LAUTECH Journal of Engineering and Technology 20 (2) 2026: 146-157
10.36108/laujet/6202.02.0201

Modelling and Optimisation of Corncob-Reinforced Polymer Composite using Response Surface Methodology

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Article Info

Article history:

Received: April 13, 2026
Revised: July 29, 2026
Accepted: Aug. 4, 2026

Keywords:

Corncob,
Composite,
Polymer,
Tensile Strength

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ABSTRACT

This research involves the development and optimisation of corncob-reinforced polymer composites as an eco-friendly substitute for synthetic polymers. This is due to the need to mitigate the growing environmental pollution problems and the necessity to utilize agricultural waste materials. Corncob, a lignocellulosic material, was used as fiber reinforcement for the unsaturated polyester resin. This material was first processed and characterized to determine its chemical composition before being incorporated into the matrix at different fiber loading levels and fiber lengths. Response Surface Methodology (RSM) using a Box-Behnken design was applied in the investigation and optimisation of the effect of fiber loading level and fiber length on some mechanical properties such as tensile strength, flexural strength and impact energy. It was observed that both parameters have significant effects on composite properties, with interaction and quadratic effects being evident. Analysis of variance (ANOVA) proved the significance of the obtained models in terms of accuracy, as evidenced by high coefficients of determination ($R^2 > 0.96$). Optimisation of the model indicated that the best mechanical properties were obtained at 23.54% fiber loading and 1.04mm fiber length. These properties include 11.74 MPa tensile strength, 20.90 MPa flexural strength and 0.815 J impact energy. BET analysis resulted in a very high surface area of 266.971 m²/g with a high correlation coefficient (r = 0.99297), which indicates high porosity of the material. SEM analysis confirmed the uniform dispersion and porosity, while EDX analysis showed high silicon content apart from carbon and oxygen content. FTIR analysis identified the main functional groups, showing the presence of silicate, carbonyl, alkyl and hydroxyl functional groups.

INTRODUCTION

Research interest in biodegradable materials and renewable materials for engineering applications has been enhanced due to sustainability concerns, the depletion of fossil resources and the growing amount of agricultural waste produced (Sarmin *et al*., 2024). Recently, there have been significant changes and the use of many materials has changed to new materials that are much more environmentally friendly than what was used before. The materials used in this way can help to reduce damage to the environment and even boost performance. These residues from biomass production are becoming an alternative to synthetic reinforcements that are biodegradable, low-cost, easily available, carbon-neutral, and have low environmental impact (Kumar *et al*., 2025; Choudhary *et al*., 2023).

Polymer bio-composites development has been found to enhance the stiffness, strength and dimensional stability, and to foster resource efficiency and circular economy with the use of natural fillers (Jia *et al*., 2022; Ganopathy *et al*., 2024). As alternatives to petroleum-based materials, natural fibre-reinforced composites are emerging as an acceptable option for many engineering applications. Corncob (CC) is a by-product of maize processing, which is a lignocellulosic residue that not only hinders the use of maize but is also abundant in many developing regions (Kumar *et al*., 2022; Karchi *et al*., 2025). Traditional practices like open burning, dump disposal and indiscriminate dumping have been identified as causing environmental pollution, greenhouse gas emissions and their associated health impacts (Jia *et al*., 2020). Therefore, the use of corncob to create added-value products like polymer composites can provide a sustainable and economically viable solution, both in terms of waste management and the materials sector (Merinto and Miraculas, 2025; Stanescu *et al*., 2024).

Corncob, an important lignocellulosic biomass, can improve the strength and toughness of the polymer matrix structure (Kumar and Sah, 2022). The inclusion of one natural filler, however, could make certain properties more desirable, such as tensile strength and modulus, but it may not result in an optimum balance of strength, toughness and durability due to interfacial bonding and agglomeration of fillers and/or non-uniform dispersion of the filler. Although green fibre composites have attracted attention, there are very few systematic studies on corncob-reinforced epoxy composites, especially on optimizing the processing parameters and characteristics of the filler. The overall performance of composites can be strongly affected by key parameters like filler loading, particle size and fibre geometry, but the synergistic effect of these parameters is not well known. The knowledge gap has to be filled using powerful optimisation methods.

