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DEVELOPMENT AND CHARACTERIZATION OF BANANA FIBER (TREATED & UNTREATED) REINFORCED HPMC FILMS

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ABSTRACT

This research explores the promising potential of Hydroxypropyl Methylcellulose (HPMC) composites enriched with banana fibers, aiming to enhance mechanical and thermal properties for versatile applications, particularly in biomedicine. The study investigates different banana fiber percentages and novel plasticizers' effects on these composites, emphasizing the use of glycerol to improve flexibility and processability. Banana fiber-reinforced HPMC films were successfully fabricated with varying loadings (2%, 4%, 6%, and 8%) and were characterized using various analytical techniques. The key findings include improved thermal stability with chemical treatment of banana fibers, the optimal enhancement of tensile modulus at 4% treated banana fiber loading, and the significant improvement in mechanical properties through alkaline treatment. Enhanced adhesion between fibers and matrix, confirmed by SEM analysis, underscores the potential of banana fiber-reinforced composites for engineering applications, such as automotive interiors, packaging, and construction, due to their improved mechanical and thermal properties.

1.INTRODUCTION

This research delves into the promising realm of HPMC composites enriched with banana fibers, offering versatility and adaptability for diverse applications. Incorporating natural fibers into polymer matrices has emerged as a means to enhance film and composite mechanical and thermal properties, particularly in the biomedical domain. Existing literature underscores the potential of HPMC composites and fiber-reinforced films, yet a comprehensive exploration of various fiber percentages and their impact on physico-chemical properties remains a gap. This study also ventures into uncharted territory by investigating novel plasticizers and their effects on these composites. The research focuses on preparing and characterizing banana fiber-reinforced HPMC films via the solution casting method. Glycerol serves as a chosen plasticizer to enhance flexibility and processability, a facet not extensively explored in existing knowledge. The specific objectives encompass the development of these films across different weight percentage ratios, followed by thorough characterization using various analytical techniques. The study's broader purpose is to contribute to the field of polymer composites, offering potential applications, especially in biomedicine, and addressing pressing challenges across industries, ultimately benefiting society at large.

2. MATERIALS AND METHOD

2.1 Materials Used

For synthetic purpose Analytical grade (Sigma Aldrich, BDH, Merck, Ranbaxy) HPMC and
glycerol was used. Banana fiber was bought from banana fiber products, Wayanad, Kerala. Sodium hydroxide was supplied in pellet form by Fisher Scientific India Pvt. Ltd.
Base matrix- HPMC, Reinforcement material- Banana fiber (treated and untreated). The solvents were purified by standard methods. The characteristics of HPMC, banana fiber and glycerol are given in Table

Sl.no	Material	Molecular weight (g/mol)	Solubility
1	HPMC	373447	Water
2	Glycerol	92.10	Water
3	Sodium hydroxide pellets	40	Water

Table 2.1 Physical characteristics of the polymers used

2.2 Method

The study utilized the solution casting method to create polymer-reinforced films. Banana fibers were prepared by cleaning, cutting into 10mm pieces, and drying at 90°C for 6 hours to remove moisture and impurities. For the film matrix, a 5% HPMC solution with 1% glycerol as a plasticizer was prepared. To maintain uniform film thickness, the solution volume was kept constant. The HPMC solution was prepared with continuous stirring, left to stand for 10 minutes, and then dried in a hot air oven at 80°C for 7 hours. The resulting films were stored in a desiccator to prevent moisture absorption. Similarly, banana fiber-reinforced HPMC

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films were created by adding banana fibers at varying weight percentages (2%, 4%, 6%, 8%) to the HPMC solution. These films were prepared using the same methodology as pure HPMC films.
Chemically treated banana fibers were produced by soaking them in a 5% NaOH solution for 6 hours, followed by thorough washing and drying. Four sets of HPMC films containing treated banana fibers at different weight percentages (2%, 4%, 6%, 8%) were prepared using the same procedure. These methods ensure consistency in film preparation and enable the investigation of how both untreated and treated banana fibers affect the properties of the resulting films.

