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Thermal and Morphological Characterization of Rice Starch–Charcoal Composites for Eco-Friendly Engineering Applications

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Abstract

This work focuses on the development and evaluation of rice starch–charcoal–based composite materials to overcome the limitations of natural composites with low thermal properties. In order to examine the impact of filler concentration on thermal and structural performance, eight composite specimens were created by altering the ratios of rice starch and charcoal. TGA, DTA, AFM, SEM, and measurements of thermal conductivity and effusivity were used to thoroughly characterize the composites. Because of its high carbon content and porous structure, which may offer significant heat absorption and be helpful for boosting thermal stability and transmitting heat alongside the starch matrix, charcoal was selected to serve as functional reinforcement. Due to their weak thermal resistance, most traditional starch-based composites are not suitable for energy storage applications and cannot tolerate high temperatures. Due to the higher degradation temperature in TGA and higher heat absorption peaks in the DTA studies, the addition of charcoal improved the thermal resistance deficiencies in these composites. Improved particle dispersion and interfacial bonding within the starch matrix were suggested by the surface morphology obtained by SEM and AFM, which demonstrated a more uniform microstructure and decreased porosity with increased charcoal loading. Fill concentration was further shown to be advantageous over heat transfer characteristics in thermal analysis. With increasing charcoal content, the thermal effusivity of the composites grew steadily until specimen 8, which had the greatest bamboo charcoal content, reached its maximum of 1075 Ws½/m²K. Similarly, the trend of thermal conductivity and stability confirmed that adding more charcoal improved the composite's capacity to absorb and store heat. Therefore, the rice starch-charcoal composite with a greater filler amount generally received improved thermal responsiveness, dimensional stability, and surface integrity. Therefore, our results present the creation of charcoal-reinforced starch composites as extremely interesting candidate materials for applications in packaging, energy management systems, and thermal insulation that can be handled economically and sustainably. As a result, the project opens the door for potential environmentally friendly thermal composites made from inexpensive, renewable natural materials.

Keywords: Charcoal composites, rice starch, thermal analysis, SEM, AFM

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INTRODUCTION

Thermal materials play a crucial role in regulating heat transfer across industrial, commercial, and residential applications. Conventional thermal management has relied heavily on synthetic materials such as metals, ceramics, and polymer composites due to their high thermal conductivity or insulation performance. However, the production of these materials is energy-intensive and relies on non-renewable resources, raising environmental concerns. Consequently, research has shifted toward natural, renewable alternatives, including biochar, plant-based fibers, and starch. Rice starch, a naturally occurring polysaccharide derived from rice grains, has gained attention as a biodegradable and eco-friendly binder in thermal composites. It provides mechanical stability, reduces heat transfer, and allows the formation of uniform coatings or panels. Bamboo charcoal, obtained through pyrolysis of bamboo biomass, exhibits high porosity, large surface area, and low thermal conductivity, making it an excellent candidate for thermal insulation. Corn charcoal, derived from agricultural residues like corn cobs, is another sustainable carbon-rich material with porous microstructure and moderate thermal conductivity. Combining these materials in starch-based composites enables eco-friendly, lightweight, and thermally efficient solutions. These composites can be tailored by varying starch content or particle size, enhancing heat retention or dissipation as required.

The thermal performance of rice starch–bamboo charcoal–corn charcoal composites is characterized using techniques such as thermogravimetric analysis (TGA), differential thermal analysis (DTA), and thermal conductivity measurements. Bamboo and corn charcoals contribute to heat regulation by trapping air in their pores, reducing thermal conductivity, and providing passive insulation. Rice starch acts as a binding matrix, holding charcoal particles together while maintaining structural integrity and controlling porosity. Such composites are suitable for thermal paints, coatings, insulation panels, and energy-efficient construction materials. Their lightweight and biodegradable nature reduces environmental impact compared to conventional materials. Additionally, utilizing agricultural residues such as corn cobs and rapidly renewable bamboo supports sustainable manufacturing and circular economy principles. The versatility of these composites allows customization for diverse applications, from wall coatings to protective films. Optimization of starch content, charcoal type, and particle distribution ensures a balance between mechanical strength, thermal insulation, and eco-friendliness. Overall, rice starch-based natural composites offer a promising alternative to synthetic thermal materials, aligning with green chemistry and sustainable material development goals.

The development of natural and biodegradable composites for thermal applications has gained considerable attention in recent years. Jang et al. (2018) investigated the incorporation of bamboo charcoal powder into styrene-butadiene rubber (SBR) latex compounds and reported improved thermal stability and mechanical properties, demonstrating its potential as a filler in thermoplastic composites [1]. Wang et al. (2020) focused on biodegradable flame-retardant bamboo charcoal composites in polylactic acid (PLA) matrices, showing improved thermal and flame-retardant properties suitable for sustainable building applications [2]. Kremensas et al. (2019) examined biodegradable thermoplastic polymer-based biocomposite boards made from hemp shivs and corn starch, highlighting their mechanical performance and potential for construction applications [3]. Pandecha et al. (2016) assessed corn husk fiber as insulation for flat plate solar collectors and reported low thermal conductivity, confirming its effectiveness as a thermal insulator [4]. Balčiūnas et al. (2016) studied hemp shivs composites and observed that structural parameters such as porosity and density significantly influence thermal conductivity, making them promising for energy-efficient insulation systems [5]. Bovo et al. (2022) contributed to the thermal and acoustic characterization of corn cob for bio-based insulation, providing valuable data supporting its eco-friendly application and multifunctional insulation behavior [6]. Zou et al. (2022) further confirmed that bamboo charcoal enhanced the curing characteristics, mechanical performance, and thermal stability of SBR composites [7]. Additionally, repeated investigations by Wang et al. (2020), Kremensas et al. (2019), Pandecha et al. (2016), Balčiūnas et al. (2016), Bovo et al. (2022) and Karuppiah et al. (2020) reinforced the thermal and mechanical performance improvements offered by bamboo charcoal, corn husks, hemp shivs, and starch-based composites [8-13]. Collectively, these studies demonstrate that combining biochar, agricultural residues, and natural starch matrices can yield lightweight, thermally efficient, and sustainable materials suitable for coatings, panels, and insulation. The research highlights the potential for eco-friendly alternatives to conventional synthetic fillers, emphasizing biodegradability, renewable sourcing, and tunable thermal properties for energy-efficient applications. Padmanabhan et al. (2024) examined the