Response Surface Methodology (RSM) is a useful statistical and mathematical method to model, analyse and optimise complex processes that have several variables. It helps to build predictive models, analyze interactions between variables and identify the best conditions of operation using fewer experiments. This is especially applicable for designing and optimizing composite processes. The corncob-reinforced polymer composite was prepared in this study with different corncob loading levels and particle sizes. The mechanical properties of the prepared composites, such as tensile strength, flexural strength and impact energy, were tested. Focus was given on the mechanisms of fibre–matrix interactions, the effect of process parameters and the performance trade-offs. Thus, the purpose of this study is to develop predictive models using RSM and find optimum process parameters to develop a corncob-based polymer composite with enhanced mechanical properties for the sustainable development of materials, and to utilize agricultural waste efficiently.

MATERIALS AND METHODS

Materials and Equipment

Unsaturated polyester resin (UPR) and methyl ethyl ketone peroxide (MEKP) were manufactured by ebenCHEM Germany and were bought from Galaxy Interiors and Epoxy Venture, Abuja. Corncob was purchased from local traders in Umuahia. All the reagents and glassware used were purchased from General Sales Organization, Chemical, Enugu, Enugu State. Fourier infrared spectrometer (Bruker Alpha I, U.S.A), an SEM/EDX machine (Hitachi TM – 400) anda universal testing machine were manufactured by Wincom, China.

Corncob Materials Preparation

Corncob used as composite was air-dried for one week. The dried materials were crushed using a milling machine. The crushed samples were sieved using a sieve size of 250 µm. This was to obtain uniform-sized samples with enhanced surface area. Figures 1a and b are whole and ground corncob.

Figure 1a: Corncob

Figure 1b: Ground Corncob

Lignocellulose Characterization of Corncob

Sample defatting (extractives): 200 g of sample was measured with an electronic balance and put in a 1000 mL flat-bottom flask. The sample was shaken vigorously after the addition of 250 mL of n-hexane to fully cover the sample. The flask was covered and fixed with aluminum foil and tape and the flask was set aside for 48 hours to complete extraction of fats. Following extraction, the n-hexane-containing oil was decanted and the sample was dried in the air at ambient temperature. The percentage fat content was determined by using equation 1:

$$Fat\ (\%) = \frac{\text{Initial wt.of sample} - \text{final wt.of sample}}{\text{Initial wt.of sample}} \times 100 \quad (1)$$

Bleaching (lignin removal): The defatted sample was placed in a three-necked round-bottomed flask. 7.5% (w/v) hydrogen peroxide (H_2O_2) was added to the solution. The system was equipped with a reflux condenser and lignin was removed from the system at 90oC for 2 hours. During heating, cold water was circulated through the condenser jacket. The resulting mixture was cooled, vacuum-filtered, washed with hot water to neutral pH and dried at ambient temperature. The formula is displayed in equation 2.

$$(\%) = \frac{\text{Initial wt.from lignin removal} - \text{final wt.}}{\text{Initial wt.}} \times 100 \quad (2)$$

Sodium hydroxide treatment (hemicellulose removal): The bleached sample was transferred into a flat-bottom flask and 500 mL of 18% NaOH solution was added to the flask. The mixture was stirred for 30 minutes at room temperature, with the use of aluminium foil covering the mixture. The mixture was filtered, washed with 500 mL of 20% acetic acid (hot) to neutralize the alkali and then washed with distilled water until neutral pH was attained. The solid fraction was dried. The hemicellulose content was calculated from equation 3:

$$Hemicellulose\ (\%) = \frac{\text{Initial wt. from hemicellulose removal} - \text{final wt.}}{\text{Initial wt.}} \times 100 \quad (3)$$

