materials proceedings

MDPI

Proceeding Paper

Fuel Composites Development Using Cow Dung and Agricultural Biomass †

Muhammad Tufail Anwar [1,*], Nehar Ullah [1], Saifullah Khalid [1], Naeem Ahmad [1] and Muhammad Shahzeb Khan [2]

[1] Department of Chemical Engineering, University of Engineering and Technology, Peshawar 25120, Pakistan; neharullah@uetpeshawar.edu.pk (N.U.); saifsf2013@gmail.com (S.K.); naeemyousafzai111@gmail.com (N.A.)
[2] School of Chemical and Materials Engineering, National University of Science and Technology, Islamabad 44100, Pakistan; shahzebk9936@gmail.com
* Correspondence: tufailmarwat115@gmail.com; Tel.: +92-344-521-2223

† Presented at the 6th Conference on Emerging Materials and Processes (CEMP 2023), Islamabad, Pakistan, 22–23 November 2023.

Abstract: A sustainable alternative to fossil fuels, cow dung is a renewable energy source that might considerably lower carbon emissions. By modifying its characteristics, such as its gross calorific value (GCV), it could be utilized as a flexible and effective fuel for both industrial and domestic use. To create a fuel composite with a higher heating value, this research examines the heating values and proximate analysis of local cow dung as well as the effects of blending it with agricultural waste. To provide the best heating value, the technique comprises infusing prepared agricultural biomass blends and cow dung at particular ratios. The composite's quality was enhanced by increasing GCV from 3066 Kcal/kg to 3600 Kcal/kg, increasing volatile matter content, i.e., from 60% to 68%, as well as lowering the ash content of the resultant pellet from 19% to 11%, on average.

Keywords: biomass; cow dung; fuel composite; gross calorific value (GCV); proximate analysis; structural modification

check for updates

Citation: Anwar, M.T.; Ullah, N.; Khalid, S.; Ahmad, N.; Shahzeb Khan, M. Fuel Composites Development Using Cow Dung and Agricultural Biomass. *Mater. Proc.* **2024**, *17*, 23. https://doi.org/10.3390/materproc2024017023

Academic Editors: Sofia Javed, Waheed Miran, Erum Pervaiz and Iftikhar Ahmad

Published: 22 April 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Energy resources, including fossil fuels like coal, oil, and gas, as well as renewable energy sources like sun, wind, ocean, hydropower, and biomass, are necessary for a country's prosperity [1]. As a consequence of the expansion of the global population and industrial activities, the danger of natural fossil fuel stocks being exhausted in the near future is approaching [2]. The utilization of fossil fuels on a global scale is resulting in the depletion of these finite resources [2]. It is projected that within a few decades, the availability of fossil fuel resources may become depleted or financially burdensome for individuals of average means [3]. Fossil fuels release significant amounts of carbon dioxide and nitrogenous oxides into the atmosphere, contributing to ozone depletion, climate change, noise pollution, and global warming [4]. The combustion of biomass as a fuel results in the emission of an equivalent quantity of carbon dioxide (CO_2) as it sequesters from the atmosphere, thus establishing a state of carbon neutrality. The process of ozone depletion permits the ingress of detrimental radiation into the Earth's atmosphere, resulting in the occurrence of skin cancer and other related skin ailments [1]. In response to the imperative of mitigating energy crises, there is a global transition underway towards the utilization of renewable fuels. Global action is being driven by sustainable development and the utilization of eco-friendly biomass combustion methods. Biomass energy generation and residential consumption have been actively encouraged by countries globally [5].

Renewable energy from biomass is growing worldwide. Several studies combined coal and other fossil fuels with cow manure. According to research by Sweeten et al., adding zoo-mass and cow manure to the energy mix lowers the consumption of fossil fuels and lowers waste disposal. The study noted the downsides of mixing high-ash cow manure with low-ash coal. Cow dung could yield a significant ash [6].

