Physicochemical Characterization Of A Flaxseed–Chitosan Composite Film Enriched With Phytochemicals Of Solanum Torvum Leaf Extract

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Abstract

Background: The growing need for biodegradable & eco-friendly materials has stimulated the development of polymeric films derived from natural resources.

Objective: To study the physicochemical characterization of a flaxseed–chitosan composite film enriched with phytochemicals of solanum torvum leaf extract.

Methods: In the present study, an herbal composite film was prepared using flaxseed mucilage and chitosan incorporated with phytochemicals extracted from solanum torvum leaves. The film was made with the glycerol as a plasticiser in the solvent casting process. The physicochemical properties of the composite films were evaluated in terms of thickness, tensile strength, elongation at break, moisture content, and swelling behaviour. Structural and chemical characterization was performed using x-ray diffraction (xrd), scanning electron microscopy (sem) and fourier transform infrared spectroscopy (ftir).

Results: Ftir analysis confirmed the presence of functional groups corresponding to polysaccharides, chitosan, and phenolic compounds from the plant extract. Xrd analysis demonstrated the composite's semi-crystalline structure film with reduced crystallinity after incorporation of plant extract. Sem micrographs demonstrated a homogeneous and smooth film surface with well-distributed phytochemical particles.

Conclusion: The results suggest that the developed flaxseed–chitosan composite film containing solanum torvum leaf extract exhibits promising characteristics for potential biomedical and biodegradable packaging applications.

Keywords: Flaxseed Mucilage, Chitosan, Solanum Torvum, Herbal Composite Film, Ftir, Xrd, Sem.

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INTRODUCTION

Biodegradable polymeric films derived from natural materials have gained considerable interest due to environmental concerns associated with synthetic plastics (1). Natural polymers, like polysaccharides, Proteins and fats have been widely explored due to the development of biodegradable films with potential applications in food packaging, pharmaceuticals, and biomedical engineering. Flaxseed (*Linum usitatissimum*) mucilage is a natural hydrocolloid composed mainly of polysaccharides including arabinoxylans and rhamnogalacturonans. It possesses excellent film-forming ability, high viscosity, and good water retention properties, making it suitable for biodegradable film production.

Chitosan, a deacetylate derivative of chitin, is another biopolymer used extensively in biomedical and pharmaceutical fields because of its biocompatibility, biodegradability, and antimicrobial properties (2). The combination of flaxseed mucilage and chitosan can enhance the mechanical strength and functional properties of composite films. Plant extracts rich in phytochemicals can further improve the biological properties of such films. *Solanum torvum*, often referred to as turkey berry, is a plant that is used extensively in traditional medical systems (10). The leaves of *Solanum torvum* contain several bioactive substances such as saponins, alkaloids, phenolic acids, and flavonoids, which exhibit antimicrobial, antioxidant, and anti-inflammatory activities.

Incorporating phytochemicals from *Solanum torvum* into polymeric films may enhance their antimicrobial and functional properties. Therefore, the present study aims to prepare a flaxseed–chitosan composite film incorporated with *Solanum torvum* leaf extract and evaluate its physicochemical properties and structural characteristics using FTIR, XRD, and SEM analyses.

MATERIALS AND METHODS

Materials

Flaxseeds (*Linum usitatissimum*): An herbal composite film based on flaxseed mucilage is a biodegradable material developed using natural polymers and plant-derived bioactive compound. Flaxseed mucilage acts as a film-forming agent due to its polysaccharide-rich composition and excellent gel-forming ability.

Chitosan: Chitin, a naturally occurring polymer present in shellfish, is the source of chitosan. The properties of chitosan are biodegradable, biocompatible, and non-toxic. Wound healing is an important function of chitosan. They play a vital role in Haemostatic (stops bleeding), antimicrobial, and anti-inflammatory, and also enhance drug delivery and skin permeability. It is mainly used in wound dressings, suturing, and skin regeneration.

Solanum Torvum Leaf: Due to its antibacterial, anti-inflammatory, and antioxidant qualities, Solanum torvum, also referred to as Turkey berry, is a medicinal plant that is frequently used in traditional medicine. The leaves' therapeutic potential in wound healing is attributed to the presence of bioactive substances like flavonoids, alkaloids, tannins, and phenolic compounds. Studies have demonstrated that these phytochemicals enhance fibroblast proliferation, reduce oxidative stress, and prevent microbial infections, thereby accelerating tissue regeneration.

METHODS:

***Solanum torvum* Leaf Extract:** The leaves of Solanum torvum were gathered, washed and shade-dried and ground has fine powered, and the extract was prepared with a Soxhlet apparatus with Methanol (36). After the extract has been prepared, it is placed into a rotary vacuum evaporator to remove the solvent, and finally, a dry residue is formed. The final extract has been used for the study.