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mechanical properties and structural aspects of Al-Hybrid fibre metal laminates (HFMLs) reinforced with fibres from basalt, hemp, and bamboo, including commercial-grade Al6061 alloy mesh (Al-DMEM) [14]. Ayrilmis et al. (2024) investigated the potential of using recycled manhole cover flour (CMC) and medium density fibreboard (MDF) sawdust as low-cost fillers for recycled polypropylene (PP) composites [15]. Ramasubbu et al. (2024) explored the physical and chemical attributes of Areca catechu fiber (ACF) [16]. Aruchamy et al. (2025) investigated the enhancement of mechanical characteristics of hybrid polymer composites reinforced with Palmyra Palm Leaflet (PPL) and Coconut Sheath Leaf (CSL) fibers by integrating Tamarind Shell Powder as a filler material [17]. Kar et al. (2024) studied the effect of Calamus tenuis fibers as reinforcing material in polymer composites, and investigated their viscoelastic, mechanical, and morphological attributes [18].

There is need to develop sustainable, cost-effective, and eco-friendly thermal management materials to replace conventional synthetic fillers and insulators, which are often non-biodegradable, energy-intensive, and environmentally harmful. While natural materials like bamboo and corn charcoal offer renewable alternatives with good thermal potential, their performance must be systematically studied and optimized for practical use. A key challenge is achieving a balance between thermal efficiency, mechanical strength, and environmental sustainability, as charcoal alone may lack cohesion and starch binders may reduce durability and conductivity. Therefore, identifying the optimal combination of natural fillers and starch binders, along with analyzing their structural, morphological, and thermal characteristics through advanced techniques, is essential to create composites suitable for eco-friendly paints, coatings, and insulation applications.

MATERIALS AND METHODS

In this study, natural composite materials were prepared to investigate their thermal properties, focusing on bamboo charcoal powder, corn (con) charcoal powder, and starch powder as the primary components. Table 1. Shows the material composition of Eight distinct samples were designed by varying the weight percentages of starch, bamboo charcoal, and corn charcoal powders to evaluate their influence on thermal performance. All powders were procured in fine form to ensure uniform mixing and homogeneity. Totally 8 samples are prepared. Each sample was accurately weighed using a digital balance with ±0.01 g precision. The powders were gradually combined in a clean mixing container, starting with starch as the base, followed by the respective charcoal powder, and mechanically stirred for 10–15 minutes to ensure uniformity.

The preparation of individual components was carried out with careful attention to quality and consistency. Figure 1 shows that, Bamboo charcoal was produced by pyrolyzing mature bamboo stems at 500–800°C in a limited-oxygen environment, generating a highly porous structure with excellent thermal stability. Figure 2 shows that, the Corn charcoal was prepared similarly from cleaned corn husks at 400–700°C, providing a biodegradable filler with moderate thermal conductivity. Rice starch powder was extracted from high-quality rice grains, washed, soaked, ground, filtered, and dried at 50–60°C to produce fine, uniform particles that served as the binder matrix. The sieved powders, typically 100–200 µm, ensured consistent particle size and optimal interaction between starch and charcoal fillers. A PVC base plate, flattened using controlled heating and pressing, was used for casting the composite samples, providing a stable, non-reactive surface for uniform sample formation.

Table 1. Material compositions.

Sample no.	Starch powder (g)	Bamboo charcoal powder (g)	Corn charcoal powder (g)
1	11	5	0
2	9	7	0
3	7	9	0
4	5	11	0
5	11	0	5
6	9	0	7
7	7	0	9
8	5	0	11

Figure 1. Bamboo charcoal.

Figure 2. Corn charcoal.

Specimen preparation involved precise weighing, thorough mixing, and controlled application of the composite paste onto the PVC plates. Water was gradually added to form a workable paste, and mechanical and manual stirring ensured even dispersion of fillers within the starch matrix. The paste was spread uniformly to a consistent thickness, avoiding air pockets, and allowed to dry at room temperature for three days. After drying, samples were carefully demolded and cut for characterization. Thermal stability and decomposition behavior were evaluated using Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA), while thermal conductivity was measured via a steady-state method. Surface morphology and particle distribution were examined with Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM), with repeated measurements to ensure reproducibility and accuracy across all eight samples.

Thermogravimetric Analysis

Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA) are essential techniques used to evaluate the thermal stability and decomposition behavior of composite materials. TGA measures the change in mass of a sample as it is subjected to a controlled temperature program, providing insights into moisture content, decomposition temperatures, and overall thermal resistance. This technique helps identify the onset of degradation and the temperature ranges over which weight loss occurs, which is particularly useful for composites containing natural fillers like bamboo and corn charcoal. DTA, on the other hand, measures the difference in heat flow between a sample and an inert reference under identical heating conditions, revealing endothermic or exothermic transitions. Together, TGA and DTA provide complementary information: TGA quantifies thermal decomposition, while DTA identifies phase transitions, thermal events, and reaction enthalpies. Applying these analyses to the prepared starch-charcoal composites allows for a comprehensive understanding of how filler type and concentration influence thermal behavior, stability, and potential performance in insulation applications.