Sample code	% Of HPMC	% Of Banana fiber
HPMC	100	0
HB100/2	100	2
HB100/4	100	4
HB100/6	100	6
HB100/8	100	8

Table2.2 Formulation of films

Fig 2.1 (a) Untreated Banana Fiber (B) Treated Banana Fiber

3.RESULTS AND DISCUSSION

3.1 FTIR-ATR Analysis

The FTIR spectra of the untreated and treated banana fiber in the wavenumber range of 500–4000 cm^{-1} are shown in Fig. 3.1

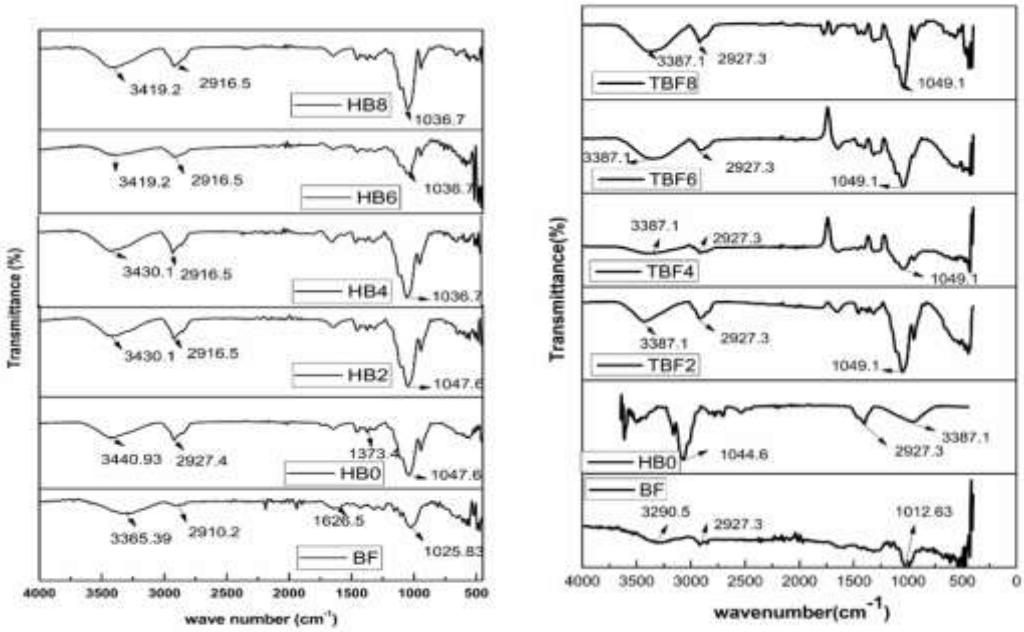

Fig 3.1 (a) FTIR spectra of untreated banana fiber HPMC film, (b) FTIR spectra of treated banana fiber HPMC film

Banana fiber contains cellulose microfibrils with hydrogen bonding in the cell wall, forming a crystalline structure. Major absorption bands in banana fiber are due to lignocellulosic components: O-H stretching at 3500-3100cm^{-1}, C-H stretching at 2940 cm^{-1}, and C=C bond in lignin at 1640 cm^{-1}. The 1105-1155cm^{-1} band corresponds to cellulose stretching. Treated banana fiber lacks the 1740 cm^{-1} carbonyl C=O band, indicating the absence of hemicellulose[1]. HPMC (Hydroxypropyl methylcellulose) shows peaks at 3500-3220 cm^{-1} for O-H stretching and 1000-1100 cm^{-1} for C-O stretching. The fingerprint region between 800 and 1490 cm^{-1} indicates cellulose in HPMC. Comparing treated and untreated banana fiber HPMC film, the OH stretching frequency decreased from 3420-

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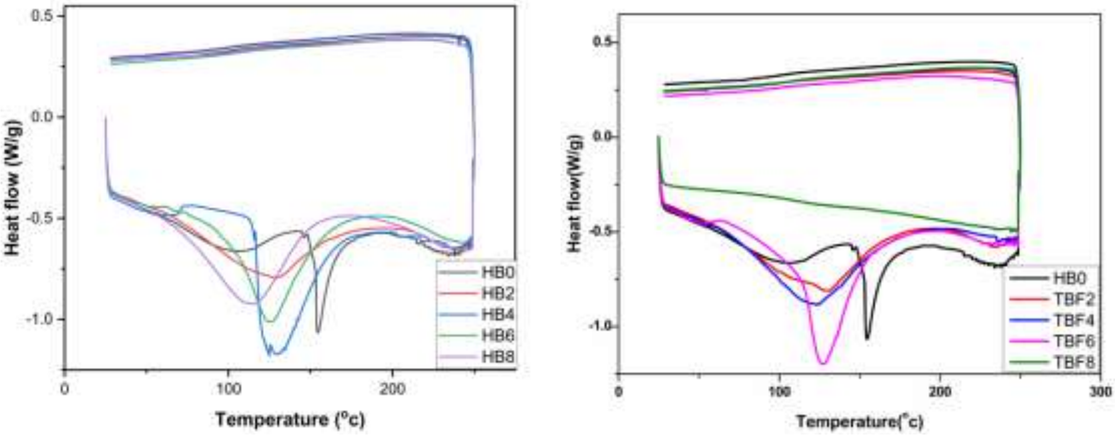
30 to 3387 cm^{-1}, suggesting intermolecular hydrogen bonding between HPMC and banana fiber, causing the shift in the -OH absorption band to a lower frequency.

