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Influence of Alkali Treatment and Loading on the Physical, Mechanical, and Morphological Properties of the Composites from Waste Corn Cob Reinforced Polystyrene Foam

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Abstract

This study investigated the influence of alkali (NaOH) treatment and filler loading on the performance of waste corn cob–reinforced polystyrene foam composites. The work was motivated by the need to convert agricultural residues into value-added materials suitable for lightweight structural applications. Composites were produced with corn cob filler contents ranging from 0 to 50 wt.%, and the treated fillers were incorporated into the polymer matrix through conventional processing techniques. To evaluate performance, physical and mechanical tests were conducted, including flexural strength and modulus, tensile strength and modulus, hardness, density, and water absorption. In addition, scanning electron microscopy (SEM) was used to examine the interfacial interaction between the filler and the matrix. Data were collected systematically across all filler loadings to determine the effect of reinforcement level on composite behaviour. The results showed that alkali treatment improved filler–matrix adhesion, particularly at moderate filler contents. Flexural strength was highest in the unreinforced matrix (31.687 MPa) but decreased with increasing filler content, reaching 12.844 MPa at 50 wt.%. However, the flexural modulus peaked at 30 wt.% (2428.646 MPa), indicating improved stiffness at this composition. Tensile modulus increased progressively with filler loading, attaining 1858.215 MPa at 50 wt.%, while tensile strength declined to 1.431 MPa. Hardness values varied across compositions, with the highest value (388) recorded at 20 wt.%. Water absorption increased as filler content rose due to the hydrophilic nature of corn cob, whereas density decreased, reflecting reduced compactness at higher loadings. SEM observations confirmed improved dispersion and interfacial bonding at moderate filler levels but

revealed agglomeration at higher contents. Therefore, the study demonstrates that alkali-treated corn cob can serve as a viable and sustainable reinforcing filler in polystyrene foam composites. Optimal performance was achieved between 20 and 30 wt.% filler loading, where a balance between stiffness, strength, and durability was observed. It is recommended that future studies focus on optimizing fiber dispersion and exploring surface modification techniques to further enhance mechanical performance at higher filler loadings.

Keywords: Alkaline**,** waste corn cob, polystyrene foam, composites, mechanical properties, morphology.

Introduction

The growing need for sustainable materials has accelerated research into natural fiber-reinforced composites, offering an environmentally friendly alternative to synthetic composites (Salisu & Maigari, 2022; Jawaid et al., 2011). Natural fibers such as corn cob, jute, coir, and sisal have emerged as promising reinforcements due to their lightweight, renewability, biodegradability, and low cost (Ghori et al., 2023). Among these, corn cob, a by-product of maize processing, is particularly attractive due to its high cellulose content, low density, and abundance in agricultural regions, making it an ideal candidate for reinforcing polymer composites (Khalili et al., 2023).

Polystyrene foam, a petroleum-based polymer widely used for packaging, insulation, and construction, has faced growing environmental concerns due to its non-biodegradability and accumulation in landfills (Akabe et al., 2025; Kistaiah et al., 2014). Recycling and repurposing waste polystyrene foam into composite materials has gained attention as an effective strategy to mitigate environmental pollution. However, polystyrene foam's hydrophobic nature limits its compatibility with natural fibers, resulting in poor interfacial bonding and reduced mechanical performance of the composites (Khalili et al., 2023.

To overcome these limitations, surface treatments such as alkali treatment (using sodium hydroxide, NaOH) are employed to enhance the bonding between natural fibers and polymer matrices (Zhou et al., 2023; Kudva et al., 2024). Alkali treatment removes surface impurities, wax, and lignin from the fiber surface, exposing more cellulose and creating rougher surfaces, which improves fiber-matrix interfacial adhesion (Rao et al., 2020; Rajesh & Pitchaimani, 2019). Additionally, this treatment increases the fiber's hydrophobicity by reducing hydroxyl groups, thereby minimizing moisture absorption and improving the composite's mechanical properties (Howlader et al., 2025; Khalili et al., 2023).

Scanning Electron Microscopy (SEM) is a critical analytical tool used to examine the surface morphology and structural changes in natural fibers after chemical treatment

(Varma & Chandran, 2021; Zhou et al., 2023). SEM analysis provides insight into the removal of non-cellulosic components and the degree of roughness induced by alkali treatment, which directly influences the fiber-matrix interface and mechanical performance of composites (Jiyas et al., 2025). Studies have shown that alkali-treated natural fibers exhibit enhanced tensile strength, flexural strength, and modulus, owing to improved load transfer efficiency at the interface (Mylsamy & Rajendran, 2021; Sonali et al., 2023).

The incorporation of alkali-treated corn cob into waste polystyrene foam matrices holds significant potential for developing cost-effective and lightweight composites with improved mechanical performance. The structural integrity, tensile properties, flexural strength, and impact resistance of these composites are crucial parameters for evaluating their suitability in applications such as packaging, automotive, and construction industries (Ofora et al., 2014; Akabe et al., 2025). Furthermore, understanding the influence of alkali treatment on fiber morphology and interfacial bonding through SEM analysis provides a deeper understanding of the composite's behavior under mechanical loading (Zhou et al., 2023).