The TGA and DTA analysis of specimen 4 reveals significant thermal behavior between 56°C and 987°C. The TGA curve in Figure 3 shows an initial mass of 3.968 mg, with slight loss to 3.938 mg at 238°C, followed by major reductions to 2.557 mg at 551°C and 2.51 mg at 987°C, indicating progressive decomposition. The DTA profile exhibits prominent endothermic and exothermic peaks at 297°C (22.17 µV), 414°C (24.16 µV), and 465°C (23.54 µV), corresponding to key thermal transitions. DTG analysis identifies primary decomposition rates at 366°C (92.8 µg/min), 466°C (62.5 µg/min), and 515°C (62.1 µg/min), highlighting the temperatures of maximum weight loss. Collectively, these results elucidate the thermal degradation patterns, phase transitions, and decomposition kinetics of the composite. The TGA curve in Figure 4 shows specimen 8, in which the initial weight loss around 274°C, decreasing from 7.966 mg to 7.653 mg at 341°C, indicating the evaporation of volatiles or initial decomposition. Further significant mass losses occur at 485°C (5.849 mg) and 577°C (4.956 mg), corresponding to major pyrolytic or oxidative reactions. The DTA curve (green line) exhibits notable endothermic and exothermic peaks at 411°C (13.0 µV) and 466°C (14.0 µV), representing energy changes linked to phase transitions, decomposition, or chemical reactions. These combined TGA and DTA results provide a comprehensive understanding of the thermal stability, decomposition steps, and energetic behavior of specimen 6, essential for evaluating its performance in high-temperature applications.

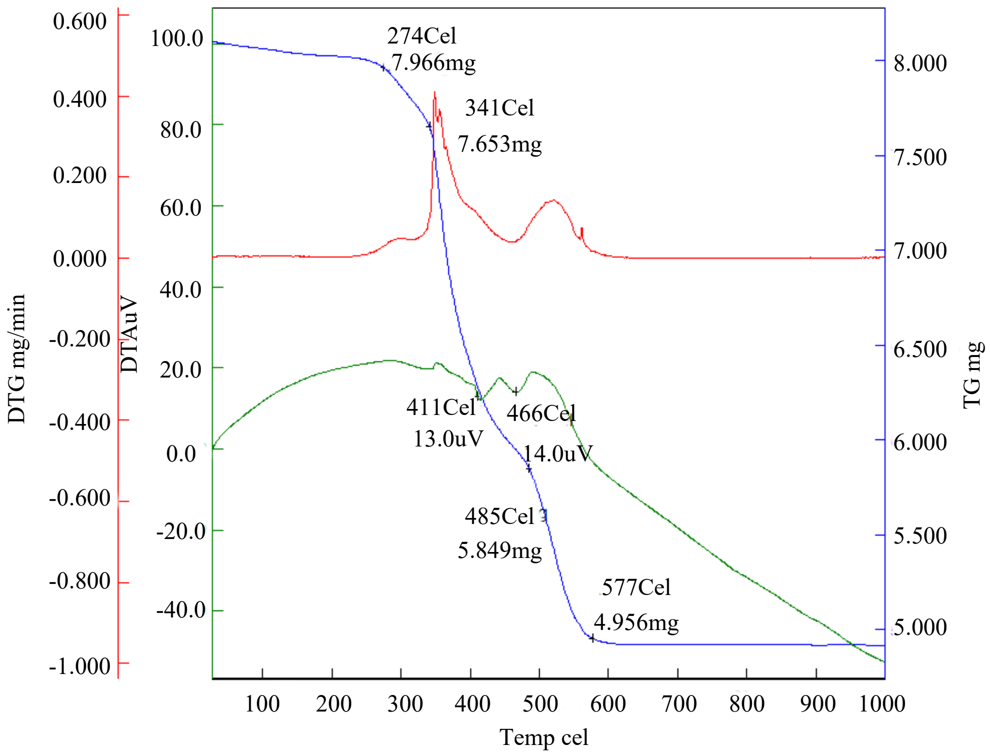

Figure 3. TGA report for specimen 4.

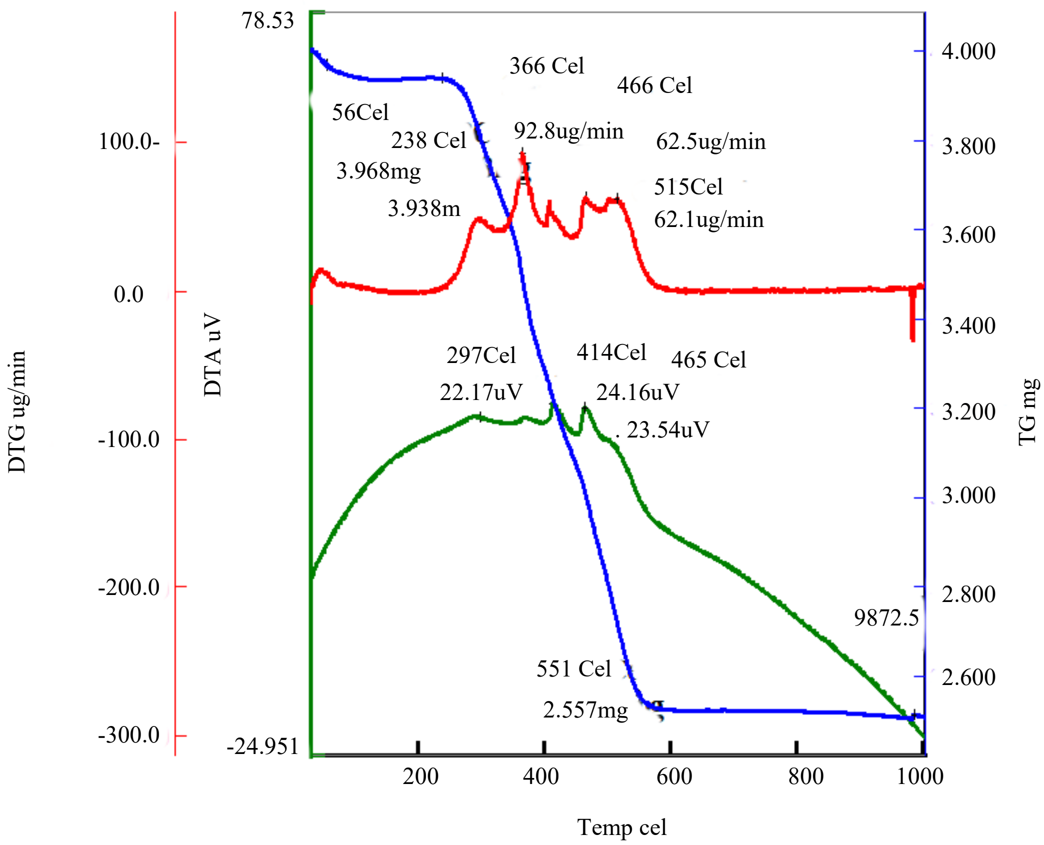

Figure 4. TGA report for specimen 8.

