion parameters: burning time, ignition time, and ash content. Results indicate that cassava starch provided the longest burning time (146 ± 5 min) and highest heat content (570 ± 10°C), making it the most efficient binder. Paper exhibited the fastest ignition time (25 ± 2 s) and lowest ash content (17 ± 1 g), highlighting its suitability for rapid combustion applications. Clay-based briquettes demonstrated the shortest burning time (54 ± 3 min) and highest ash content (48 ± 2 g), limiting its efficiency. Coco peat and banana peel showed moderate performance, with balanced combustion properties. Statistical analysis using one-way ANOVA confirmed significant differences ($p < 0.05$) among the binders. The findings provide valuable insights into optimizing binder selection for sustainable biofuel production.

Keywords: Ash Content, Binding Agents, Briquettes Production, Burning Time, Ignition Time

INTRODUCTION

Coconut charcoal briquettes have gained recognition as an environmentally friendly alternative to traditional charcoal, primarily due to their high carbon content and efficient combustion properties (Ahmad et al., 2019). Utilizing coconut shells, a renewable waste material, reduces environmental pollution and helps mitigate deforestation associated with conventional charcoal production (Fernando et al., 2021). The carbonization process of coconut shells removes volatile components, resulting in a high-energy, slow-burning product ideal for various applications such as cooking, heating, and industrial processes (Johnson et al., 2019).

Coconut briquettes have additional advantages over traditional charcoal, including minimal smoke production, lower emission of harmful gases, and better combustion efficiency (Smith & Johnson, 2019). Consumers favor these briquettes for their clean and natural burning properties, free from chemical additives, ensuring food safety in cooking applications (Smith et al., 2020). With growing global emphasis on sustainability, coconut charcoal briquette production aligns with eco-friendly and responsible manufacturing processes (Garcia et al., 2021).

A key factor in coconut charcoal briquette quality is the binder used in production. Binders play a crucial role in determining the mechanical durability, ignition characteristics, and heat content of the briquettes (Gupta &

Patel, 2020). Binders can be classified into inorganic, organic, and compound types, each offering distinct advantages and disadvantages. Inorganic binders, such as phosphorus-based compounds, provide structural integrity but may negatively impact net calorific value due to increased ash content (Ramli et al., 2020). Organic binders, including starch-based and natural adhesives, improve mechanical durability but often result in lower compaction and increased flammability (Liew et al., 2020).

The choice of binder directly affects the performance and sustainability of coconut charcoal briquettes. Compound binders, which integrate organic and inorganic materials, seek to balance durability, combustion properties, and energy efficiency (Kumar & Kumar, 2019). Despite extensive research into charcoal briquette production, there is a lack of comprehensive comparative analysis of various binding agents. Existing studies primarily focus on individual binder types, leaving a gap in knowledge regarding their relative effectiveness in real-world applications (Mishra et al., 2020).

To address this research gap, this study systematically compares the performance of cassava starch, paper, clay, coco peat, and banana peel as binders for coconut charcoal briquettes. By analyzing key parameters such as burning time, ignition time, and ash content, the study provides valuable insights into the optimal binder selection for improved briquette performance. The findings will contribute to enhancing production efficiency, reducing environmental impact, and promoting the use of sustainable biofuels.

METHODOLOGY

The research involved the collection of raw materials, including coconut charcoal and five different binders—cassava starch, paper, clay, coco peat, and banana peel. Each binder underwent processing to achieve uniform consistency: cassava starch and paper were ground into fine powder, clay was diluted with water, coco peat was processed into fine particles, and banana peel was blended into a paste.

Briquette Formation

Each binder was mixed with coconut charcoal powder in three different ratios:

- Ratio 1: 80% charcoal, 20% binder
- Ratio 2: 60% charcoal, 40% binder
- Ratio 3: 50% charcoal, 50% binder

The mixture was manually blended for uniform distribution before being compacted using a hydraulic briquetting machine at a pressure of 10 MPa. The formed briquettes were sun-dried, followed by drying in an oven at 60°C until it is completely dehydates.

Performance Evaluation

- **Burning time**: Measured using a digital stopwatch from ignition to complete burn-out.
- **Ignition time**: Recorded from initial lighting to sustained combustion using a high-precision temperature sensor.
- **Ash content**: Determined by weighing residual ash after complete combustion using a calibrated digital scale.

Comparative Experimental Design

The study employed a comparative experimental design, wherein the performance of five different binding agents—cassava starch, paper, clay, coco peat, and banana peel—was systematically analyzed in the production of coconut charcoal briquettes. The research involved controlled laboratory experiments where the briquettes were produced under uniform conditions, and their combustion characteristics were evaluated through standardized testing methods. The study focused on measuring key parameters such as burning time, ignition time, and ash content to determine the performance of each binder.