Despite extensive research on natural fiber-reinforced composites, limited studies have explored the specific effects of alkali treatment and loading on corn cob-reinforced polystyrene foam composites. Therefore, this study aims to evaluate the influence of alkali treatment on the physical, mechanical, and morphological properties of corn cob-polystyrene foam composites. By analyzing the microstructural changes, tensile strength, flexural properties, and interfacial behaviour, this research seeks to contribute to the development of sustainable and high-performance composite materials for industrial applications.

Materials Sourced

The waste polystyrene foam (WPSF) was sourced locally from *Sabon Gari* in Kaduna South Local Government Area, Kaduna State, Nigeria. The collected WPSF was screened, thoroughly washed, and air-dried at room temperature before being sent for recycling (composites fabrication) at the Nigerian Institute of Leather and Science Technology (NILEST), Zaria, Nigeria. Similarly, the corn cobs were procured locally from *Layin Sarki* in Unguwan Sanusi, Kaduna South Local Government Area, Kaduna State, Nigeria.

Corn cobs preparation and treatment

The collected corn cobs were sorted, washed, and air-dried at room temperature for 72 hours. Once dried, the corn cobs were pulverized into fine particles with a size of 150 micrometers, as described by Ismail et al. (2021), in the Department of Mineral Resources and Petroleum Engineering Laboratory at Kaduna Polytechnic, Kaduna. Sodium hydroxide and litmus paper used in the process were sourced from the Chemical Engineering Laboratory at the same institution. The dried and ground corn cobs were soaked in a 2% (w/v) NaOH solution prepared in a 1:6 ratio (corn cob to NaOH solution) for 14400 seconds at room temperature with intermittent stirring to remove soluble lignocellulose fractions. After soaking, the solution was decanted, and the corn cob particles (CCP) were thoroughly washed multiple

times with water to eliminate residual NaOH solution from their surfaces. Finally, the corn cobs were rinsed with deionized water until the pH reached neutral and then air-dried for 86400 seconds at room temperature.

Production of the Composites

Waste corn cob particle (WCCP) was incorporated into the waste polystyrene foam (WPSF) during the mixing process to produce composite specimens (S-0, S-10, S-20, S-30, S-40, and S-50, respectively). Using a 2 roll mill machine, the rolls rotated counterclockwise while the WPSF was softened for 300 seconds at a temperature of 150 °C and a speed of 79 rpm. Once the WPSF formed a band on the front roll, WCCP was gradually added and cross-mixed with the softened WPSF. The mixture was allowed to blend thoroughly for 180 seconds. The resulting composite material was then transferred into a metal mould with dimensions of 160×180×3 mm and cured using a compression moulding machine at 150 °C and 2.5 psi for 300 seconds. After curing, the composite was removed from the hot plate and allowed to cool for 120 seconds on a cool plate before being taken out of the mould and labeled accordingly. Composite Specimens with varying WCCP loadings, ranging from 0 to 50 weight percent (0, 10, 20, 30, 40, and 50 wt.%), were prepared using this process. Correspondingly, the WPSF matrix ranged from 100 to 50 weight percent, with increments of 10 wt.% WCCP. After fabrication, three Specimens, each measuring 50×10 mm, were cut, weighed, and taken to the laboratory for further testing and analysis.

Physical properties test of composites

The physical properties of the composites, including percentage weight gain (water absorption), density, and hardness, were analyzed at different fiber loadings. These tests were conducted in accordance with the ASTM D570-98 standard, as adopted by Martínez et al. (2021). The water absorption test for WCCP-reinforced WPSF composites involved immersing the Specimens in deionized water at room temperature. The composite specimens were removed after 1400 seconds (24 hours) to measure the amount of water absorbed. Each specimen's surface was wiped clean to remove any residual water before being immediately weighed using a digital scale. The percentage weight gain was determined using the weight (mass) difference over time, calculated using Equation (1) to evaluate the percentage weight gain of the composites at various intervals.

$$\text{Percentage Weight Gained (\%)} = \frac{M_2 - M_1}{M_1} \times 100 \qquad (1)$$

where; M_1 and M_2 are the initial (dry) and final (wet) masses of specimens (g).

Also, the composite Specimens density tests were performed by cutting specimens at 25x25x3 mm for varying WCCP or fiber ratio. A clean composite Specimens after cut were weighed accurately and then suspended in water. The weights of the Specimens when suspended in water were determined, and the volumes of the composite Specimens were determined from

the effect of displacement by water (Archimedean principle). Equation (2) was used to evaluate the density of the developed composite Specimens:

$$\text{Density}, \rho = \frac{M}{v} \quad (2)$$

where; ρ is the density (g/cm^3), V is volume of specimen (cm^3), and M is the mass of specimen (g), respectively.

The Vickers Hardness Tester Machine Model MV 1-PC, System Number 07/2012-1329, was used to evaluate the composite specimens' hardness in compliance with ASTM E384 standard. This standard outlines the method for determining microhardness, including Vickers hardness, by applying a load to a diamond indenter and measuring the resulting indentation.