Table 2. Thermal analysis results for different specimens.

Sample	Thermal conductivity, k (W/mK)	Effusivity (Ws½/m²K)	R²	1/m	Temperature (°C)
1	0.6642	1011.1	0.9997	33.7	26.1
2	0.6628	1009.8	0.9997	33.6	26.1
3	0.6587	1006	0.9998	33.6	26.1
4	0.6723	1018.8	0.9997	33.8	26.1
5	0.6643	1011.2	0.9997	33.7	26
6	0.7082	1060.6	0.9999	33.8	26.2
7	0.7151	1060.9	0.9999	33.9	26
8	0.7208	1075	0.9999	33.5	26

Thermal Analysis

Based on the results obtained from the E-therm analyzer, the data are presented in Table 2, in which specimen 8 demonstrates the best thermal performance among all prepared samples. It exhibits the highest thermal conductivity of 0.7208 W/mK, indicating superior ability to conduct heat compared to the other specimens. Its effusivity value of 1075 Ws½/m²K is also the highest, reflecting excellent capability to exchange heat with the surrounding environment. The high R^2 value of 0.9999 confirms the accuracy and reliability of the measurement. The 1/m value of 33.5 and measurement temperature of 26°C further support the reproducibility of the results. These findings indicate that specimen 8, composed of the highest proportion of corn charcoal powder (11 g) combined with starch (5 g), provides the optimal combination of thermal conductivity and heat transfer efficiency, making it the best candidate for thermal insulation or heat management applications among the eight samples.

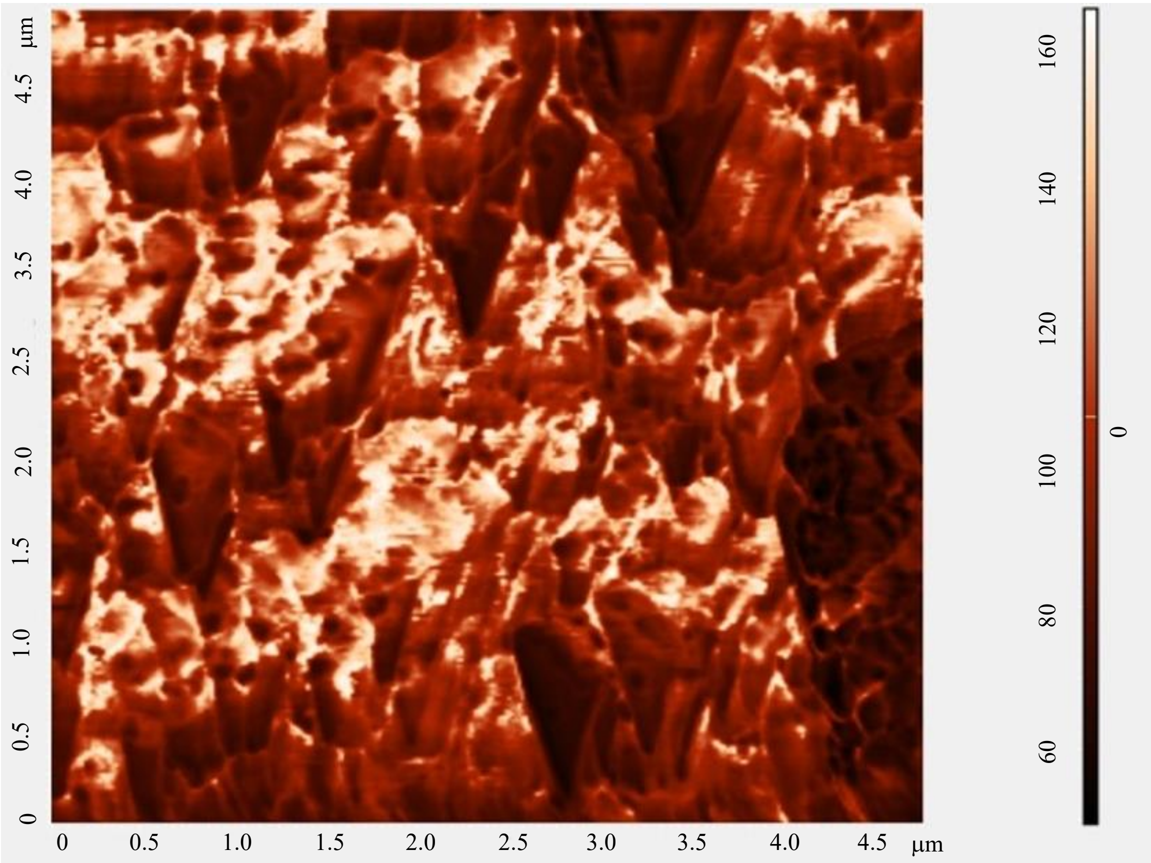

Figure 5. AFM result for specimen 1.