3.2 Differential Scanning Calorimetry (DSC)

In Figure 3.2, DSC curves for HPMC under a nitrogen atmosphere at a heating rate of 10°C/min are shown. The DSC thermogram of banana pseudo-stem resembles that of other lignocellulosic fibers. The peak in the DSC curve (around 50–150°C) represents moisture evaporation from the fiber. Lignin degradation starts at approximately 200°C, while hemicellulose and cellulose degrade at higher temperatures. Chemical treatment can enhance the thermal stability of banana fiber by removing hemicellulose and lignin, leading to improved interfacial adhesion and fiber roughness [2]. Pure HPMC exhibits a broad endothermic transition between 60 and 150°C, with a peak around 110°C [3]. The endothermic peak of HPMC films, both treated and untreated with banana fiber, increases with higher weight percentages of banana fiber. This increase is greater than that of HPMC alone, indicating that the addition of banana fiber enhances HPMC's thermal stability due to interactions between HPMC and banana fiber molecules. Treated banana fiber HPMC film offers greater thermal stability compared to the untreated film.



(a) (b)

Fig 3.2 DSC curves of (a) untreated banana fiber HPMC film, (b) treated banana fiber HPMC film

3.3 Thermo-Gravimetric Analysis (TGA)

Fig. shows the TGA curves obtained from tests. The thermal degradation analysis conducted in a nitrogen environment with a constant heating rate of 10°C/min revealed key insights. Untreated banana fiber showed an initial degradation at 178°C due to the presence of hemicellulose, with acetyl groups contributing to its decreased stability. Cellulose degradation followed at 296°C, followed by lignin degradation [61]. HPMC, characterized by strong hydrogen bonding and rigidity, exhibited high thermal stability, elevating the degradation temperature. This increase can be attributed to the physical interaction and cohesive strength between HPMC and banana fiber. HPMC itself began degrading at 500°C [3]. The TGA graph indicated that the degradation of banana fiber incorporated with HPMC fell between these two extremes. Notably, untreated fiber films lost weight earlier at 288.47°C compared to treated fiber films at 304.5°C. Additionally, untreated fiber experienced higher weight loss at various temperatures, likely due to the effective removal of hemicellulose and waxes from the banana fiber surface during treatment, resulting in improved thermal stability of the treated fibers.

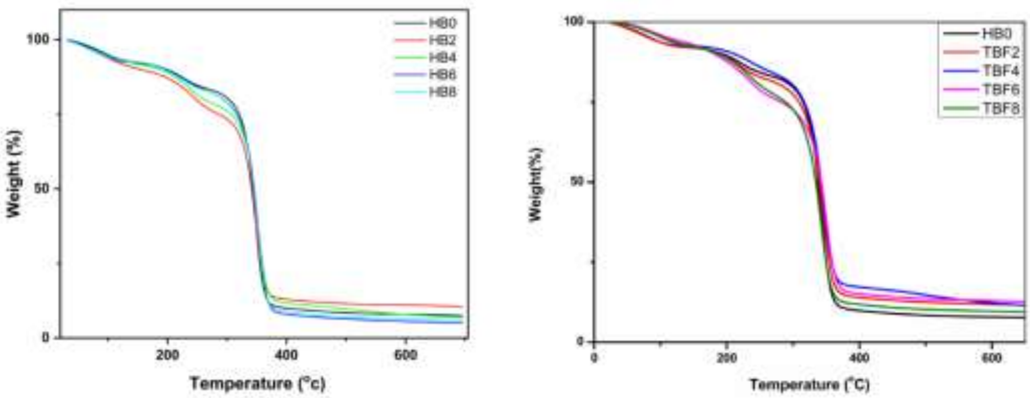


Fig 3.3 TGA curves of (a) untreated banana fiber HPMC film, (b) treated banana fiber HPMC film

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3.4 X-ray Diffraction (XRD) Analysis