The goal of the current study is to determine how different ratios of agricultural phytomass i.e., sawdust, bagasse, wheat straw, canola husk, and rice husk affect zoo-mass i.e., cow dung. In terms of proximate analysis parameters and heating value. The proximate analysis parameters and the consequent heating value are the main subjects of this analysis. The phytomass content of the composite fuel varies, with percentages of 30, 60, and 100% by weight.

2. Materials and Methods

2.1. Raw Material Preparation

The process involved collecting cow dung and other plant-based agricultural biomass from Naika village near Fauji cement factory in Pakistan. The raw materials were sun-dried for two days to remove moisture and prevent blockage at the inlet of the mill mesh. The waste was then ground using a cross-beater mill, which was then used to create the first batch of fuel composite pellets.

The material then went through grinding through mortar and pestle, resulting in a particle size < 2 mm to compare the effect of the particle size with the previous batch, i.e., particle size > 2 mm. The grinding process is shown in Figure 1. Raw materials grinding process. The material underwent grinding to decrease the dimensions of larger sticks and particles, as well as to achieve size homogenization according to the specified requirements, as depicted in the before and after images of the raw material in Figure 2.

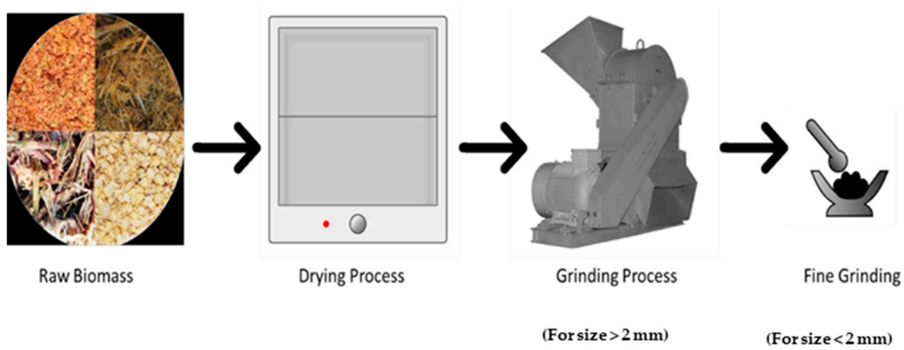

Figure 1. Raw materials grinding process.

2.2. Proximate Analysis of Raw Material

The source material was subjected to proximate analysis in the quality control laboratory of Fauji Cement Company, Punjab, Pakistan. The moisture content of the raw material samples was examined using the ASTM D-3302 [7], also known as the Standard Test Method, for analyzing Total Moisture in Coal. In this test, a solid fuel sample's weight change is measured using the gravimetric technique in a tightly controlled hot air environment. The volatile matter content in the raw material samples was examined using the ASTM D-3175 [8], also known as the Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke. The weight loss of raw material samples is assessed inside a precisely regulated hot air environment, i.e., 950 °C for 2–3 min. The ash content of the submitted raw material samples was evaluated using the ASTM D-3174 [9], commonly known as the Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal. The mass loss of a coal sample or composite fuel is measured using the gravimetric method after being exposed to controlled temperatures between 700 and 750 °C for 2.5 h [10].

The gross calorific value (GCV) of biomass is calculated using a bomb calorimeter, which measures its energy content by introducing a fuel sample, pressurizing it with pure oxygen, and measuring the heat released by the combustion reaction [11].

