

# Characteristics of Chitosan-Shellac Based Biocomposite Fabric for Packaging

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## ABSTRACT

**Aim:** The increasing environmental concerns regarding the use of non-biodegradable plastic packaging have driven the search for sustainable alternatives. Chitosan, a biopolymer obtained from chitin, is known for its biodegradability, biocompatibility and antimicrobial properties. Shellac, a natural resin secreted by the lac bug, is also biodegradable and widely used in food and pharmaceutical coatings. Combining these materials to create a biocomposite fabric for packaging could offer a viable eco-friendly alternative to traditional plastics. This research seeks to create and analyze a biocomposite fabric made from chitosan and shellac for use in packaging. It examines the mechanical strength, barrier effectiveness and biodegradability of the biocomposites to determine their potential as eco-friendly packaging solutions. **Materials and Methods:** Chitosan, obtained from chitin and commercially available shellac, a natural resin, were utilized to create biocomposite films. The process involved dissolving chitosan in acetic acid and shellac in ethanol. Mechanical properties were assessed by measuring tensile strength and elongation at break with a universal testing machine. Barrier properties were examined using Water Vapor Transmission Rate (WVTR) and water contact angle tests. Additionally, the biocomposites were characterized using FTIR, SEM and TGA analyses. **Results:** The biocomposite films exhibited good tensile strength and flexibility. The optimal chitosan-to-shellac ratio provided a balance between strength and flexibility, making the material suitable for packaging. The biocomposites demonstrated significant resistance to moisture and oxygen permeation, crucial for maintaining the integrity of packaged goods. The study ascertains the biocomposite formation and their thermal stability. The study successfully developed a chitosan-shellac based biocomposite fabric with promising characteristics for packaging applications. The biocomposites exhibited favorable mechanical properties, effective barrier performance and excellent thermal stability. These findings suggest that chitosan-shellac biocomposite fabrics could serve as a sustainable alternative to conventional plastic packaging, contributing to environmental conservation and sustainability efforts. Further research may explore the scalability of production and the potential for incorporating other natural additives to enhance performance

**Keywords:** Chitosan, Shellac, Biocomposite, Packaging, Biodegradability, Sustainable Materials, Mechanical Properties, Barrier Properties.

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## INTRODUCTION

The antimicrobial packaging and active packaging are the leads of current research and development for food packaging. The active antimicrobial packaging protects the food product through continuous interactions over a specified shelf life and internal environmental

modifications. Through interacting with the packed food products these active antimicrobial packaging prevents the growth of disease causing microorganisms. The effectiveness of an antimicrobial agent often diminishes when added directly to the food material hence storing the food product in food packaging material containing the antimicrobial agent will be more successful than the direct method. The growth of undesirable microbes on the surface of packed food material can be inhibited by controlled diffusion of antimicrobial chemicals from the packaging material. As the food spoilage mostly starts on the surface the antimicrobial agent only needed to be added to the airspace rather than to the entire food content.<sup>[1]</sup>

Active packaging technologies present new prospects for the food business in terms of food preservation.

This is a very new and intriguing field of food science that might greatly enhance the preservation of a variety of foods. Active packaging is becoming more popular due to advancements in material science, pack-aging and changing customer expectations.<sup>[2]</sup>

Chitosan, derived from chitin, exhibits versatile applications across various fields. In the biomedical sector, chitosan is utilized for drug delivery, tissue engineering, wound healing and antimicrobial purposes. Its biocompatibility, biodegradability and antimicrobial properties make it ideal for these applications. Moreover, chitosan's solubility, stability and easy functionalization have enhanced its role in drug delivery systems and controlled-release mechanisms.<sup>[3]</sup>

Due to its antibacterial and antioxidant qualities, chitosan films are essential for improving food preservation and prolonging the shelf life of food items.