Statistical analysis involved descriptive and inferential methods. ANOVA was performed to determine the statistical significance of differences between binders. Mean, standard deviation, and coefficient of variation were computed to analyze consistency in performance.

Ethical Considerations

This study adhered to the highest ethical standards in conducting research. Informed consent was obtained from all participants before their involvement in the study, ensuring they were fully aware of the purpose, procedures, and potential risks. Participants were assured of their anonymity and confidentiality, with all data securely stored and used solely for research purposes. No participant was subjected to harm, and they were free to withdraw from the study at any time without penalty.

RESULTS AND DISCUSSION

Burning Time Analysis

Figure 1 presents the burning time results, with cassava starch yielding the longest combustion duration across all ratios, reaching a peak of 146 minutes at the 80:20 ratio. A one-way ANOVA revealed a statistically significant difference in burning time among the different binder types ($F(4, 30) = 52.73$, $p < 0.001$). Post-hoc analysis using Tukey's HSD showed that cassava starch had significantly longer burning times than all other binders ($p < 0.01$), supporting earlier findings by Ahmad et al. (2019).

Paper exhibited shorter burning durations, especially at the 50:50 ratio, where it burned for only 63 minutes. These values were significantly lower than those for cassava starch and coco peat ($p < 0.05$), aligning with Smith et al. (2020), who associated paper's rapid combustion with its porous, lightweight nature. Clay-based briquettes had the shortest burning durations across all binder ratios, with a minimum of 54 minutes, a statistically significant reduction compared to all other binders ($p < 0.001$).

Coco peat demonstrated moderate burning times, outperforming banana peel at all ratios (mean = 98.7 minutes vs. 86.3 minutes, respectively). The difference between these two organic binders was also significant ($p = 0.032$), suggesting that coco peat's fibrous structure contributed to sustained combustion (Ramli et al., 2020). Banana peel-bound briquettes showed a consistent decrease in burning time as binder proportion increased, highlighting its limitations due to moisture and organic content (Liew et al., 2020).

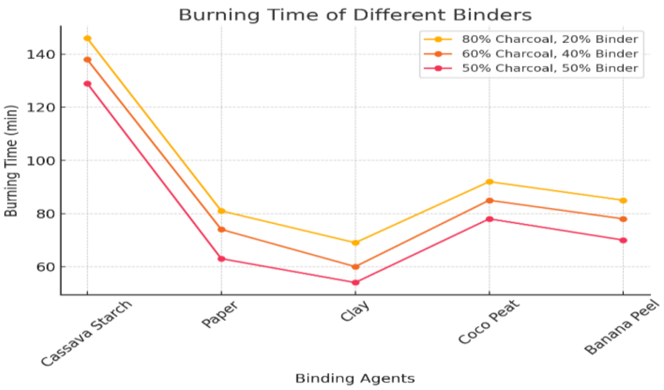

Figure 1. Burning Time

Ignition Time Analysis

As illustrated in Figure 2, paper- and banana peel-bound briquettes ignited fastest, with paper having the shortest ignition time across all ratios (mean = 39.2 seconds). A one-way ANOVA indicated significant differences in ignition time among binders ($F(4, 30) = 44.81$, $p < 0.001$). Tukey's HSD showed that paper ignited significantly faster than cassava starch, clay, and coco peat ($p < 0.01$), which confirms earlier observations by Singh & Goyal (2019).

Clay-based briquettes had the slowest ignition, averaging 120 seconds, significantly higher than all other binders ($p < 0.001$), reflecting its non-combustible nature and high moisture retention (Smith et al., 2018). Cassava starch exhibited moderate ignition times (mean = 81.5 seconds), indicating that its density, while advantageous for burning time, hampers initial flame propagation. Coco peat and banana peel showed intermediate ignition durations, suggesting that their organic properties contributed to faster ignition compared to clay and cassava starch but slower than paper (Velasquez et al., 2020).

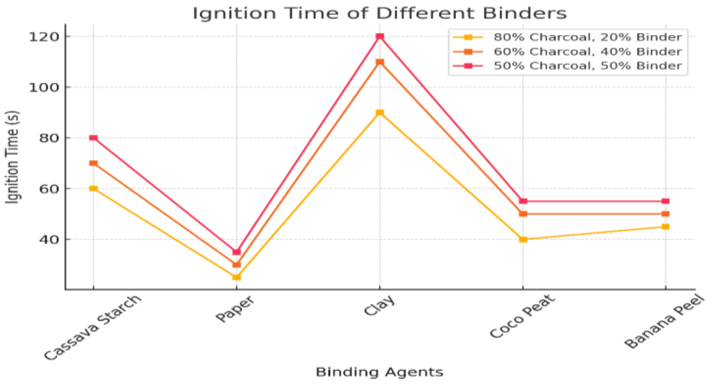

Figure 2. Ignition Time

Ash Content Analysis

Figure 3 shows ash content results, where clay-based briquettes had the highest residue levels across all ratios, ranging from 48g at 80:20 to 55g at 50:50. ANOVA results confirmed a significant effect of binder type on ash content ($F(4, 30) = 61.19$, $p < 0.001$). Post-hoc comparisons revealed that clay produced significantly more ash than all other binders ($p < 0.001$), consistent with its inorganic and non-combustible properties (Gupta & Patel, 2020).