Total ash: A clean porcelain crucible was weighed (w1). About 2 g of sample (w2) was added and heated in a furnace at 600°C for 3 hours to burn off organic matter. The crucible was cooled in a desiccator and reweighed (w3). The formula is displayed in equation 4.

$$Ash\ (\%) = \frac{\text{Sample weight (w2)} - \text{weightloss}}{\text{w2}} \times 100 \quad (4)$$

Cellulose Content

The quantity of cellulose was calculated by difference, as shown in equation 5:

Cellulose (%) =100 - (Fat + Lignin + Hemicellulose + Ash) (5)

Design of Experiment for the Composite Preparation

The two independent parameters have their ranges: fibre loading (15, 20 and 25) % and length (1, 3 and 5) mm, as shown in Table 1, were evaluated to investigate how they affected tensile strength, flexural strength and impact energy of the composite.

Table 1: Factor Range for the Composite Preparation

Factor	Units	Low level	Mid level	High level
Fibre loading	%	15	20	25
Fibre length	mm	1	3	5

RESULTS AND DISCUSSION

Lignocellulose Characterization Results

The results presented in Table 2 indicate that corncob has a higher hemicellulose content (36.434 %) and oil content (8.489 %) that may affect its moisture absorption and dimensional stability properties.

Process Optimisation using Design Matrix

The experimental results obtained by using the Box-Behnken Design (BBD) for the study of the effect of the major process parameters on the composite production are presented in Table 3. To systematically explore the influence of the input variables on the tensile, flexural and impact properties, a total of 13 experimental runs were performed. The model equations are shown in equations 6,7 and 8, respectively. The results demonstrated that all the selected factors significantly influenced the process. To establish a mathematical relationship between the process parameters and response, a second-order (quadratic) polynomial model was developed using response surface methodology (RSM). The independent variables used were: (A) fibre loading, (B) fibre length. The individual and combined effects of these factors on output were tested and optimized by the RSM method. Multiple regression analysis was used to construct the regression model, which is expressed as a quadratic polynomial. The linear coefficient represents the direct effect of each variable on the response, whereas the interaction and quadratic coefficients represent combined and non-linear effects, respectively (Sarmin *et al*., 2024; Jia *et al*., 2024; Stanescu *et al*., 2024).

Table 2: Lignocellulose characterization of corncob

Sample	Moisture (%)	Lignin (%)	Hemicellulose (%)	Ash (%)	Oil (%)	Cellulose (%)
Corncob	3.461	19.189	36.434	1.642	8.489	30.785

Table 3: Process optimisation using design matrix

Run	Fibre loading (%)	Fibre length (mm)	Tensile strength	Flexural strength	Impact energy
1	20	3	15.8	27.9	0.91
2	20	3	15.8	27.9	0.91
3	25	1	10.8	18.2	0.83
4	25	5	14.98	23.4	0.88
5	20	3	15.8	27.9	0.91
6	20	3	15.8	27.9	0.91
7	20	0.171573	8.2	14.9	0.58
8	15	5	10.9	19.7	0.75
9	15	1	9.2	15.6	0.61

10	27.0711	3	16.7	28.6	0.99
11	12.9289	3	11.7	19.5	0.66
12	20	3	15.8	27.9	0.91
13	20	5.82843	11.9	17.9	0.75

Tensile strength = 15.80 +1.59A +1.39B + 0.622AB - 0.9637A^2 -3.04B^2 (6)

Flexural strength = 27.90+ 2.40A +1.69B +0.2750AB- 2.17A^2- 6B^2 (7)

Impact energy = 0.91 + 0.1021A+ 0.0538B- 0.0225AB-0.0369A^2-0.1169B^2 (8)

Where A = fibre loading (%), B = fibre length (mm).