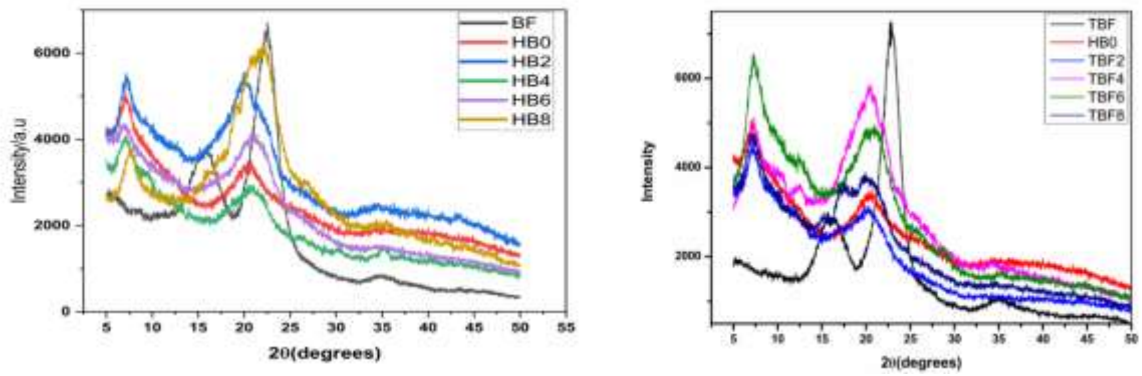


Fig 3.4 XRD spectra of (a) untreated banana fiber HPMC film, (b) treated banana fiber HPMC film

The X-ray diffractograms of both treated and untreated banana fiber HPMC films reveal a combination of crystalline and amorphous regions. Banana fibers predominantly exhibit the cellulose I structure with prominent peaks at $2\theta = 16°$ (I_{101}) and $2\theta = 22°$ (I_{002}) [5]. Comparing the X-ray patterns, it's evident that the signal characteristics in different fiber conditions are similar. The increase in banana fiber content from 2% to 8% results in minor changes in crystallinity for both treated and untreated banana fiber-reinforced HPMC composites. The intensity of the HPMC pattern increases with added banana fiber, indicating reduced amorphousness in the matrix due to the fiber addition. This increase in crystallinity suggests decreased miscibility between the components.

3.5 Thickness and Mechanical Properties

The tensile properties of treated and untreated banana fiber-reinforced HPMC films, including tensile strength, Young's modulus, and % elongation, were investigated. The results, as shown in the figure, reveal that both treated and untreated banana fiber-reinforced HPMC films exhibit increased tensile strength compared to HPMC films without reinforcement. This suggests improved stiffness in the fabricated films, attributed to strong adhesion between the hydrophilic fibers and the matrix. Specifically, a maximum tensile strength of 20.2 N/mm² was observed for the 4% banana fiber-loaded (treated) HPMC film, in contrast to 12.2 N/mm² for the unloaded film. Notably, the incorporation of treated banana fiber into the HPMC matrix led to more significant improvements in tensile strength compared to untreated banana fiber. This improvement is indicative of the effective removal of hemicellulose and other non-cellulosic substances from the fiber surface, resulting in enhanced adhesion between the fibers and the matrix [6], [7].