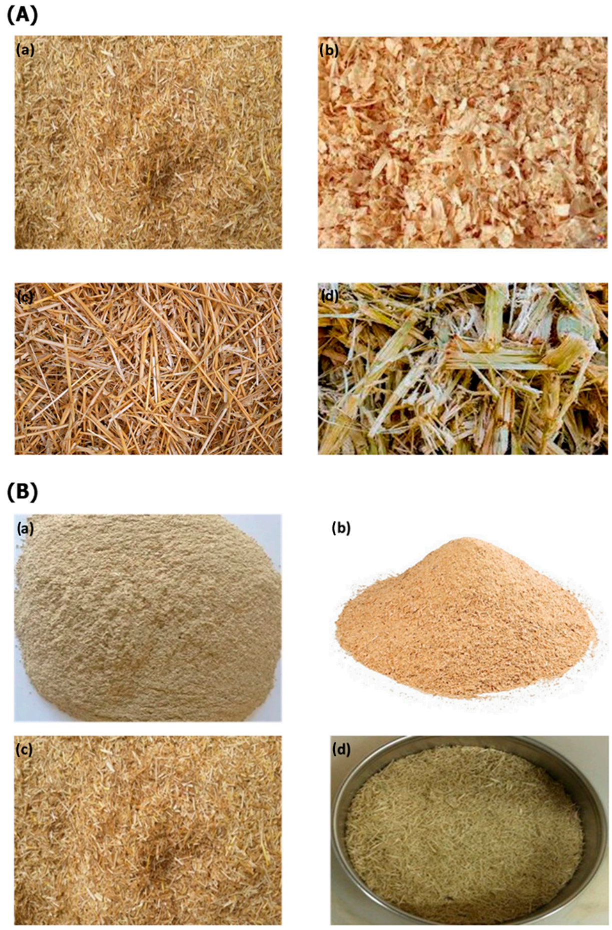

Figure 2. Raw materials (**A**) before grinding and (**B**) after grinding: (**a**) rice husk; (**b**) saw dust; (**c**) wheat straw; (**d**) bagasse.

2.3. Fuel Composite Formation

Cow dung was adjusted to (a) 30% and (b) 60% by weight while keeping various Phytomass (Plant-based biomass) constant to create composite fuel. First, proximate analysis was conducted on a fuel composite that was made by combining 30% cow dung and 70% biomass. Second, a combination made up of 60% cow dung and 40% phytomass was completely mixed before being analyzed proximally and evaluated for gross calorific value. These compositions were made with particle sizes between 2 and 4 mm.

Now, the composition with the best results was noted, i.e., either from (a) or (b), and each raw material was further ground to <2 mm. All of the phytomass, 2 g each, was mixed with each other and then thoroughly mixed with cow dung using a mortar and pestle, keeping the phytomass to cow dung ratio constant. This mixture was then tested for its proximate analysis parameters as well as gross calorific value (GCV).

2.4. Formation of Fuel Composite Pellets

Following the appropriate mixing process, round dies of several diameters were selected, specifically 8 mm, 13 mm, and 30 mm. The combination underwent a palletization process by means of a hydraulic press, which applied a pressure of 5000 bar for 20 min (see Figure 3). Subsequently, the compressed pellets were subjected to a drying process, after which further measurements were conducted to determine the size of said pellets. A scale was used to measure the diameter of 30 mm pellets, while a screw gauge was used to measure the diameters of 8 mm and 13 mm pellets.

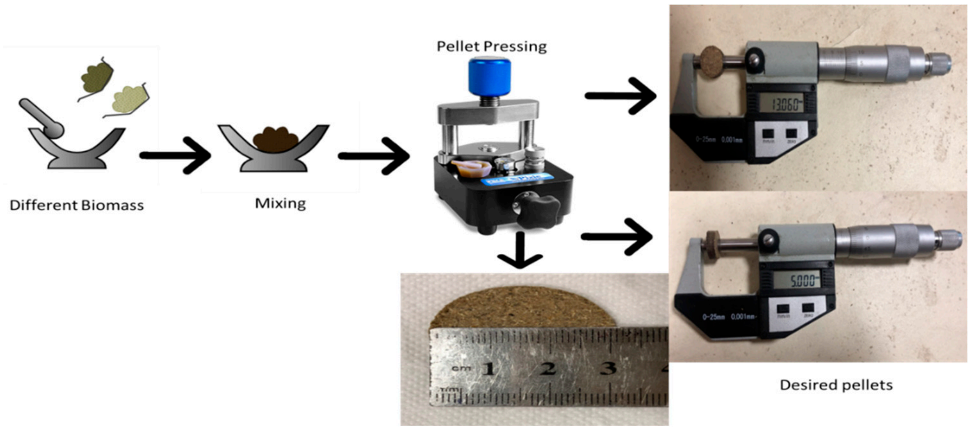

Figure 3. Method of preparation of desired pellets.