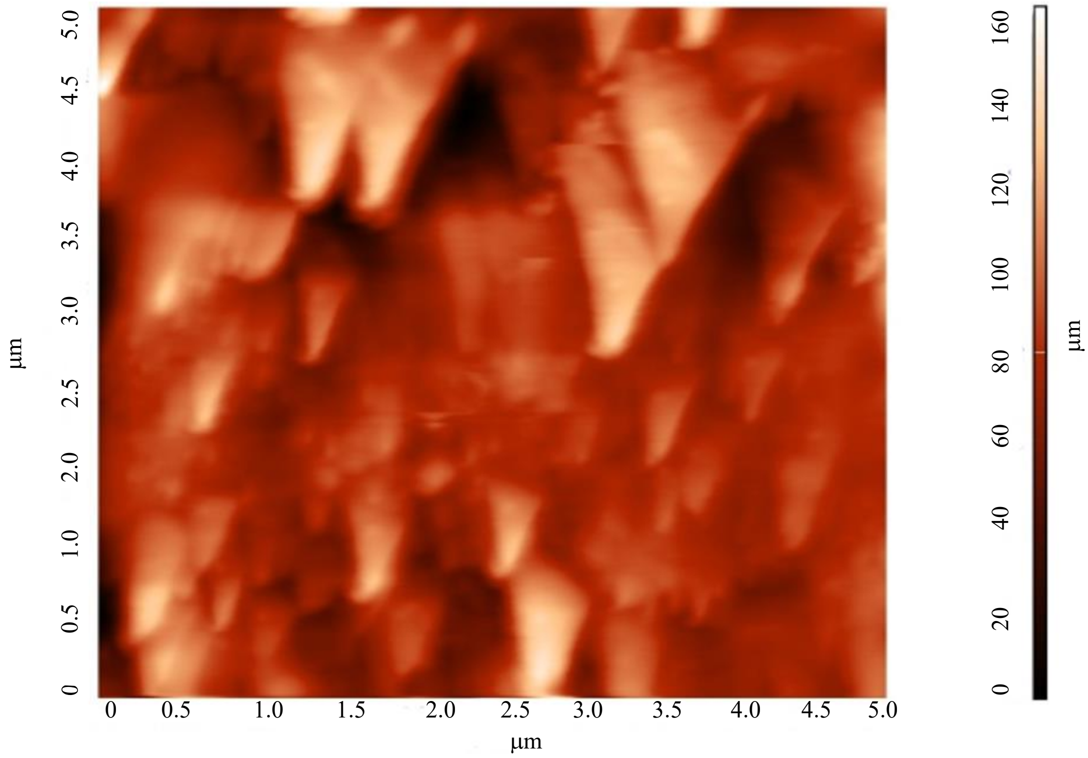

Figure 6. AFM result for specimen 2.

Table 3. AFM Result.

Composite type	Roughness average (Ra, nm)	Waviness (nm)	Root mean square (RMS, nm)
1	5	8	6
2	6	9	7
3	10	15	12
4	12	16	14
5	15	18	16
6	18	20	19
7	20	22	21
8	23	24	25

Atomic Force Microscopy Analysis

AFM was employed to examine the surface morphology, roughness, and particle distribution of the prepared composite specimens at the nanoscale level. This technique uses a sharp cantilever tip that scans the surface of the sample, generating high-resolution topographical images. AFM provides valuable insights into the uniformity of the starch matrix, the dispersion of bamboo and corn charcoal particles, and the presence of voids or agglomerates that could influence thermal and mechanical properties. Figure 5 and Figure 6 showed that the 3D surface profiles obtained from AFM reveal how well the natural fillers are embedded within the matrix, highlighting areas of high particle density and smoother regions of the binder. By analyzing surface roughness parameters, AFM helps correlate microstructural features with thermal conductivity and stability, enabling a comprehensive understanding of the composite's performance. Overall, AFM serves as a critical tool for assessing the microstructural integrity and quality of the bio-composite materials.

Table 3 is the AFM analysis results, it summarizes the surface texture characteristics of the eight composite specimens, highlighting roughness, waviness, and RMS values in nanometers. Specimen 1 exhibits the smoothest surface with the lowest Ra of 5 nm, minimal waviness at 8 nm, and an RMS of 6 nm, indicating a uniform matrix with well-dispersed fillers. As the filler content increases in subsequent samples, both Ra and RMS values gradually rise, reaching the highest values in specimen 8 (Ra = 23 nm, waviness = 24 nm, RMS = 25 nm), suggesting a rougher surface with greater topographical variations. The increasing trends in roughness and waviness reflect the effect of higher charcoal loading on surface morphology, where more filler particles lead to increased surface irregularities.

SEM Analysis

The SEM analysis was performed on all eight composite specimens to examine the surface morphology, filler distribution, and matrix-filler interaction at the microstructural level. Figure 7 and Figure 8 are the SEM Images, revealed that specimens with lower filler content, such as Sample 1 and Sample 2, exhibited a relatively smooth and uniform surface with well-dispersed charcoal particles embedded in the starch matrix. As the filler content increased in higher-numbered samples, In Figure 9,10,11 and 12 are SEM Images of samples of 3,4,5 and 6 respectively are exhibits medium filler distribution compared to other specimens, particularly Figure 13 and Figure 14 are Samples of 7 and 8, the micrographs showed more pronounced particle agglomeration, voids, and rougher surfaces, indicating challenges in achieving uniform dispersion at higher loading. The analysis also highlighted the porous nature of both bamboo and corn charcoal particles, which contributed to thermal insulation properties by introducing micro voids that reduce heat transfer. SEM observations confirmed the AFM results, showing that increasing filler content directly affects surface texture and microstructural uniformity. These insights are critical for understanding the relationship between composite composition, structural integrity, and thermal performance, and they help identify optimal filler-to-matrix ratios for practical applications in thermal insulation.

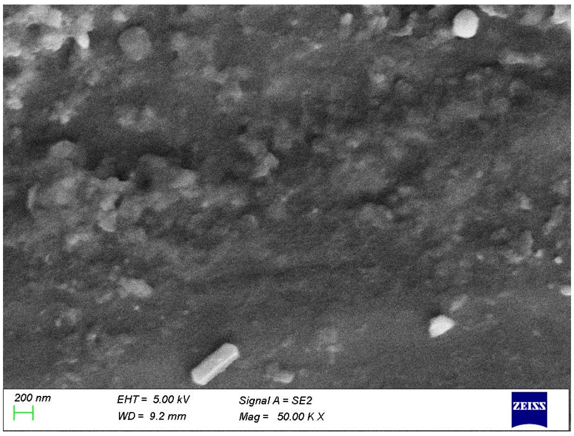

Figure 7. SEM report for specimen 1.