Mechanical properties of composites

Mechanical tests, including tensile and flexural strength assessments, were conducted to evaluate the fabricated strength of the composite material. These tests adhered to the relevant ASTM standards, specifically ASTM D638 for tensile strength and ASTM D790 for flexural strength, as adopted by Akabe et al. (2022). The tests were performed on the waste corn cob particles-reinforced waste polystyrene foam composite specimens using the Hounsfield Monsanto Tensometer Machine, Model W6466. The results provided values for tensile stress, tensile young's modulus, and flexural strength and modulus, all obtained in compliance with ASTM standards.

Scanning electron microscopic study

The microstructure of the developed composites was analyzed using a Scanning Electron Microscope (Phenom ProX model) manufactured by Phenom World, Eindhoven. This analysis aimed to evaluate the dispersion of WCCP and WPSF within the composite. The instrument uses electrons instead of light to produce highly magnified images. The specimen was prepared by placing it on an aluminum holder stub with sticky carbon tape. The analysis involved assigning appropriate elements to identify the composition of atoms on the specimen surface. The process began with the lowest scan mode of 10x, followed by clicking the TV scan. The magnification was progressively increased to 1000x at a slow scan, and subsequently to 2000x, 3000x, and 5000x. Finally, the image was saved. This procedure, referred to as Scanning Electron Microscopy, is also valuable for determining the elemental composition of a specimen's surface.

Density

Figure 1 summarizes the density results of polystyrene foam composites reinforced with NaOH-treated corn cob at varying weight percentages. The neat polystyrene matrix (0 wt.% corn cob) exhibited the highest density of 1.758 g/cm³, serving as the baseline. As the corn cob content increased, a gradual reduction in density was observed, with 10 wt.% filler (S-10) showing a density of 1.697 g/cm³, likely due to the lower density of the corn cob compared to

the polystyrene matrix. At 20 wt.% filler (S-20), the density further decreased to 1.548 g/cm³, attributed to the increasing filler volume. This trend continued with 30 wt.% filler (S-30), where the density slightly dropped to 1.536 g/cm³, reflecting diminishing density reductions at higher filler content. A more significant decrease was recorded at 40 wt.% filler (S-40), with a density of 1.458 g/cm³. The lowest density, 1.411 g/cm³, was observed at 50 wt.% filler (S-50), confirming the impact of a high filler-to-matrix ratio on reducing the composite's density.

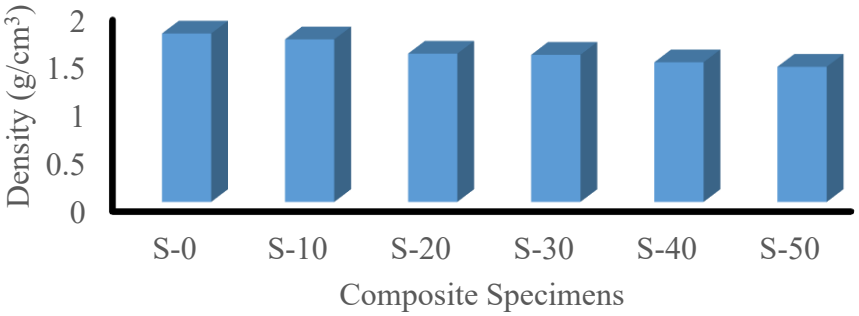


Figure 1: Impact of NaOH and CCP Content on the Density of Composites Produced.

The decline in density with increasing filler content results from the lower density of the corn cob compared to the polystyrene matrix. Alkali treatment further reduced filler weight by removing impurities, lignin, and hemicellulose, exposing cellulose, which contributes to the observed trend. However, excessive filler loadings disrupt matrix continuity, potentially leading to diminished mechanical properties. Specimen S-20 (20 wt.%) appears optimal, balancing reduced density with sufficient matrix-to-filler interaction. Similar findings were reported by Abubakar et al. (2025), where natural fiber-reinforced composites showed consistent density reductions with increased filler content

Water Absorption

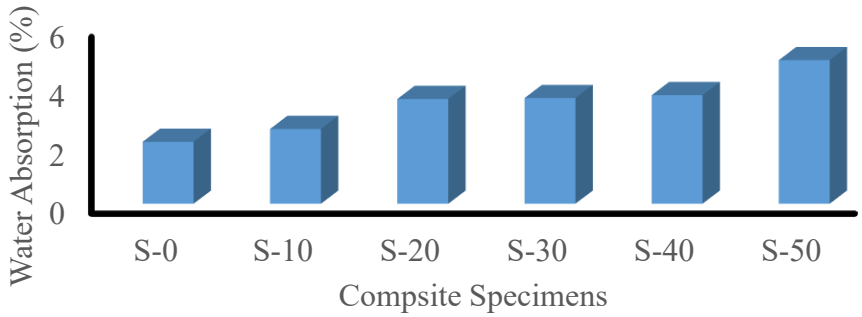


Figure 2: Impact of NaOH and CCP Content on the Water Absorption of Composites Produced.