3. Results and Discussion

3.1. Proximate Analysis Results for the Raw Material

An investigation of proximate analysis of particular phytomass and zoomasses is displayed in Figure 4. The data reveals important information, such as the fact that cow dung has the highest ash concentration and that sugarcane bagasse has the highest volatile matter content. Sugarcane bagasse also has the amount of ash content of only 1.55% by weight. Sawdust has the highest amount of moisture content among all tested biomass, i.e., 29.03%, while the lowest amount of moisture was present in wheat straw in this case, which amounted to 10.80% by weight.

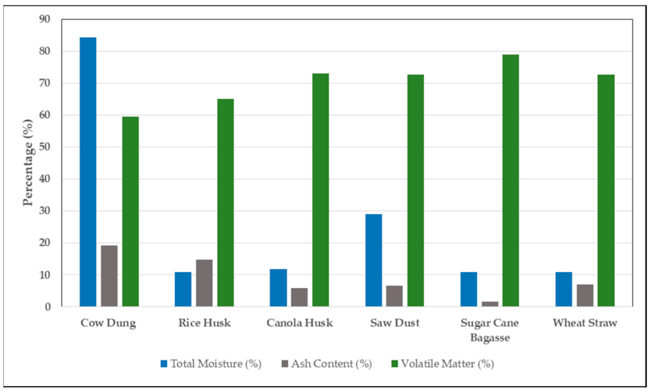

Figure 4. Proximate analysis of raw material.

The raw material also went through testing for calorific value, shown in Figure 5. The testing showed us that the highest gross calorific value among all tested biomass is of sawdust, i.e., 4129 Kcal/kg, whereas the GCV of cow dung was the lowest among all tested biomass, i.e., 3066 Kcal/kg.

3.2. Proximate Analysis Results for the 30 wt.% Cow Dung Fuel Composite

The fuel composite was made with two compositions: phytomass and zoo-mass. First, different mixtures of 30 wt.% cow dung and 70 wt.% phytomass with particle sizes of 2–4 mm were made. This resulted in the following proximate analysis, as shown in Figure 6. The moisture content was significantly reduced to an average of 31.7% for all fuel composites from 84.2% (Pure 100% cow dung). Volatile matter was also increased to an average of 72.2% from 59.5% (Pure 100% cow dung). Also, ash content was reduced to 9.6% for all biomass fuel composites from 19.2%.

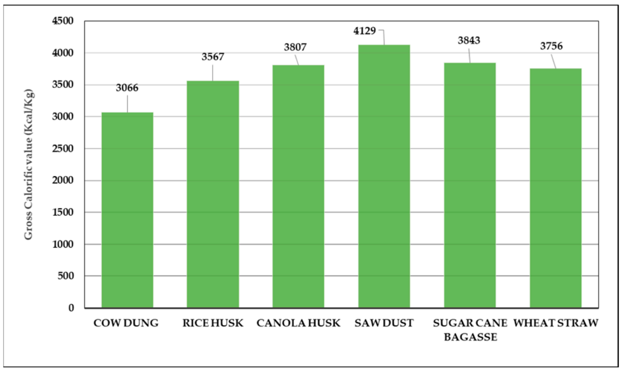

Figure 5. Gross Calorific Value (GCV) of raw material.

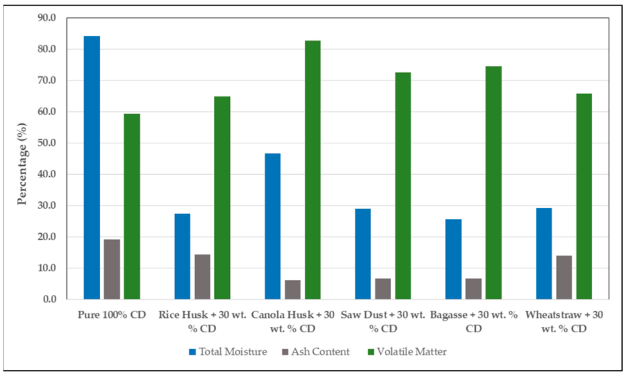

Figure 6. Proximate analysis of 30 wt.% cow dung fuel composite mixture.