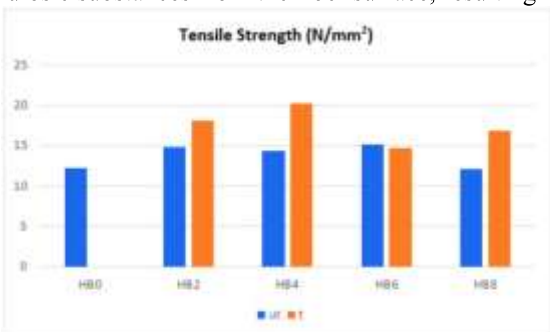


Fig 3.51 Tensile Strength Graph of untreated and treated banana fiber HPMC film

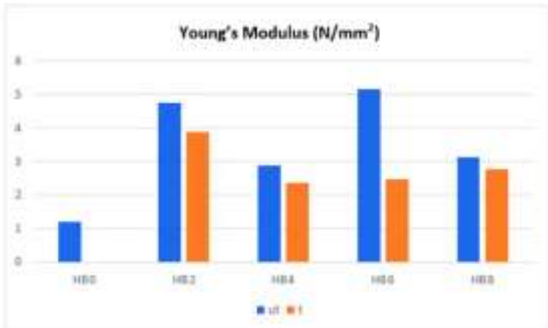


Fig 3.52 Young's modulus graph of untreated and treated banana fiber HPMC film

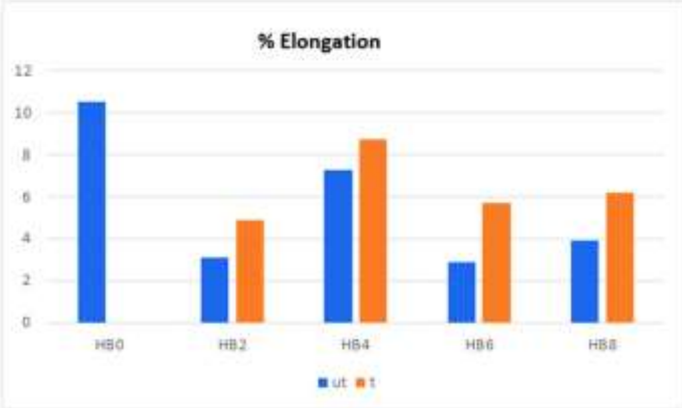
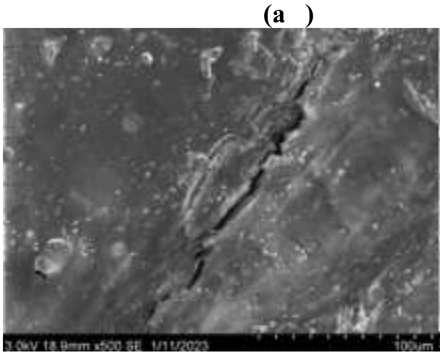
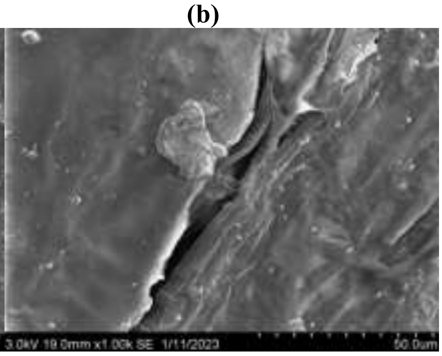


Fig 3.53 Percentage elongation graph of untreated and treated banana fiber HPMC films

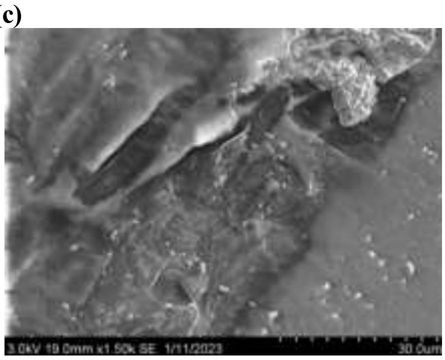
3.6 Surface Morphology Analysis

Morphological examination confirms improved adhesion between the hydrophilic matrix and fibers following alkali treatment. Complete coverage of banana fiber by the matrix indicates strong bonding. Homogeneous fiber dispersion within the matrix, along with excellent adhesion, contributes to the superior mechanical properties of the composite.


(a) **(b)**

(c) **(d)**



(e)

Fig 3.61 SEM images of untreated banana fiber reinforced HPMC films a) 0% b) 2% c) 4% d) 6% e) 8%