Water absorption results, summarized in Figure 2, revealed that the neat polystyrene matrix (S-0) exhibited the lowest water absorption at 2.101%, reflecting its hydrophobic nature. Incorporating NaOH-treated corn cob increased water absorption, with 10 wt.% filler (S-10) showing 2.537% absorption due to the hydrophilic nature of the corn cob. A significant increase was observed at 20 wt.% filler (S-20), with water absorption reaching 3.556%. For 30 wt.% filler (S-30), water absorption stabilized at 3.587%, indicating saturation of matrix-filler interaction. Slight increases were recorded at 3.686% for 40 wt.% filler (S-40) and a peak of 4.876% at 50 wt.% filler (S-50).

The trend is consistent with the hydrophilic cellulose and hemicellulose components of corn cob. Alkali treatment exposed more cellulose, increasing hydrophilicity and void formation at higher filler contents. These voids allowed water ingress, further raising water absorption. While the hydrophobic matrix moderates water absorption at lower filler contents, its effect diminishes with higher loadings. Findings align with those of Kumar et al. (2025); and Singh et al. (2018), who observed increased water absorption in natural fiber composites due to hygroscopic fibers and reduced matrix continuity.

Hardness

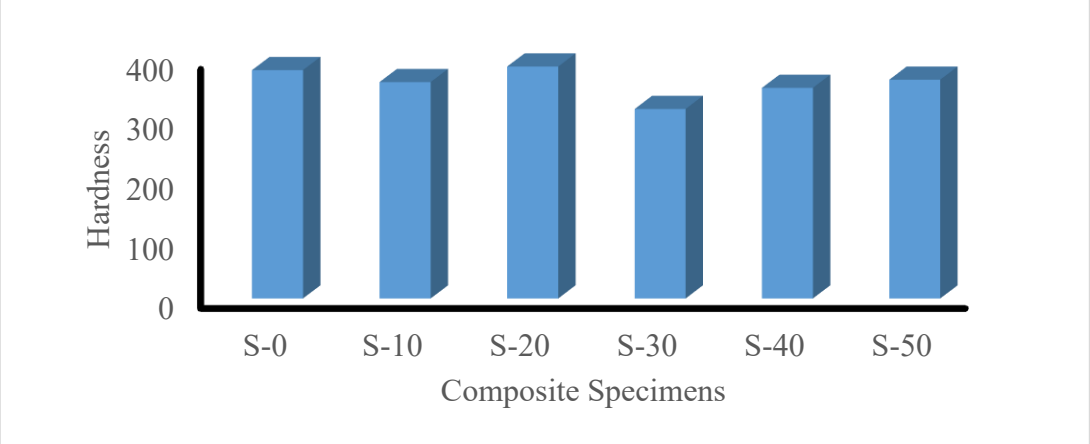


Figure 3: Impact of NaOH and CCP Content on the Hardness of Composites Produced.

Hardness results, as shown in Figure 3, indicate that the neat polystyrene matrix (S-0) exhibited the highest hardness value of 382. The addition of NaOH-treated corn cob influenced hardness, with a slight decrease to 362 at 10 wt.% filler (S-10). This was followed by an increase to 388 at 20 wt.% filler (S-20), suggesting improved reinforcement and enhanced filler-matrix bonding. However, a notable drop to 317 was observed at 30 wt.% filler (S-30), likely due to filler agglomeration. A marginal recovery to 352.3 was recorded at 40 wt.% filler (S-40), and a slight increase to 366 was observed at 50 wt.% filler (S-50).

At lower filler contents, improved dispersion and matrix interaction enhanced hardness. However, excessive filler content disrupted the matrix structure, reducing hardness. The marginal improvement at 50 wt.% (S-50) suggests structural densification compensating for

matrix disruption. Similar trends were reported by Senthil et al. (2020), where excessive filler loadings reduced hardness due to agglomeration and poor matrix continuity.