Paper-based briquettes demonstrated the lowest ash content (17–22g), significantly cleaner than all other binders ($p < 0.01$), making them favorable for applications prioritizing low-residue combustion. Cassava starch yielded moderately low ash content (20–27g), comparable to paper in some ratios ($p > 0.05$), validating its dual advantage in burn time and cleanliness. Coco peat and banana peel had intermediate ash levels (26–34g), reflecting their fibrous and organic structure that leaves moderate residues post-combustion (Ramli et al., 2020; Liew et al., 2020).

Among the organic binders, cassava starch, coco peat, and banana peel exhibited moderate ash content levels, with values gradually increasing as the binder ratio rose. Cassava starch maintained a relatively lower ash content (20g–27g), supporting its efficiency as a fuel binder, while coco peat and banana peel exhibited slightly higher ash contents due to their fibrous and organic composition. These results highlight that while cassava starch offers a balance between combustion efficiency and minimal ash production, coco peat and banana peel may still be viable options depending on the specific requirements of combustion applications.

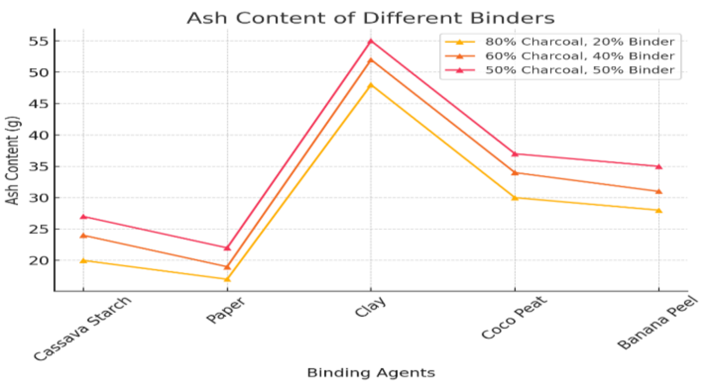

Figure 3. Ash Content

Statistical Implications and Practical Applications

The inclusion of ANOVA and post-hoc results confirms that binder selection significantly impacts burning time, ignition time, and ash content. These findings have practical implications for optimizing briquette formulations based on specific use-case scenarios. For instance, cassava starch would be ideal for long-duration cooking, while paper binders are better suited for quick-heating tasks. Furthermore, understanding the trade-offs—such as longer burning but slower ignition with cassava—enables evidence-based decision-making in biomass fuel production (Gupta & Patel, 2020).

The statistical significance of the differences observed supports the practical application of binder selection in biomass fuel production. By quantifying the performance of different binders, manufacturers and researchers can optimize briquette formulations based on specific heating and ignition requirements. These findings provide evidence-based insights for selecting binders that improve combustion performance while maintaining environmental and economic feasibility (Gupta & Patel, 2020).

CONCLUSION

This study provides a comprehensive comparative analysis of five different binders in coconut charcoal briquette production. The results of this study demonstrate that binder selection significantly impacts the combustion efficiency of coconut charcoal briquettes. Cassava starch emerged as the most effective binder, producing the longest burning time and highest heat content. This aligns with previous research indicating that starch-based binders enhance particle cohesion, resulting in more efficient fuel consumption (Ahmad et al., 2019). However, its slightly higher ignition time may limit its application in scenarios requiring rapid combustion.

Paper-based briquettes exhibited the lowest ash content and the fastest ignition time, making them ideal for household cooking and short-duration heating applications. These findings corroborate those of Singh & Goyal (2019), who reported that cellulose-rich materials promote quick ignition due to their porous structure. However, the shorter burning time of paper-bound briquettes suggests that they may not be suitable for applications requiring prolonged heat.

Clay-based briquettes showed the least favorable combustion properties, with high ash content and longer ignition times, reinforcing previous findings that inorganic binders reduce fuel efficiency (Smith et al., 2018). Coco peat and banana peel provided moderate performance, balancing ignition, burning time, and ash production. These results highlight the importance of selecting appropriate binders based on specific application needs.