ANOVA Analysis

Tables 4, 5 and 6 present the statistical evaluation for tensile strength, flexural strength and impact energy, respectively, which shows that the linear terms (A: fibre loading and B: fibre length), interaction term (AB) and quadratic terms (A^2 and B^2) are significant to the mechanical properties of the developed composites. This indicates that individual factors and their interactions are important for the composite performance when fabricating it. Key statistical indicators support the models developed as quadratic models to be adequate and reliable. The coefficient of determination (R^2 = 0.9890), the adjusted R^2 (0.9812) and the predicted R^2 (0.9219) show very good agreement between the experimental and the predicted values for tensile strength. Similarly, for flexural strength, R^2 = 0.9692, adjusted R^2 = 0.9472, and predicted R^2 = 0.7810, while for impact energy, R^2 = 0.9856, adjusted R^2 = 0.9752, and predicted R^2 = 0.8973. The high values of R^2 suggest that these models explain a significant amount of the variation in the responses. The adjusted R^2 values are close to the predicted R^2 values, especially for tensile strength and impact energy, indicating that there is not much overfitting of the models and that they have good predictive capabilities in the design space.

A slightly larger deviation can be seen in the flexural strength model, but still within an acceptable range, which means that the model performs well. All the precision values achieved are much higher than the minimum value of 4, indicating good signal-to-noise ratios and good confidence in the accuracy of the models for use to navigate the design space. In addition, all lack-of-fit tests are not statistically significant ($p>0.05$), which means that the differences between the experimental and predicted responses are due mainly to random experimental error and not the model. The low standard deviation values and the coefficients of variation (C.V. <10%) are also indicative of good reproducibility and precision of the obtained experimental data and further support the reliability of the models. There is a great deal of consistency between the predicted and observed responses. Overall, it has been noted from the statistical results that prove that the developed RSM models are robust, reliable, and suitable for prediction and optimisation of mechanical properties of corncob-reinforced polymer composites. The results also indicate that proper regulation of the fibre loading and fibre length in composite preparation is essential for optimal performance of the materials (Ganopathy *et al*., 2024; Karchi*et al*., 2025; Patnaik *et al*., 2022).

Optimisation Studies

The optimisation study was performed using Response Surface Methodology (RSM) to determine the optimum processing variables needed to obtain a composite with a well-balanced improvement of mechanical properties. Under the optimum condition, the fibre loading was 23.544% and the fibre length was 1.04134 mm.

Table 4: ANOVA for quadratic model for tensile strength

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	103.81	5	20.76	126.13	< 0.0001
A-fibre loading	20.32	1	20.32	123.46	< 0.0001
B-fibre length	15.44	1	15.44	93.77	< 0.0001
AB	1.54	1	1.54	9.34	0.0184
A^2	6.46	1	6.46	39.25	0.0004
B^2	64.24	1	64.24	390.22	< 0.0001
Residual	1.15	7	0.1646		
Lack of Fit	1.15	3	0.3841		
Pure Error	0.0000	4	0.0000		
Cor Total	104.96	12			
Std. Dev.	0.4057	R^2	0.9890		
Mean	13.34	Adjusted R^2	0.9812		
C.V. %	3.04	Predicted R^2	0.9219		
		Adeq Precision	30.3604		

Table 5: ANOVA for quadratic model for flexural strength

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	333.32	5	66.66	44.06	< 0.0001
A-fibre loading	45.93	1	45.93	30.36	0.0009
B-fibre length	22.93	1	22.93	15.15	0.0060
AB	0.3025	1	0.3025	0.1999	0.6683
A^2	32.91	1	32.91	21.75	0.0023
B^2	250.43	1	250.43	165.51	< 0.0001
Residual	10.59	7	1.51		
Lack of Fit	10.59	3	3.53		
Pure Error	0.0000	4	0.0000		
Cor Total	343.91	12			
Std. Dev.	1.23	**R^2**	0.9692		
Mean	22.87	**Adjusted R^2**	0.9472		
C.V. %	5.38	**Predicted R^2**	0.7810		
		Adeq Precision	17.2245		