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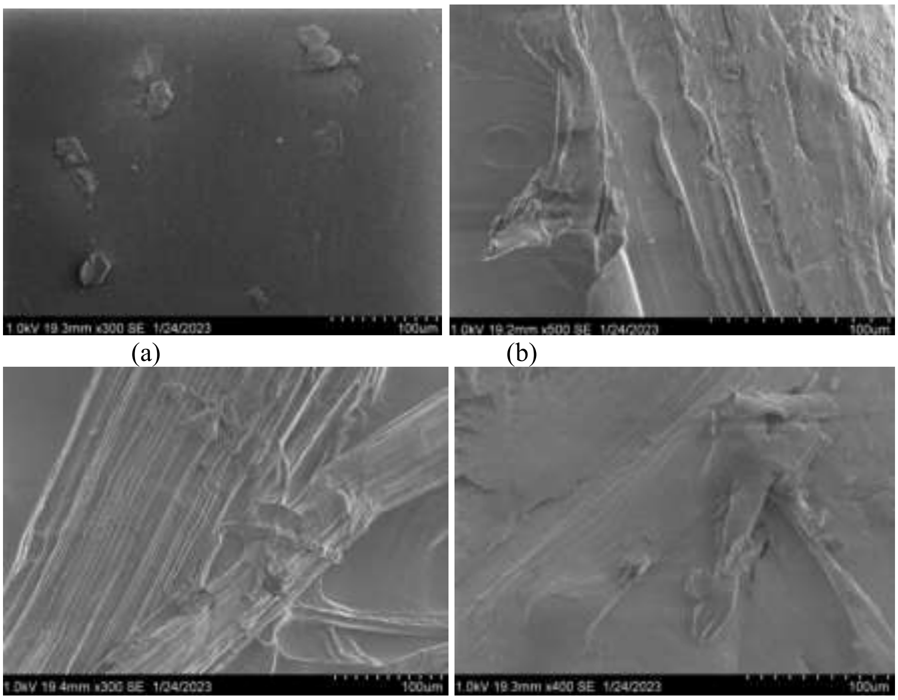
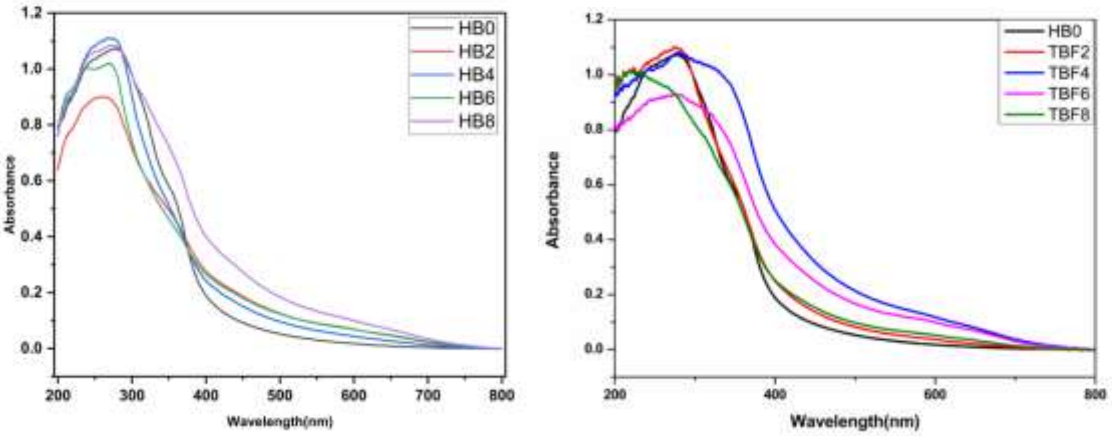


(a) (b) (c) (d)

Fig 3.62 SEM images of treated banana fiber reinforced HPMC film composites a) 2% b) 4% c) 6% d) 8%

3.7 UV-Visible Spectroscopy

The UV spectra analysis of treated and untreated banana fiber-reinforced HPMC films reveals a significant change in the absorption peak compared to untreated fiber film, indicating a reduction in acidic sites. These surface changes are attributed to interactions with alkali and the removal of hemicellulose and lignin. In cellulose films containing 2% lignin, there is nearly complete UV-B (280–320 nm) and a majority of UV-A (320–400 nm) absorption. Both HPMC and banana fiber contain cellulose, resulting in UV-ray absorption. The 4% film exhibits higher absorbance in the 280-350 nm range, suggesting its potential use as protective coverage against sunlight [8].



(a) (b)

Fig 3.71 UV Spectra of untreated and treated banana fiber HPMC films

4. CONCLUSION

In this study, varying loadings (2%, 4%, 6%, and 8%) of banana fiber-reinforced HPMC films were successfully fabricated via solvent casting. Thermal stability of both treated and untreated banana fiber was compared. The influence of fiber loading and alkaline treatment on mechanical properties was examined. SEM analysis was conducted. Banana fiber, known for its strength, has diverse applications in composites, packaging, textiles, and design, driven by environmental awareness and sustainability.

Key findings:

1. Thermal stability of banana fibers improved with chemical treatment.

2. Tensile modulus showed the most improvement at 4% treated banana fiber loading.
3. Alkaline treatment significantly enhanced all mechanical properties.
4. Improved adhesion between fibers and matrix was observed after chemical treatment.
5. SEM micrographs confirmed enhanced adhesion post-alkaline treatment.

In conclusion, banana fiber-reinforced composites hold great potential for various engineering applications, including automotive interiors, packaging, and construction, driven by their improved mechanical and thermal properties.

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