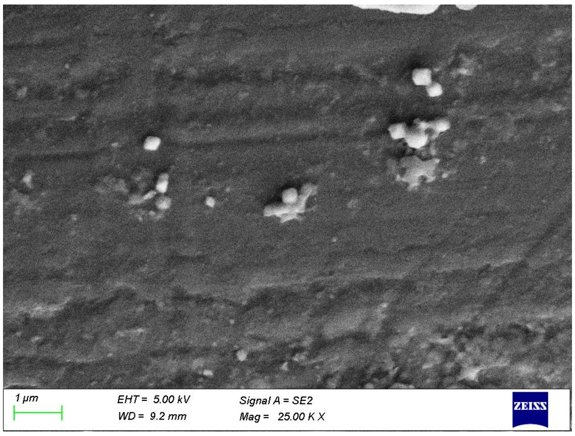

Figure 8. SEM report for specimen 2.

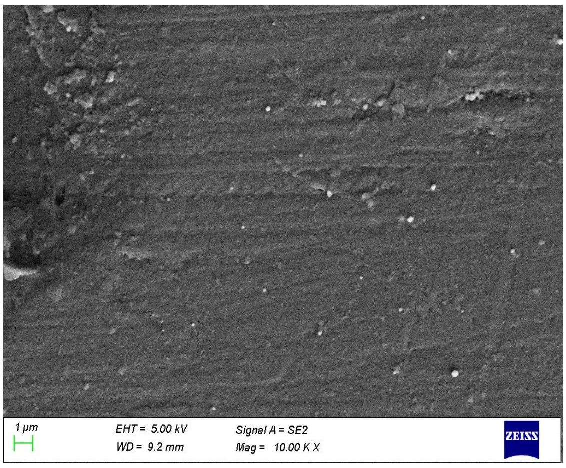

Figure 9. SEM report for specimen 3.

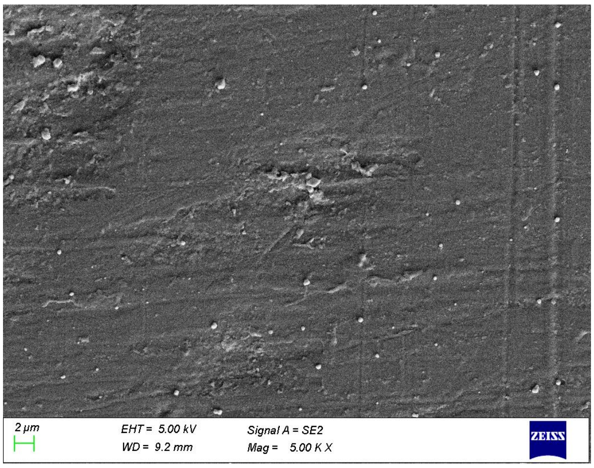

Figure 10. SEM report for specimen 4.

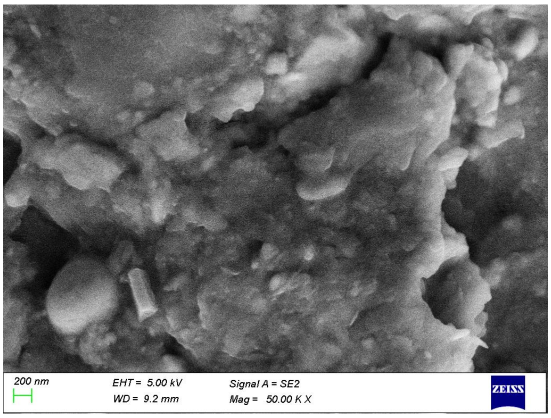

Figure 11. SEM report for specimen 5.

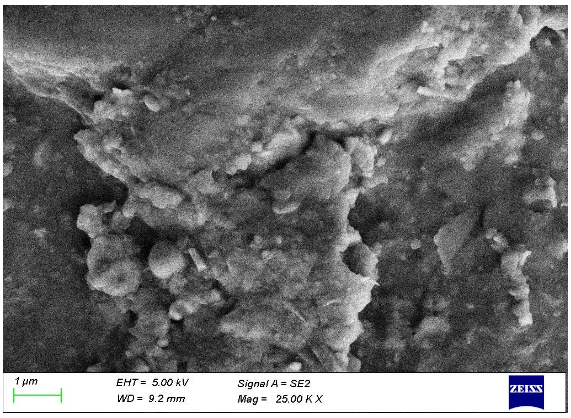

Figure 12. SEM report for specimen 6.

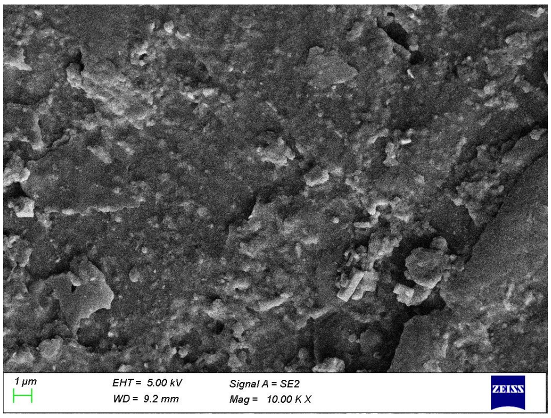

Figure 13. SEM report for specimen 7.

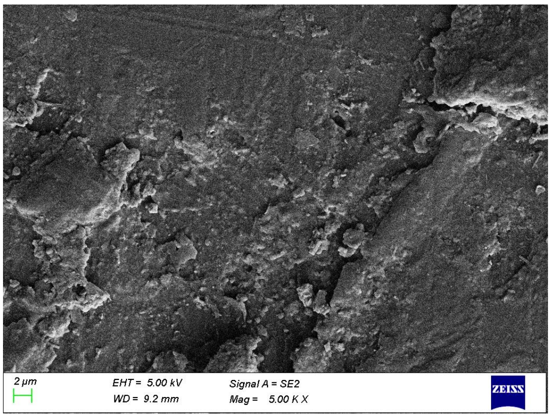

Figure 14. SEM report for specimen 8.