Table 6: ANOVA for quadratic model for impact energy

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	0.2069	5	0.0414	95.52	< 0.0001
A-fibre loading	0.0834	1	0.0834	192.46	< 0.0001
B-fibre length	0.0232	1	0.0232	53.46	0.0002
AB	0.0020	1	0.0020	4.67	0.0674
A^2	0.0095	1	0.0095	21.84	0.0023
B^2	0.0950	1	0.0950	219.36	< 0.0001
Residual	0.0030	7	0.0004		
Lack of Fit	0.0030	3	0.0010		

Pure Error	0.0000	4	0.0000
Cor Total	0.2099	12	
Std. Dev.	0.0208	**R^2**	0.9856
Mean	0.8154	**Adjusted R^2**	0.9752
C.V. %	2.55	**Predicted R^2**	0.8973
		Adeq Precision	28.4843

Under these optimum conditions, the composite had a tensile strength of 11.7404 MPa, flexural strength of 20.9024 MPa, and impact energy of 0.814688 J. These values represent the ideal balance of strength, stiffness and toughness, reflecting good transfer of stresses between fibre and matrix, and thus good bonding at the fibre-matrix interphase. The enhancement in mechanical properties at moderate fibre loading observed in the study is attributed to the optimal distribution of fibres in the polymer matrix; thereby, the load-bearing capacity of the composites increases without fibre agglomeration or poor fibre wetting in the polymer matrix. Similarly, the relatively short fibre length helps to achieve a more even distribution of stress and reduces the number of stress concentration points that might cause failure. Moreover, the optimized outcomes demonstrate the importance of the relationship between fibre length and fibre loading, as both have a combined effect on the overall composite performance. Longer fibre lengths or excessive fibre loading can result in inferior mechanical efficiency as a result of poor matrix adhesion, increased void content and fibre entanglements. The results are similar to those of Sarmin *et al*. (2024)on Sisal and Bamboo reinforced composites, respectively. The results overall show that it is crucial to carefully control and optimize the processing parameters to ensure the desirable properties of the composite are achieved. The optimized conditions give a practical guideline for the preparation of high-performance, environmentally friendly composites obtained from agricultural residues such as Corncob (Merinto and Miraculas, 2025; Kumar *et al*., 2022). The conditions are shown in Figure 2.

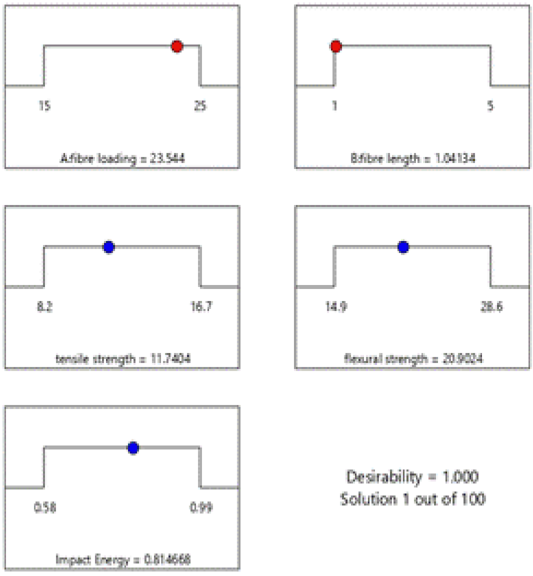

Figure 2: Optimisation ramp graph

Analysis of the Optimized Composite

The developed Corncob composite is shown in Figure 3.