Tensile Stress

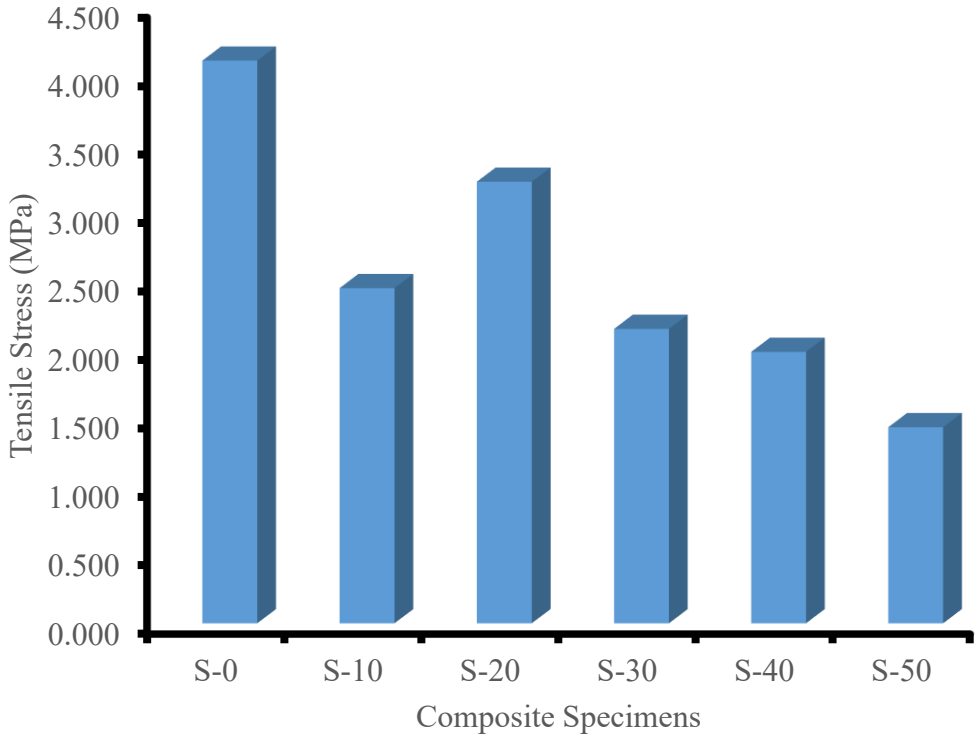


Figure 4: Impact of NaOH and CCP Content on the Tensile Stress of Composites Produced.

Figure 4 presents the tensile strength results, showing that the neat polystyrene matrix exhibited the highest tensile strength of 4.107 MPa. Adding corn cob caused a significant reduction to 2.446 MPa at 10 wt.% filler (S-10), followed by an improvement to 3.223 MPa at 20 wt.% filler (S-20), reflecting optimal filler-matrix interaction. The tensile strength declined to 2.149 MPa at 30 wt.% filler (S-30) and further decreased to 1.981 MPa and 1.431 MPa at 40 wt.% and 50 wt.% filler (Specimens S-40 and S-50, respectively).The initial reduction in tensile strength at 10 wt.% is attributed to poor dispersion and weak bonding. At 20 wt.% (S-20), improved filler-matrix interaction enhanced tensile strength. Beyond this point, agglomeration and matrix dilution reduced load transfer efficiency. Alkali treatment improved compatibility at moderate loadings but was insufficient at higher contents. Shelly (2025) observed similar trends, with tensile strength peaking at moderate filler content.

Tensile Modulus

The tensile modulus measures the stiffness of a composite material under tension.

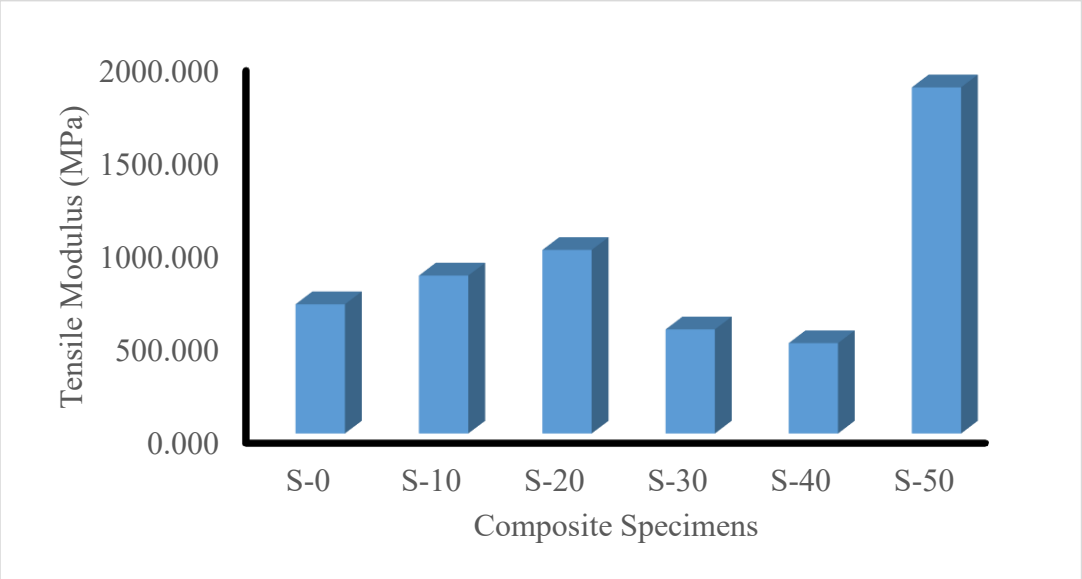


Figure 5: Impact of NaOH and CCP Content on the Tensile Modulus of Composites Produced.

Figure 5 presents the tensile modulus results of composites with varying weight percentages of alkali-treated corn cob reinforcement in a polystyrene foam matrix. The tensile modulus of the unreinforced matrix (0 wt.% corn cob) was initially 693.986 MPa. With the addition of corn cob, the modulus increased to 848.112 MPa at 10 wt.% corn cob loading, indicating enhanced stiffness due to the reinforcement effect. A further increase to 985.492 MPa at 20 wt.% corn cob content represented the peak stiffness among lower filler contents, attributed to improved reinforcement and filler-matrix interaction. However, a sharp decline to 559.160 MPa was observed at 30 wt.% corn cob, likely caused by filler aggregation and reduced matrix continuity. This downward trend continued with a modulus of 485.180 MPa at 40 wt.% corn cob, reflecting worsening structural integrity due to excessive filler content. Surprisingly, the tensile modulus significantly increased to 1858.215 MPa at 50 wt.% corn cob, deviating from the observed trend and suggesting a unique interaction at high filler loading, potentially resulting from a compact structure or reduced ductility compensating for stiffness.