The fuel composite mixture then went through analysis for calorific value through a bomb calorimeter, as per the results shown in Figure 7. The testing showed us a significant improvement in the GCV, as the addition of phytomass increased the GCV to average. 3768 Kcal/kg from 3066 Kcal/kg (of pure 100% cow dung). All fuel composites showed promising results with each of them having a higher GCV than pure 100% cow dung.

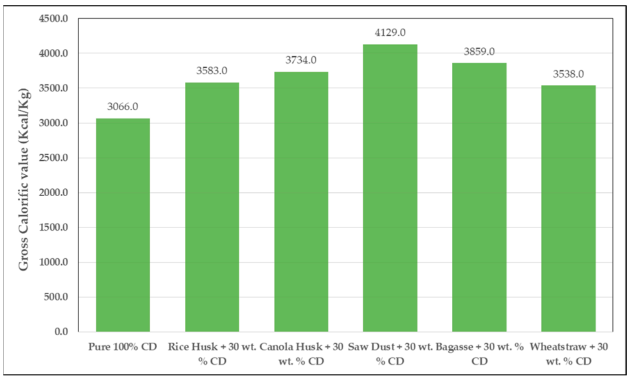

Figure 7. Gross Calorific Value (GCV) of 30 wt.% cow dung fuel composite mixture.

3.3. Proximate Analysis Results for the 60 wt.% Cow Dung Fuel Composite

Proximate analysis was conducted on 60 wt.% cow dung and 40 wt.% phyto-mass fuel composite mixture, having a particle size of 2–4 mm. This resulted in the following proximate analysis, as shown in Figure 8.

The moisture content was significantly reduced to an average of 49.2% for all fuel composites from 84.2% (Pure 100% cow dung). Volatile matter was also increased to an average of 65.6% from 59.5% (Pure 100% cow dung). Also, ash content was reduced to 13.3% for all biomass fuel composites from 19.2%. This is, however, not better than 30 wt.% cow dung fuel composite mixture, which showed significantly better results.

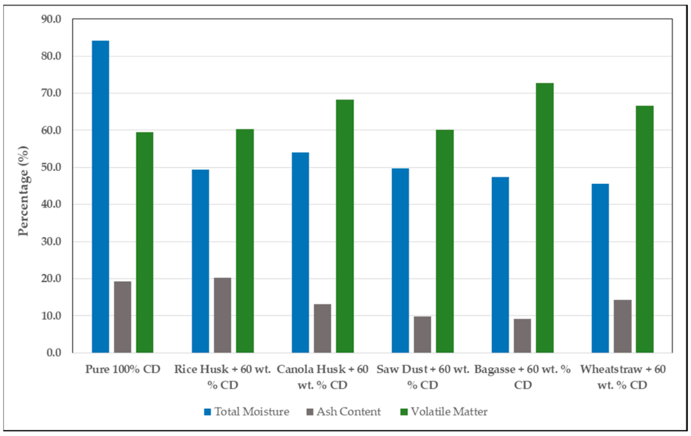

Figure 8. Proximate analysis of 60 wt.% cow dung fuel composite mixture.

The fuel composite mixture then went through analysis for calorific value through a bomb calorimeter, as per the results shown in Figure 9. The testing showed us comparatively less improvement in the GCV than 30 wt.% fuel composite mixture, as the addition of phyto mass increased the GCV to an average of 3626 Kcal/kg from 3066 Kcal/kg (of pure 100% cow dung). All fuel composites showed better results, with each of them having higher GCV than pure 100% cow dung. However, these improvements were comparatively less than 30 wt.% biomass fuel composite mixture.