Figure 3: Corncob hybrid composite

SEM Analysis

The SEM micrograph in Figure 4 at higher magnification (8000×) illustrates the surface topography of the developed composite, clearly demonstrating the dispersion of corncob particles throughout the matrix material. The image suggests that the reinforcing particles are relatively evenly dispersed throughout the image, indicating good interfacial adhesion between the corncob phases. This uniformity is crucial to stress transfer and better composite performance. The morphological characterization of the corncob composite has been performed at 8000× and 10000× using scanning electron microscopy (SEM), in Figures 4 and 5. The overall surface appears rough and uneven, with some areas appearing more compacted than others, suggesting a relatively dense structure in general. The compacted zones are useful because they increase the bonding between the particles and lead to increased mechanical strength. The presence of gaps and voids in the visible area of some areas, however, indicates local porosity that can act as local stress concentration and crack initiation points. A higher level of magnification in Figure 5 (10000×) gives the SEM image a more detailed view of the particles, showing the presence of surface texture, size variation and the interactions between the fibrous and particulate components.

The composite material seems to be composed of interlocked particles and fibrous components, both of which are densely packed and interspersed with gaps. The compact parts are beneficial for load-bearing; however, on the application of mechanicalload, the observed voids can affect the structure. Also, the porosity can be used to provide moisture movement into or out of the material for applications requiring moisture permeability or moisture interactions. Applications that demand dimensional stability and moisture resistance, on the other hand, may have an issue with the porosity. The results from the SEM tests indicate that the composite has a heterogeneous microstructure, but they bond well. This is in agreement with previous studies on composite materials that suggest that the dispersion, bonding of the matrix/interface and porosity are critical factors in determining the mechanical and functional properties of composite materials (Zhang *et al*., 2022; Kailasanathan *et al*., 2022; Ghaib *et al*., 2024).

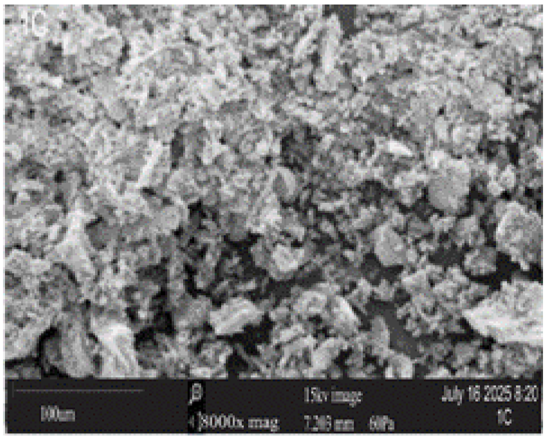

Figure 4: SEM of the composite (8000x magnification)

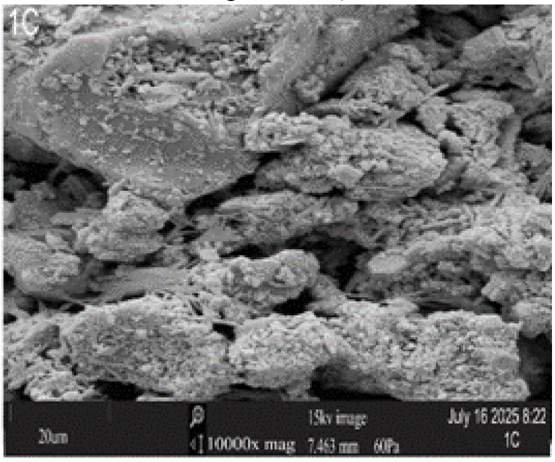

Figure 5: SEM of the composite (10000x magnification)

Elemental Composition (EDX) Analysis

The EDX analysis of the composite material in Figure 6 shows that the material is mainly made up of silicon (57.0%), carbon (19.5%) and oxygen (10%). Minor constituents include iron (5.5%), calcium (4.5%), magnesium (4.0%), and sulfur (3.0%). This elemental composition reflects the heterogeneous composition of the corncob composite; it also provides some clues regarding the potential functional properties of the composite. The silicon content is also high, indicating good thermal stability, hardness, and