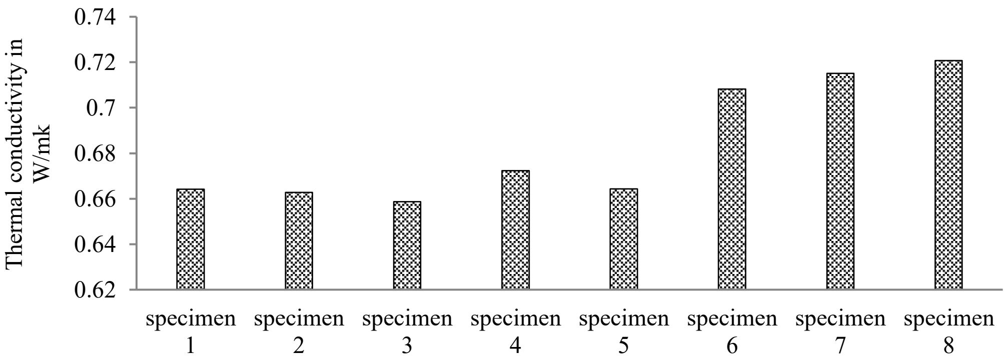

Figure 15. Thermal conductivity results.

In the SEM analysis of the composites, the white regions observed in the micrographs correspond to rice starch powder, which acts as the binding matrix, while the black regions represent the charcoal particles (bamboo or corn). This clear contrast in color provides a visual confirmation of how well the starch matrix encapsulates and holds the charcoal fillers. In samples with lower filler content (Samples 1–2), the white starch regions are more dominant and evenly spread, with charcoal particles (black zones) uniformly dispersed. In contrast, in higher filler-loaded samples (Samples 7–8), the black charcoal regions become more prominent, often appearing in clusters or agglomerations, reducing the visible dominance of starch. This distribution pattern not only illustrates the effectiveness of mixing but also highlights the impact of filler loading on the microstructure, surface roughness, and potential thermal behavior of the composites.

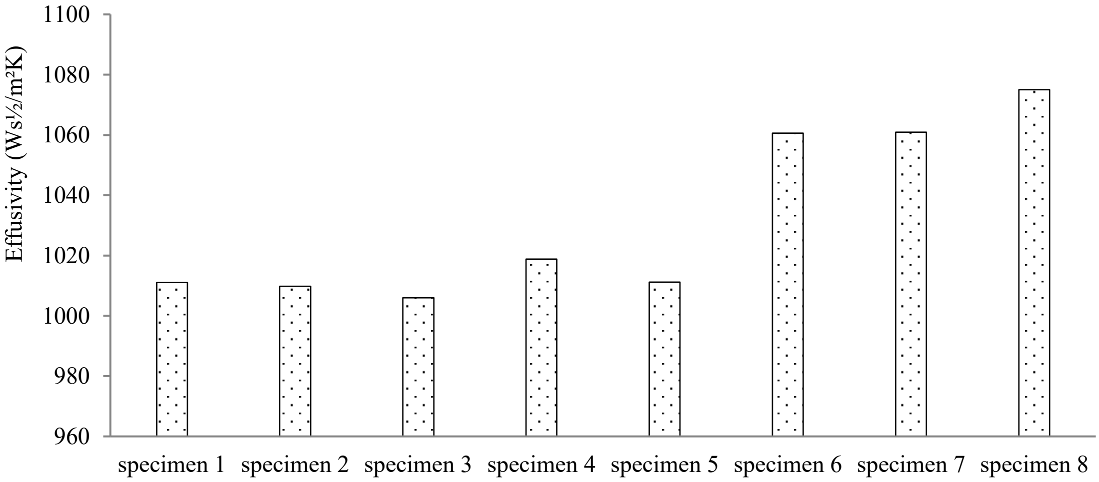

Figure 16. Thermal effusivity results.

RESULTS AND DISCUSSION

The results and discussion highlight the influence of rice starch and charcoal-based composites on thermal and structural performance. Among the prepared specimens, the incorporation of charcoal proved to be highly beneficial, enhancing thermal conductivity, effusivity, and stability due to its superior heat absorption and transfer characteristics.

The Results Are Presented in Graphs Below.

Figure 15 represents the thermal conductivity results for the eight specimens indicate noticeable variations based on the composition of starch and charcoal powders. Specimens 1 to 5 exhibit relatively lower thermal conductivity values, ranging between 0.6587 W/mK and 0.6723 W/mK, reflecting the dominant influence of starch with moderate filler content. Among them, specimen 4 showed the highest thermal conductivity (0.6723 W/mK), suggesting improved heat transfer due to a higher bamboo charcoal proportion. In contrast, specimens 6 to 8 demonstrated a significant increase in thermal conductivity, with values of 0.7082, 0.7151, and 0.7208 W/mK, respectively. These results highlight the effect of higher charcoal loading, where specimen 8 achieved the maximum conductivity (0.7208 W/mK), confirming that increased filler content enhances thermal performance by improving heat conduction pathways within the composite matrix.

Figure 16 shows that the thermal effusivity values of the eight specimens reveal the influence of filler concentration on the composites' ability to absorb and release heat. Specimens 1 to 5 show relatively lower effusivity values, ranging from 1006 to 1018.8 Ws½/m²K, with specimen 4 exhibiting the highest within this group (1018.8 Ws½/m²K) due to its higher bamboo charcoal content. In contrast, specimens 6 to 8 display a considerable increase, with effusivity values of 1060.6, 1060.9, and 1075 Ws½/m²K, respectively. The maximum value observed in specimen 8 (1075 Ws½/m²K) indicates superior thermal responsiveness, as higher charcoal loading enhances the material's ability to exchange heat efficiently.