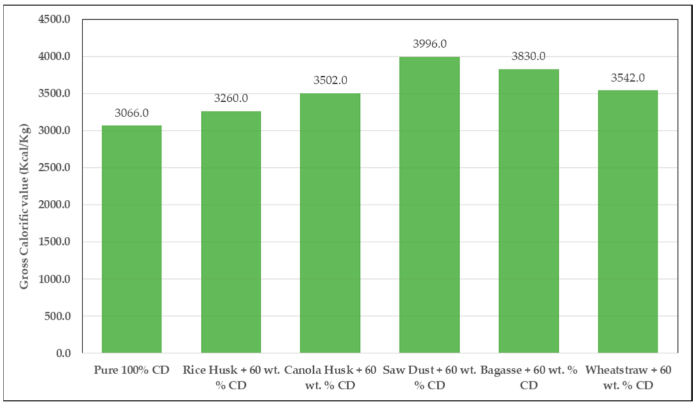

Figure 9. Gross Calorific Value (GCV) of 60 wt.% cow dung fuel composite mixture.

3.4. Proximate Analysis Results of Fuel Composite (<2 mm Constituent Size)

To analyze the effects of the size of the constituent particles, the raw material was ground to <2 mm size and then tested for its proximate analysis parameters. This analysis was conducted with 30 wt.% cow dung fuel composite composition due to its better performance in previous tests. Figure 10 shows the proximate analysis results for this composition.

The moisture content was significantly reduced to an average of 25.65% for all fuel composites from 84.2% (Pure 100% cow dung). Volatile matter was also increased to an average of 68.72% from 59.5% (Pure 100% cow dung). Also, ash content was reduced to 12.62% for all biomass fuel composites from 19.2%. These values, when compared to >2 mm size fuel composite mixture, show that <2 mm size of war materials reduces the efficiency of fuel composite mixture.

The fuel composite mixture then went through analysis for calorific value through a bomb calorimeter, as per the results shown in Figure 11. The testing showed us less GCV than <2 mm fuel composite mixture, as the reduction in the size of the raw materials decreased the GCV to an average of 3701 Kcal/kg from 3768 Kcal/kg (of pure 30 wt.% cow dung fuel composite mixture at >2 mm size). However, All fuel composites showed better results, with each of them having higher GCV than pure 100% cow dung.

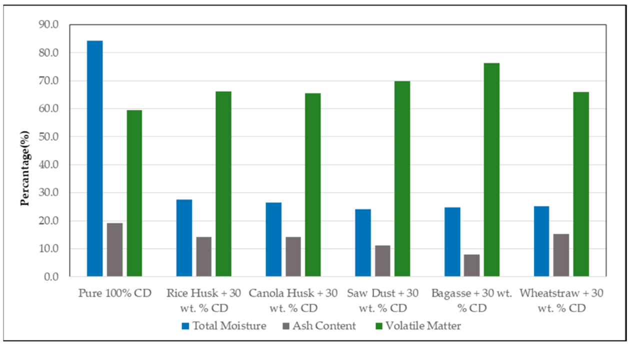

Figure 10. Proximate analysis of 30 wt.% cow dung fuel composite mixture (<2 mm particle size).

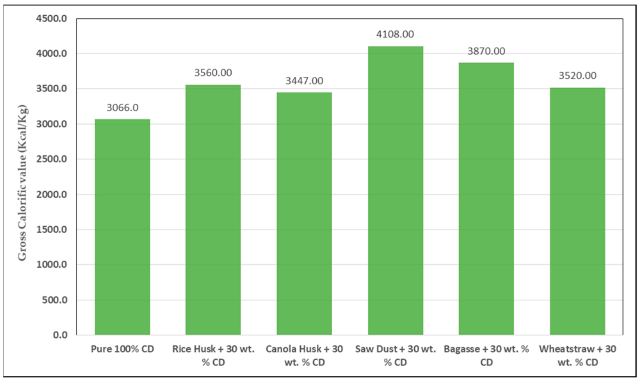

Figure 11. Gross Calorific Values (GCV) of 30 wt.% cow dung fuel composite mixture (<2 mm particle size).