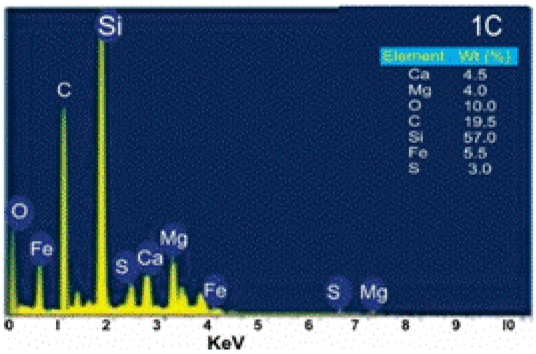

Figure 6: EDX of the composite

durability, which are crucial for structural and high-temperature applications. Carbon provides greater mechanical strength and may also increase electrical conductivity; oxygen is related to the formation of oxides and surface functional groups, which can affect interphase interactions and reactivities. The presence of calcium indicates that it might be used as a filler material, enhancing stiffness and biocompatibility in certain applications. In moderate amounts, iron can provide magnetic properties to the product, but may also make it more prone to corrosion in certain environments. Magnesium has been proven to improve the strength-to-weight ratio and can affect the chemical reactivity and the behavior of the interface bonds, and sulfur can affect the chemical reactivity and the behavior of the interface bonds. In general, these components' occurrence and distribution in the composite matrix are important factors in determining the mechanical, thermal, and physicochemical properties of the material. The EDX results can thus serve as a foundation for correlating the elemental composition of the material with the performance characteristics, and for optimizing the elemental composition for specific applications such as structural applications, environmental applications and biomedical applications. The obtained results are similar to those reported by other authors in their studies on SEM–EDX analysis of complex materials (Guyett *et al*., 2024; Sevimoğlu*et al*., 2024; Piergiovanni *et al*., 2024).

FTIR Analysis

The Fourier Transform Infrared (FTIR) analysis of the obtained composite material presented in Figure 7 gives insight into the functional groups that are responsible for the physicochemical behavior of the composite, including the properties of relatively low water uptake. The absorption feature at 665.3 cm-1 is believed to be the C–H bending or Si–O stretching mode, providing evidence for organic components and perhaps silicate structures.

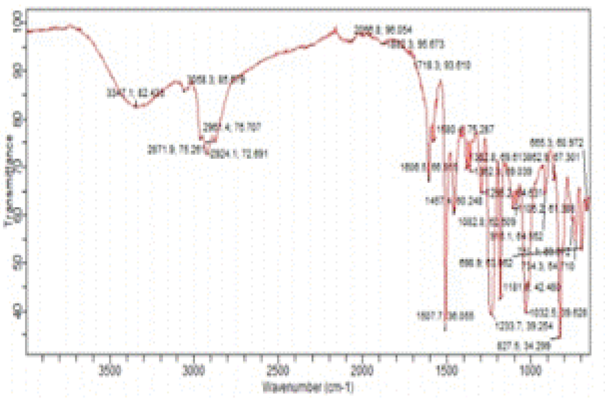

Figure 7: Image of FTIR Analysis

The peak at 1718.3 cm⁻¹ is attributed to C=O stretching vibrations, indicating the presence of carbonyl functional groups, which can come from hemicellulose and lignin in the lignocellulosic materials. The band located at 2871.9 cm-1 can be related to the C–H stretching of the aliphatic (alkyl) groups, which indicates the presence of the main chain of the composite material. In addition, the very wide absorption band at 3347.1 cm⁻¹ has been attributed to the O–H stretching vibrations, which suggests the presence of hydroxyl groups. The presence of these hydroxyl groups is characteristic of cellulose and hemicellulose, but their relative intensity is observed to be limited, meaning there are few available free hydrophilic sites, corresponding to the observed reduced water absorption properties. The overall analysis of the

FTIR data shows that there are organic as well as inorganic functional groups present in the composite, indicating that it has a complex structure and is likely to be moisture resistant. The spectral properties are essential for the understanding of the interaction between the composite constituents and for the design of the different properties of the material for specific engineering applications.