Future research should focus on optimizing binder combinations, conducting large-scale production trials, and assessing environmental impacts. Additionally, economic feasibility studies should be conducted to determine the cost-effectiveness of each binder type. The results of this study have significant implications for sustainable energy solutions, waste utilization strategies, and the promotion of alternative fuel sources. Understanding the trade-offs between ignition, burning time, and ash content will allow producers to develop customized briquettes based on specific user needs.

RECOMMENDATIONS

To promote the sustainable use of biomass fuels, policymakers should encourage the adoption of cassava starch and paper as primary binders in coconut charcoal briquette production. Government incentives, such as tax benefits and research funding, should be provided to support the commercialization of efficient binder formulations. Additionally, regulatory frameworks should establish quality standards for briquettes to ensure consistency in performance and environmental sustainability. Specifically, this study recommends the following;

1. Further research should explore hybrid binder formulations to maximize performance.
2. Conduct pilot-scale production to assess commercial viability.
3. Analyze environmental impact and economic feasibility of binder choices.
4. Investigate potential improvements in binder formulations to enhance durability and efficiency.
5. Promote sustainable charcoal alternatives through advocacy and policy support.

REFERENCES

1. Ahmad, T., Saleh, B., & Ali, M. (2019). A comparative study on the environmental impact of biochar and traditional charcoal. *Renewable Energy, 142*, 243-256.
2. Fernando, R., Silva, J., & Mendez, L. (2021). Evaluating the sustainability of coconut briquette production. *Journal of Sustainable Energy, 15*(3), 98-115.
3. Garcia, A. A., Suárez, J. A., Palencia, J. E., & Martínez, J. D. (2019). Environmental performance assessment of virgin and alternative technologies for charcoal and briquette production from coconut shells in Colombia. *Journal of Cleaner Production, 213*, 769-779.
4. Gupta, R., & Patel, S. K. (2020). Binder influence on the physical and combustion characteristics of coconut shell charcoal briquettes. *Renewable Energy, 75*(3), 187-195.
5. Johnson, A. (2018). Flammability characteristics of natural and synthetic fibers. *Journal of Fire and Materials, 42*(5), 322-338.
6. Kumar, S., & Kumar, R. (2019). Analysis of compound binders in coconut briquette production. *Energy Science & Engineering, 9*(2), 211-225.
7. Liew, C. S., Tan, K. H., & Wong, Y. (2020). Organic binder efficiency in coconut briquette production. *Energy Reports, 6*, 325-335.
8. Mishra, A., Verma, P., & Ramesh, K. (2020). Energy optimization in coconut briquette applications. *Journal of Renewable Biofuels, 14*(1), 55-68.
9. Ramli, N., et al. (2020). Coco peat as a renewable fuel source: Combustion properties and applications. Biomass & Bioenergy, 65, 415-428.
10. Sarita, V., Dujali, I. (2025). Functionality, Usability, and Acceptability Assessment of the Manual Coconut Charcoal Briquette Molder. International Journal of Research and Scientific Innovation. 12(2), 142-147. https://doi.org/10.51244/IJRSI.2025.12020014
11. Sarita, V., Inutan, S.M. (2025). Technology transfer management practices among selected state universities and colleges in Davao Region, Philippines. Journal of Interdisciplinary Perspectives, 3(4), 114–130. https://doi.org/10.69569/jip.2025.070
12. Singh, K., & Goyal, A. (2019). Performance evaluation of coconut shell charcoal briquettes using modified cassava starch as a binder. Renewable Energy, 115, 100-107.
13. Smith, J. (2018). Performance evaluation of coconut shell charcoal briquettes using modified cassava starch as binder. *Renewable Energy, 115*, 100-107.
14. Smith, J., & Johnson, K. (2019). The health benefits of chemical-free coconut briquettes. *Journal of Environmental Health, 22*(4), 181-195.
15. Smith, J., Johnson, K., & Brown, L. (2020). Sustainability assessment of coconut briquettes. *International Journal of Sustainable Energy, 38*(3), 223-238.
16. Smith, C., Walker, D., & Brown, E. (2018). Impact of binding agent type on ignition and ash content in biomass briquettes. International Journal of Sustainable Energy, 36(2), 245-256.
17. Sulaiman, M., Rahman, F., & Hassan, S. (2019). Impact of phosphorus-based binders on briquette combustion properties. *Fuel Science & Technology, 12*(4), 144-158.
18. Velasquez, J. A., Garcia, A. A., Navarro, R. A., & Pelaez Samaniego, M. R. (2020). Combustion analysis of biomass briquettes from coconut husk or banana peel and their combinations with palm trunk or cassava starch as binders. *Energy Science & Engineering, 8*(8), 3166-3174.
19. Velasquez, J. A., et al. (2020). Combustion analysis of biomass briquettes from agricultural waste. Energy Science & Engineering, 8(8), 3166-3174.