The initial improvement in modulus with increasing corn cob content (Specimens S-10 and S-20) can be attributed to the stiff natural fiber reinforcing the softer polystyrene matrix. However, at 30–40 wt.% filler content, the modulus declined due to poor filler dispersion, clustering, and insufficient matrix coverage. The unexpected increase at 50 wt.% (S-50) suggests structural densification or brittle behavior dominating the composite properties. Alkali treatment of the corn cob removes lignin and hemicellulose, exposing cellulose fibrils and improving filler-matrix adhesion, especially at optimal loading levels such as 20 wt.%. At higher filler contents, the benefits of alkali treatment may be overshadowed by filler agglomeration or inadequate matrix encapsulation.

While tensile strength tends to decrease at higher filler contents, the modulus increased significantly at 50 wt.%, highlighting the different behaviors of stiffness and strength in the

composite. The composite at 50 wt.% may resist deformation (high modulus) but is more prone to failure under stress due to its brittleness. These findings align with the study by Raj et al. (2025), which observed a sharp increase in modulus at very high filler loadings in composites, attributed to matrix densification and reduced elasticity.

Flexural Strength

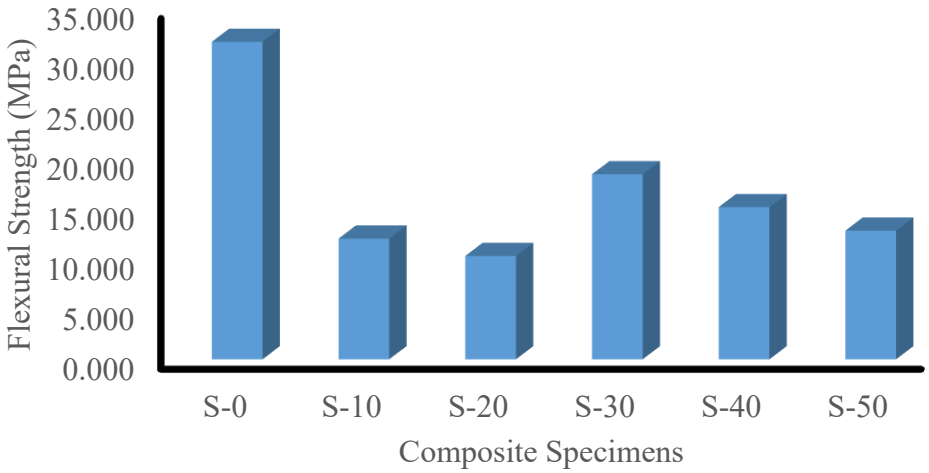


Figure 6: Impact of NaOH and CCP Content on the Flexural Strength of Composites Produced.

Figure 6 illustrates the flexural strength of composite Specimens with varying corn cob reinforcement in a waste polystyrene foam matrix. The unreinforced matrix (S-0) exhibited the highest flexural strength at 31.687 MPa. However, the strength significantly decreased to 12.047 MPa and 10.313 MPa for S-10 and S-20, respectively, corresponding to 10–20 wt.% corn cob content. A slight improvement was observed at 30 wt.% (S-30), with a flexural strength of 18.469 MPa, indicating improved load transfer due to enhanced filler-matrix interaction. The strength declined again to 15.188 MPa and 12.844 MPa for Specimens S-40 and S-50, containing 40–50 wt.% corn cob, likely due to filler agglomeration and the brittle nature of the filler.

The initial decrease in flexural strength from Specimen S-0 to S-10 and S-20 reflects the rigid nature of corn cob, which reduces matrix flexibility without significantly improving its ability to withstand bending stresses. Alkali treatment enhances filler-matrix adhesion by removing lignin and hemicellulose, exposing cellulose, and creating rougher surfaces for better mechanical interlocking. However, uneven dispersion or agglomeration, as seen in Specimens S-40 and S-50, results in stress concentration points and reduced strength.

Specimen S-30 (30 wt.% corn cob) achieved the highest flexural strength among reinforced composites, highlighting optimal filler-matrix interaction at this composition. Beyond this point, the excessive filler content in Specimens S-40 and S=50 led to agglomeration, poor stress transfer, and reduced strength. The neat polystyrene foam matrix (S-0) maintained the

highest flexural strength due to its uniform structure and absence of stress concentration points. These findings align with Ashik et al. (2017), who reported reduced flexural strength at higher filler contents in natural fiber-reinforced composites, attributed to filler agglomeration and brittle behaviour.