Extraction of Flaxseed Mucilage: Flaxseed mucilage was extracted using a hot water extraction method. 500 mL of distilled water and 50 g of flaxseeds were combined, and the mixture was heated to 70°C for an hour while being constantly stirred. To get rid of contaminants, the liquid was filtered through muslin cloth and centrifuged for 15 minutes at 5000 rpm. The base polymer was the resultant mucilage solution.

Preparation of Chitosan Solution: One gram of chitosan was dissolved in one hundred millilitres of 1% acetic acid while being continuously stirred for six hours to produce a transparent solution.

Preparation of Flaxseed–Chitosan Composite Film: Composite films were prepared using the solvent casting technique. The film-forming solution was composed of 70 mL of flaxseed mucilage solution and 30 mL of chitosan solution, with glycerol (1.5% w/v) added as a plasticizer and Solanum torvum extract (1% w/v) incorporated as the active component (42). To

create a homogenous solution, the mixture was constantly agitated for thirty minutes. After that, the mixture was put into glass Petri plates and let too dry for a full day at 40°C. The resulting films were carefully removed from the dishes after drying and kept in a desiccator for additional examination.

FTIR Spectroscopy

The functional groups were found using spectroscopy on a Bruker Alpha II apparatus. Two milligrams of the sample and two hundred milligrams of potassium bromide are used to make the pellet for FTIR analysis. Hydraulic pressure was used to compress KBr. The spectra were captured between 400 and 4000 cm 1 at a resolution of 2 cm 1, averaging 100 scans.

SEM, or scanning electron microscopy

Before being prepared for SEM analysis, samples were completely dried. Samples were deposited on carbon tape stubs and then sputter-coated with platinum for 30 seconds. SEM images were captured with a JEOL FE SEM IT800. EDS was recorded at 20 KV using software on the same device.

X-ray diffraction (XRD)

The degree of crystallinity, phase composition, and crystalline structure of materials can all be ascertained using this crucial analytical method. In polymer-based films, XRD helps identify crystalline and amorphous regions and provides insight into molecular interactions between components. In this study, Using XRD analysis, the investigation of the structural characteristics in the flaxseed–chitosan composite film incorporated with phytochemicals from *Solanum torvum* leaf extract, and to evaluate how the incorporation of natural polymers and plant-derived compounds influences the crystallinity and structural organization of the developed composite film.

RESULTS:

FTIR Spectroscopy

To determine the functional groups in the sample, Fourier Transform Infrared (FTIR) spectroscopy was used in the 4000–650 cm^{-1} range. Figure 1's spectra revealed a wide absorption band at 3287.51 cm^{-1}, which suggested the existence of hydroxyl or amine groups and indicated O–H or N–H stretching vibrations. Peaks at 2113.40 cm^{-1} and 1990.39 cm^{-1} correspond to triple bond vibrations (C≡C or C≡N) or combination bands, while the peak at 1636.30 cm^{-1} is attributed to C=O stretching or amide vibrations. Additional peaks at 1408.93 cm^{-1}, 1312.02 cm^{-1}, and 1244.93 cm^{-1} represent C–H bending and C–N/C–O stretching vibrations, and the strong band at 1043.65 cm^{-1} indicates C–O stretching associated with alcohols, ethers, or esters. Overall, the FTIR spectrum confirms the presence of hydroxyl, carbonyl, amine, and ether functional groups in the sample.

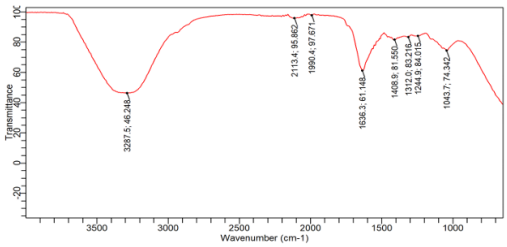
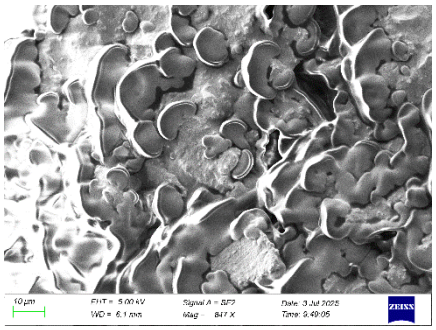


Figure 1. *FTIR spectrum of the synthesized sample showing characteristic absorption peaks at approximately* ***3287, 1653, 1468, 1321, 1210, and 1037 cm⁻¹,*** demonstrating that the substance contains functional groups.

Scanning Electron Microscopy (SEM)

The sample's surface appearance and microstructure were examined using scanning electron microscopy (SEM) analysis. The SEM images obtained at magnifications of 779× (*figure 2*) and 847× (*figure 3*) showed a heterogeneous and irregular surface morphology with clustered microstructures. The micrographs revealed irregular, flake-like and plate-like particles distributed across the surface, forming agglomerated clusters with uneven boundaries. The particle sizes were observed in the micrometre range (approximately 10 µm scale), with rough surface textures and layered structures, indicating the presence of aggregated micro domains. Overall, the morphology suggests a non-uniform particle distribution with significant agglomeration, resulting in a porous and complex surface architecture.