CONCLUSION

The overall study concludes that among all the prepared composites, specimen 8 exhibited the most superior thermal properties, supported by its highest thermal conductivity (0.7208 W/mK) and effusivity (1075 Ws½/m²K), indicating enhanced heat transfer and thermal responsiveness compared to other specimens. The TGA results further confirmed its stability, showing distinct decomposition stages at higher temperatures, while the DTA analysis revealed clear endothermic and exothermic transitions that align with strong thermal resistance and effective energy absorption. These findings demonstrate that the higher charcoal loading in specimen 8 significantly improves both structural and thermal performance, making it the best-performing model for applications requiring efficient thermal insulation and stability.

REFERENCES

1. Jang, S., Xiangxu, L., & Cho, U. R. (2018). Effect of bamboo charcoal powder on the curing characteristics, mechanical properties, and thermal properties of styrene-butadiene rubber with bamboo charcoal powder. Journal of Applied Polymer Science, 130(13), 4534–4541. https://doi.org/10.1002/app.4541
2. Wang, S., Zhang, Y., & Zhang, J. (2020). Development of biodegradable flame-retardant bamboo charcoal composites. Polymers, 12(10), 2217. https://doi.org/10.3390/polym12102217
3. Kremensas, A., Kairytė, A., Vaitkus, S., Vėjelis, S., & Balčiūnas, G. (2019). Mechanical performance of biodegradable thermoplastic polymer-based biocomposite boards from hemp shivs and corn starch for the building industry. Materials, 12(6), 845. https://doi.org/10.3390/ma12060845
4. Pandecha, K., Pongtornkulpanich, A., & Chaiwong, S. (2016). Thermal properties of corn husk fiber as insulation for flat plate solar collector. Renewable Energy, 87, 302–309. https://doi.org/10.1016/j.renene.2015.10.037
5. Balčiūnas, G., Vėjelis, S., Lekūnaitė-Lukošiūnė, L., & Kremensas, A. (2016). Assessment of structure influence on thermal conductivity of hemp shives composite. Environmental Engineering and Management Journal, 15(3), 705–711. https://doi.org/10.30638/eemj.2016.075
6. Bovo, M., Della Torre, A., & Santoro, D. (2022). Contribution to thermal and acoustic characterization of corn cob for bio-based building insulation applications. Science of the Total Environment, 806, 150456. https://doi.org/10.1016/j.scitotenv.2021.150456
7. Zou, D., Zhang, Y., & Zhang, J. (2022). Effect of different amounts of bamboo charcoal on the properties of polylactic acid composites. Composites Part A: Applied Science and Manufacturing, 152, 106648. https://doi.org/10.1016/j.compositesa.2021.106648
8. Wang, S., Zhang, Y., & Zhang, J. (2020). Development of biodegradable flame-retardant bamboo charcoal composites. Polymers, 12(10), 2217. https://doi.org/10.3390/polym12102217
9. Kremensas, A., Kairytė, A., Vaitkus, S., Vėjelis, S., & Balčiūnas, G. (2019). Mechanical performance of biodegradable thermoplastic polymer-based biocomposite boards from hemp shivs and corn starch for the building industry. Materials, 12(6), 845. https://doi.org/10.3390/ma12060845
10. Pandecha, K., Pongtornkulpanich, A., & Chaiwong, S. (2016). Thermal properties of corn husk fiber as insulation for flat plate solar collector. Renewable Energy, 87, 302–309. https://doi.org/10.1016/j.renene.2015.10.037
11. Balčiūnas, G., Vėjelis, S., Lekūnaitė-Lukošiūnė, L., & Kremensas, A. (2016). Assessment of structure influence on thermal conductivity of hemp shives composite. Environmental Engineering and Management Journal, 15(3), 705–711. https://doi.org/10.30638/eemj.2016.075
12. Bovo, M., Della Torre, A., & Santoro, D. (2022). Contribution to thermal and acoustic characterization of corn cob for bio-based building insulation applications. Science of the Total Environment, 806, 150456. https://doi.org/10.1016/j.scitotenv.2021.150456
13. Karuppiah, G., Kuttalam, K. C., Palaniappan, M., Santulli, C., & Palanisamy, S. (2020). Multiobjective Optimization of Fabrication Parameters of Jute Fiber/Polyester Composites with Egg Shell Powder and Nanoclay Filler. *Molecules*, *25*(23), 5579. https://doi.org/10.3390/molecules25235579
14. R.G. Padmanabhan, S. Rajesh, S. Karthikeyan, Sivasubramanian Palanisamy, R.A. Ilyas, Nadir Ayrilmis, ElSayed M. Tag-eldin, & Mohamed Kchaou (2024). Evaluation of mechanical properties and Fick's diffusion behaviour of aluminum-DMEM reinforced with hemp/bamboo/basalt woven fiber metal laminates (WFML) under different stacking sequences. *Ain Shams Engineering Journal*, 15, 102759, https://doi.org/10.1016/j.asej.2024.102759
15. Ayrilmis N, Kanat G, Yildiz Avsar E, Palanisamy S, Ashori A. (2024). Utilizing waste manhole covers and fibreboard as reinforcing fillers for thermoplastic composites. *Journal of Reinforced Plastics and Composites*. 44, 10.1177/07316844241238507
16. Ramasubbu, R., Kayambu, A., Palanisamy, S., and Ayrilmis, N. (2024). Mechanical properties of epoxy composites reinforced with *Areca catechu* fibers containing silicon carbide. *BioResources*, 19, 10.15376/biores.19.2.2353-2370

17. Aruchamy, K., Karuppusamy, M., Krishnakumar , S., Palanisamy, S., Jayamani, M., Sureshkumar , K., Ali, S. K., and Al-Farraj, S. A. (2025). Enhancement of mechanical properties of hybrid polymer composites using palmyra palm and coconut sheath fibers: The role of tamarind shell powder. *BioResourcesI*, 20, 10.15376/biores.20.1.698-724
18. Kar, A., Pandiarajan, N., Saikia, D., & Palanisamy, S. (2024). Effect of fiber loading on the mechanical, morphological, and dynamic mechanical characteristics of Calamus tenuis fiber reinforced epoxy composites. Journal of Vinyl and Additive Technology, 31(1), 224–240. https://doi.org/10.1002/vnl.22167