A relatively hydrophobic functional group, such as C–H and C=O, also plays a significant role in the reduced water uptake in the composite. These groups decrease the number of sites within the polymer where hydrogen bonding can occur with water molecules and therefore the ability of the polymer to absorb water. The presence of hydroxyl (O–H) groups may allow some water interaction in what are generally less polar functional groups, but do not dominate the interaction. As a result, the overall tendency of the material to bind water is decreased. The composite materials' water absorption capabilities, which are controlled, suggest they might be suitable for a range of applications where water resistance or moisture sensitivity is crucial, such as protective materials, packaging, or structural components in humid environments. Moreover, the interactions between the functional groups and the bonding at the interface of the identified functional groups with the composite matrix may influence important mechanical properties like strength, stiffness and toughness. Furthermore, these functional groups, notably carbon-based and oxygen-containing groups, may also influence thermal stability and conductivity, and thus heat transfer and degradation. The overall interpretation of the FTIR data gives an insight into the performance characteristics of the composite at the molecular level. These observations are in agreement with the earlier studies which have focused on the role of functional groups and their influence on the properties and performance of materials (Obaid and Al-Bermany, 2024; Bhuiyan *et al*., 2024).

BET Analysis

According to the BET analysis in Table 8, the material had a large surface area of 266.971 m2/g, which can affect its adsorption properties, reactivity and interactions with its environment. The correlation coefficient (r = 0.999297) was high, suggesting a strong correlation between the data and highlighting the linear relationship between the two variables, which could provide useful insight into the surface area and porosity of the composite material. The results obtained are comparable to the work done by Ravi and Thyagarajan (2024) on the Structural and magnetic properties of $CoFe_2O_4/NiFe_2O_4/CeO_2$ nanocomposites, Farghaly *et al*. (2024) on the Synergic photocatalytic degradation of methylene blue over TiO2 composites with activated carbon and reduced graphene oxide: kinetic and mechanistic study and Salama *et al*. (2024) on the synthesis and characterization of magnesium ferrite-activated carbon composites derived from orange peels for the enhancement of supercapacitor performance.

Table 8: BET Results

Parameter	Value
Surface area	266.971m^2/g
Correlation coefficient (r)	0.99297
C constant	2.801
Slope	8.388
Intercept	4.657e+00

CONCLUSION

In this study, the feasibility of using corncob as a sustainable lignocellulosic reinforcement material for the production of polymer composites was successfully shown. The characterization results showed that the corncob has a high cellulose and hemicellulose level, which is suitable for use as an improvement material for the mechanical properties of composite materials. Response Surface Methodology (RSM) was used to develop reliable predictive models for tensile strength, flexural strength and impact energy as a function of fibre loading and fibre length. The statistical analysis (ANOVA) showed that both the factors, the interaction between these factors and the quadratic terms significantly affect the mechanical performance of the composite and the high R2 values and insignificant lack-of-fit further validated the robustness and predictive power of the models. The optimisation results indicated that moderate fibre loading and short fibre length give the optimum balance of mechanical properties. This highlights the importance of proper parameter control in composite fabrication. Although some voids were observed, good interfacial bonding and uniform dispersion were observed by SEM, which may affect long-term durability. The presence of functional groups and elements that are responsible for the mechanical, thermal and chemical behavior of the composite was confirmed through the EDX and FTIR analyses. Also, the high BET surface area (266.971 m^2/g) indicates its potential for adsorption applications. In conclusion, the study demonstrates the potential of using agricultural residues like corncob to create eco-friendly, cost-effective, high-performance composites, thus advancing the sustainable development of materials and promoting the principles of a circular economy.

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