2.



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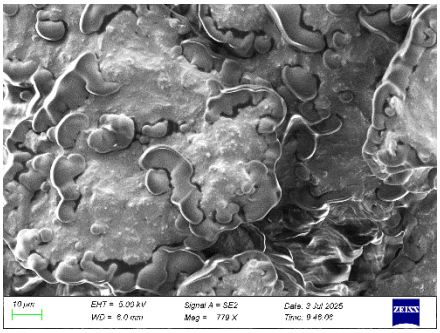

Figure 2.
Scanning Electron Microscopy (SEM) micrograph showing the surface morphology of the sample at a magnification of ***779×*** with a ***10 µm scale bar***, revealing irregular layered structures and particle agglomeration.

Figure 3.
*SEM micrograph of the sample surface at a magnification of **847× with a 10 µm scale bar**, illustrating clustered microstructures and rough surface morphology.*

X-ray diffraction (XRD)

Cu-Kα radiation (λ = 1.54056 Å) was used in X-ray diffraction (XRD) examination to examine the sample's crystallographic properties throughout a 2θ range of 3.47°–116.34°. Two conspicuous peaks at 2θ = 8.39° and 29.61°, which correspond to d-spacing's of 10.526 Å and 3.014 Å, respectively, were visible in the diffraction pattern. The peak at 29.61° exhibited the highest intensity (175.20) compared to the peak at 8.39° (126.87). The FWHM values were 0.0589 and 2.0000, respectively. Integrated profile analysis indicated a total diffraction area of 594116 counts, with 14.01% attributed to diffraction peaks and 85.99% to background radiation. No specific crystalline phase matched the reference database, suggesting that the sample possesses low crystallinity or poorly crystalline structures.

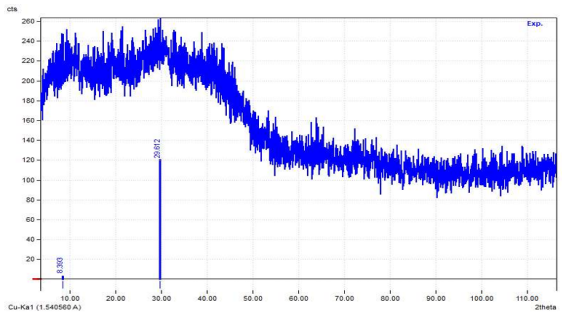

Figure 4. *XRD pattern of the sample obtained using Cu–Kα radiation (λ = 1.5406 Å) showing the diffraction peaks in the 2θ range of 5°–110°.*

DISCUSSION

The characterization and biological evaluation of the herbal flaxseed–chitosan composite film incorporated with *Solanum torvum* leaf extract demonstrated promising structural and antimicrobial properties. Numerous functional groups, including hydroxyl, amine, carbonyl, and ether groups, were validated by the FTIR study. These functional groups are commonly associated with polysaccharides and plant-derived phytochemicals, indicating successful incorporation of flaxseed mucilage, chitosan, and the bioactive compounds from *Solanum torvum*. Additionally, the presence of O–H and N–H groups raises the probability of hydrogen bonding interactions inside the composite matrix, which could support the film's stability and structural integrity.

The SEM analysis revealed a heterogeneous and irregular surface morphology with agglomerated microstructures and rough surface textures. Such morphological features indicate the formation of a composite matrix where the components are physically integrated. The porous and layered surface architecture observed in the SEM images may enhance the interaction of the film with surrounding environments, which is beneficial for antimicrobial and biomedical applications.

The XRD results indicated that the composite film exhibited low crystallinity, as only a few diffraction peaks were observed and no specific crystalline phase matched the reference database. This suggests that the film has a predominantly amorphous structure, which is typical for many polymer-based composite films. The amorphous nature may facilitate better dispersion of phytochemicals within the polymer matrix and contribute to improved flexibility and functional performance of the film.

CONCLUSION

In conclusion, the herbal flaxseed–chitosan composite film incorporated with *Solanum torvum* leaf extract demonstrated favourable structural and biological properties. FTIR analysis confirmed the existence of functional groups associated with polysaccharides and phytochemicals, while SEM analysis revealed a rough and porous surface morphology indicating effective composite formation. XRD analysis showed that the film possesses a predominantly amorphous structure with low crystallinity. These structural and morphological characteristics demonstrate that the synthesized material possesses functional chemical groups, rough surface morphology, and semi-amorphous structural properties**,** which may contribute to its potential applications in biomedical, antimicrobial, or biodegradable film-based systems**.**

CONFLICT OF INTEREST

The authors hereby declare that there is no conflict of interest.

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Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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