4. Conclusions

Biomass, a renewable energy source, can be produced from agricultural residue and animal manure, with cow dung modified for specific calorific values. Therefore, with a composition of 30% cow dung and 70% agricultural waste, by the optimization of the selected proximate parameters in this study, the Gross Calorific Value (GCV) of the composite fuel greatly increased from an average of 3066 Kcal/kg to 3600 Kcal/kg. This improvement in GCV was principally made possible by raising the volatile matter content of the cow dung from 60% to 68% and decreasing its moisture content from 84% to 40%. As shown by the GCV, the quality of the composite fuel was also improved by lowering the average ash content from 19% to 11% and adding five different types of biomass, including canola husk, wheat straw, bagasse, rice husk, and sawdust. Increased Gross Calorific Value (GCV) in the composite fuel made from cow dung is significant because it has the potential to speed up combustion and improve energy conversion and usage. This finding has significant practical ramifications, especially for appliances like stoves and other devices whose performance is directly impacted by the effectiveness of fuel combustion. Cow dung is converted into compressed, less breathable pellets, reducing smoke emissions and presenting it as an environmentally acceptable option.

Author Contributions: N.U. and M.T.A., conceptualization; M.T.A. and S.K., methodology; S.K. original draft; N.A., M.S.K. and M.T.A., formal analysis; N.U. and S.K., review; N.U., supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This study received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data will be provided upon request.

Acknowledgments: We thank Fauji Cement Company Ltd. (Pakistan) for their technical assistance and for granting us access to their lab supplies.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Rahman, A.; Farrok, O.; Haque, M.M. Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112279. [CrossRef]
2. Höök, M.; Tang, X. Depletion of fossil fuels and anthropogenic climate change—A review. *Energy Policy* **2013**, *52*, 797–809. [CrossRef]
3. Cherubini, F.; Peters, G.P.; Berntsen, T.; StrØMman, A.H.; Hertwich, E. CO_2 emissions from biomass combustion for bioenergy: Atmospheric decay and contribution to global warming. *GCB Bioenergy* **2011**, *3*, 413–426. [CrossRef]
4. Tzimas, E.; Mercier, A.; Cormos, C.-C.; Peteves, S.D. Trade-off in emissions of acid gas pollutants and of carbon dioxide in fossil fuel power plants with carbon capture. *Energy Policy* **2007**, *35*, 3991–3998. [CrossRef]
5. Bildirici, M.E. Economic growth and biomass energy. *Biomass Bioenergy* **2013**, *50*, 19–24. [CrossRef]
6. Annamalai, K.; Thien, B.; Sweeten, J.M. Co-firing of coal and cattle feedlot biomass (FB) fuels. Part II. Performance results from 30 kWt (100,000) BTU/h laboratory scale boiler burner. *Fuel* **2003**, *82*, 1183–1193. [CrossRef]
7. *ASTM D-3302*; Standard Test Method for Total Moisture in Coal. ASTM: West Conshohocken, PA, USA, 2010.
8. *ASTM D-3175*; Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke. ASTM: West Conshohocken, PA, USA, 2020.
9. *ASTM D-3174*; Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal. ASTM: West Conshohocken, PA, USA, 2020.
10. Bhavsar, P.A.; Jagadale, M.; Khandetod, Y.P.; Mohod, A.G. Proximate Analysis of Selected Non Woody Biomass. *Int. J. Curr. Microbiol. Appl. Sci.* **2018**, *7*, 2846–2849. [CrossRef]
11. Islam, M.N.; Ratul, S.B.; Sharmin, A.; Rahman, K.-S.; Ashaduzzaman, M.; Uddin, G.M.N. Comparison of calorific values and ash content for different woody biomass components of six mangrove species of Bangladesh Sundarbans. *J. Indian Acad. Wood Sci.* **2019**, *16*, 110–117. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.