Flexural Modulus

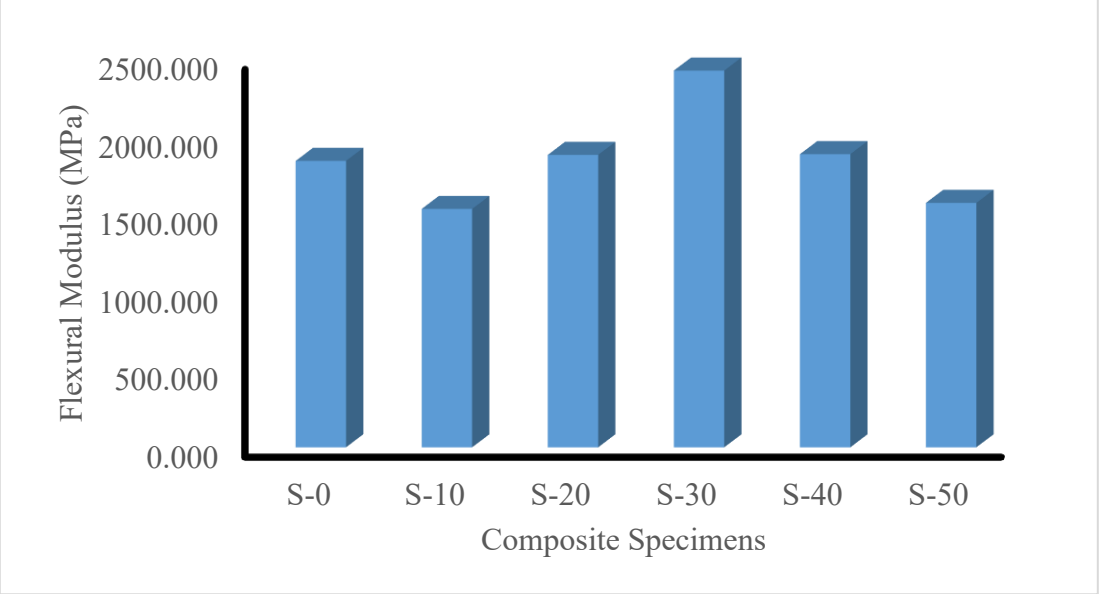


Figure 7: Impact of NaOH and CCP Content on the Flexural Modulus of Composites Produced.

Figure 7 presents the flexural modulus values for composites with varying percentages of corn cob filler in a waste polystyrene foam matrix. The flexural modulus measures the material's stiffness under bending stress. The baseline flexural modulus for the unreinforced matrix (0 wt.% corn cob) is 1846.348 MPa. A decrease to 1536.728 MPa is observed for S-10 (10 wt.% corn cob), likely due to the initial disruption of the polymer matrix's continuity by the filler. The modulus increases to 1885.279 MPa for S-20 (20 wt.% corn cob), suggesting improved stiffness resulting from better filler dispersion and interaction. The highest flexural modulus, 2428.646 MPa, is achieved at 30 wt.% corn cob (S-30), indicating optimal filler-matrix interaction at this filler content. However, the modulus decreases to 1889.632 MPa and 1575.780 MPa for Specimens S-40 and S-50 (40 wt.% and 50 wt.% corn cob, respectively), possibly due to filler agglomeration and weakened load transfer.

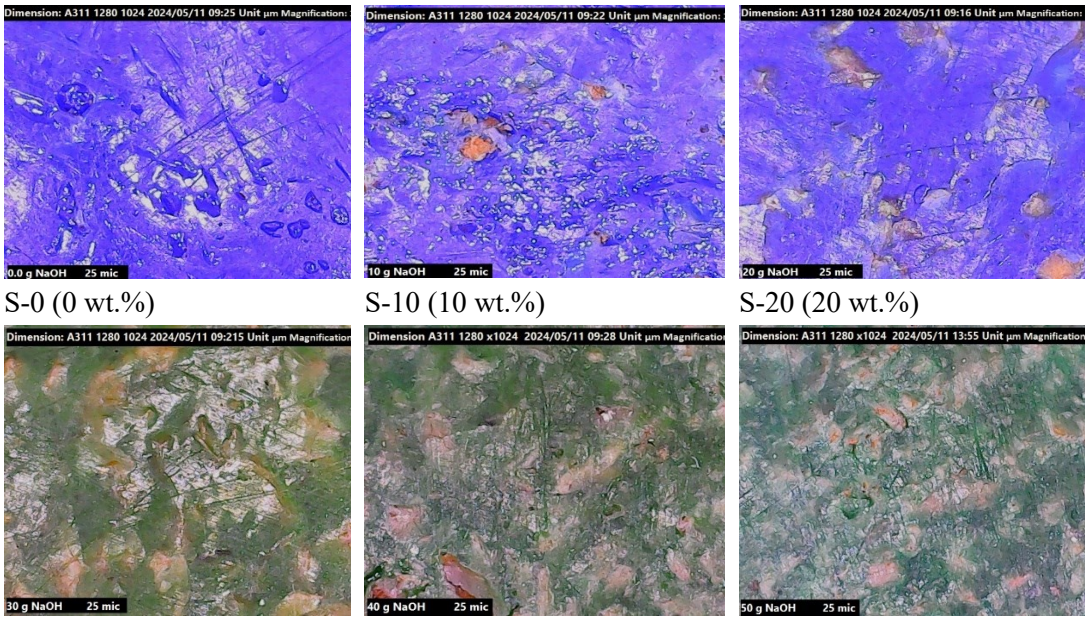
The initial decrease in flexural modulus observed for S-10 can be attributed to poor filler dispersion and weak filler-matrix bonding at low filler content. The modulus peaks at 30 wt.% filler (S-30), reflecting optimal reinforcement, where filler particles effectively distribute stresses and enhance stiffness. Alkali treatment of the corn cob removes impurities such as lignin and hemicellulose, increasing cellulose exposure and improving the bonding between the filler and the matrix. This is evident in the increase in modulus at 20 wt.% and 30 wt.%

filler contents. However, excessive filler content, as seen in Specimens S-40 and S-50, leads to agglomeration, which creates stress concentration points and reduces the modulus. At these higher filler levels, the filler particles dominate the composite's behaviour, resulting in brittleness rather than enhanced stiffness.

While specimen S-0 (unreinforced matrix) exhibits the highest flexural strength, its modulus is surpassed by specimen S-30 (30 wt.% filler), demonstrating the balance between strength and stiffness achieved at this filler content. Kontaxis et al. (2021) reported that unreinforced polymer matrices typically exhibit relatively high modulus due to their uniform structure, a trend consistent with S-0's performance in the present study.

Morphology of Composites

Figure 8 presents the SEM analysis, which illustrates the impact of filler weight percentages on surface morphology and, by extension, the composite's mechanical and physical properties. It was observed from the SEM analysis that the surface of the composite appears smoother with minimal inclusions or irregularities, characteristic of a polystyrene matrix without reinforcement (0 wt.% corn cob). Lack of structural heterogeneity indicates the absence of corn cob filler. This smooth surface generally results in weaker mechanical properties due to poor reinforcement. The introduction of corn cob (10 wt.% CCP content) results in visible particulate dispersion on the surface. Small agglomerates and some degree of fiber-matrix adhesion are evident. Slight roughness suggests improved structural reinforcement, but the lower filler content might not provide optimal mechanical interlocking.



S-0 (0 wt.%) S-10 (10 wt.%) S-20 (20 wt.%)

S-30 (30 wt.%) S-40 (40 wt.%) S-50 (50 wt.%)

Figure 8: Impact of NaOH and CCP Content on the SEM Analysis of Composites Produced.

At 20 wt.% corn cob (S-20), the surface of the composite shows increased roughness with more noticeable clusters of corn cob particles. Improved filler distribution contributes to a greater surface area for interfacial bonding. Some voids or pull-outs may appear due to incomplete adhesion at higher filler contents, though structural stability is generally enhanced. At 30 wt.% (S-30) loading of WCCP, significant roughness with visible particle clusters and better integration into the matrix is observed. Enhanced adhesion likely contributes to improved load transfer and mechanical properties. The matrix appears sufficiently wetted, reducing void content. Also, at 40 wt.% corn cob loading (S-40), the surface morphology becomes increasingly irregular, with prominent agglomerates and reduced matrix dominance. While filler integration is evident, excessive filler may lead to stress concentration points, reducing overall ductility. Similar work by Vaggar et al. (2021) reports that high filler content can lead to embrittlement and reduced impact resistance despite gains in tensile strength. The composite surface appears heavily dominated by filler particles at 50 wt.% (S-50) corn cob content, with significant agglomeration and reduced matrix coverage. Voids and pull-outs are more apparent, indicating poor filler-matrix adhesion at very high loadings. Mechanical performance might deteriorate due to diminished interfacial bonding and increased brittleness. The SEM results revealed that as corn cob content increases, the composite transitions from a smooth matrix-dominated structure to a rough, filler-dominated morphology. Optimal performance is expected between 20–30 wt.%, where filler distribution and matrix adhesion are balanced.

CONCLUSION

This study provides valuable insights into the influence of alkali treatment on the physical, mechanical, and morphological properties of waste corn cob-reinforced polystyrene foam composites. The findings highlight key trends associated with filler content and its interaction with the matrix. Flexural strength decreased with increasing filler content, indicating a loss in structural continuity at higher loadings. However, flexural modulus peaked at 30 wt.% (S-30), demonstrating improved load-bearing capacity at this filler level. Tensile modulus showed significant improvement at higher filler content, peaking at 50 wt.% (1858.215 MPa), while tensile stress decreased consistently due to poor stress transfer caused by filler agglomeration. Hardness was highest at 20 wt.% (388), emphasizing optimal dispersion and filler-matrix bonding at this level. Density decreased with increasing filler content due to the lower density of corn cob compared to polystyrene foam. Water absorption increased significantly at higher filler loadings, attributed to the hydrophilic nature of the untreated cellulose in corn cob particles. SEM analysis revealed enhanced interfacial bonding at moderate filler loadings, while higher loadings resulted in filler agglomeration and void formation, compromising mechanical performance. The results suggest that moderate filler content (20–30 wt.%) offers a balanced combination of mechanical reinforcement and structural integrity, making these composites suitable for lightweight, eco-friendly applications. This study emphasizes the viability of alkali-treated waste corn cob as a cost-effective and sustainable filler material for

polymer composites, supporting global efforts in waste valorization and environmental sustainability.

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