These films, enriched with natural extracts like beetroot, curcumin, garlic and plant extracts, have been shown to reduce biogenic amines formation, delay biochemical deterioration and improve sensory characteristics of food items such as tuna filets.<sup>[4]</sup> Additionally, chitosan-based biomaterials are biocompatible, biodegradable and possess low toxicity, making them ideal for food packaging and storage applications.<sup>[5]</sup> Studies have demonstrated that chitosan coatings on fruits like feijoa significantly reduce microorganisms and fungal growth, prolonging shelf life by delaying oxidative degradation.<sup>[6]</sup>

Antibacterial chitosan films have also been used in the food sector to preserve food quality and increase shelf life, demonstrating their potential in environmentally friendly food preservation methods.<sup>[7,8]</sup>

Shellac resin is amphiphilic, meaning it has both hydrophobic and hydrophilic properties. It is composed

of long-chain hydroxy-fatty and sesquiterpene acids, with the backbone consisting of Aleuritic acids (hydrophobic) and cyclic terpene acids (hydrophilic) connected by ester bonds. This unique composition gives Shellac its distinctive properties for various applications. Shellac can be utilized as a food additive since it is medically innocuous and nontoxic. Shellac is frequently used in the food and agricultural industries to separate lipids, water, gas and microbes as well as to extend the shelf life of products.<sup>[9]</sup>

Shellac is applied to fruits to increase their shelf life and is used as a glazing ingredient in pharmaceutical and confectionary products. Shellac, which is categorized as Generally Recognized As Safe (GRAS), is advantageous for the food and associated industries and appropriate for edible products.

Applications for chitosan films containing shellac nanoparticles are many and span a number of industries. The incorporation of chitosan nanoparticles has been shown to enhance the physicochemical properties and antifungal activity of bionanocomposite films, making them suitable for active packaging, particularly for fresh fruit commodities.<sup>[10]</sup> Additionally, chitosan films, when combined with other nanofillers, have demonstrated improved tensile strength, thermal properties, water barrier properties and antibacterial activity, making them ideal for active food packaging applications.<sup>[11]</sup> Moreover, chitosan derivatives, including chitosan nanoparticles, have been identified as safe and effective adjuvants for vaccine delivery, showcasing their potential in the pharmaceutical industry.<sup>[12]</sup> Overall, the incorporation of shellac nanoparticles into chitosan films opens up opportunities for applications in food packaging, pharmaceuticals and other industries due to their enhanced properties and functionalities.

Chitosan films, infused with plant extracts and polymers, improve physicochemical properties, making them suitable for food preservation by enhancing quality monitoring, packaging and storage in multifunctional food processing applications.<sup>[13]</sup>

The aim of this research is to create and evaluate a biocomposite fabric made of chitosan and shellac that has ideal mechanical, barrier and thermal stability qualities for usage in packaging applications that promote sustainability.

## MATERIALS AND METHODS

### Fabric collection

Two different fabrics such as thick cloth, thin cloth and brown paper were collected from local market, Tiruppur.

### Preparation of chitosan-shellac

By dissolving 2 mL of acetic acid in 100 mL of distilled water, an acetic acid solution (2% v/v) was created. A 2% (w/v) chitosan solution was created by dissolving approximately 2 grams of Chitosan (C) in 100 mL of a 2% v/v acetic acid solution. By dissolving 5g of shellac in 90 mL of acetone, a 5% v/v shellac solution was created. Distilled water was then added to bring the level up to 100 mL.

### Coating of fabrics and paper

Chitosan was applied to thin fabric, thick fabric and paper and these were left to dry for 2 hr. A set of uncoated fabrics was kept as a standard. The fabrics were then coated with shellac and their physical characteristics were evaluated.

### Physical parameters

#### Thickness

Using a dial thickness gauge and the thickness test method-ISO 9073-2, the thickness of the films was measured at 3 randomly selected locations on the coated textiles and paper sample, yielding an accuracy of 0.01 mm.

#### Tear strength

There are two methods for testing a material's tear strength: the tongue tear method and the trapezoid tear method. Both approaches are frequently used to improve tear property characterization. Elmendorf tear strength tester was used in this experiment to test the tear strength.

#### Air permeability

The volume of air passed per sec through per unit area of the fabrics and paper. It is tested using ASTM D 737 and it is mentioned as cubic cm per sec per sq cm ( $\text{cm}^3/\text{sec}/\text{cm}^2$ ).

#### Grams per Square Meter (GSM)

A technique for calculating the weight of paper or textiles stated in grams per square meter is called grams per square meter. Its unit is gms/sqmt, or GSM as it is commonly called. Using ASTM D 3776, specimens of 10 cm by 10 cm are sliced, weighted and the GSM is calculated by dividing the area.

#### Water contact angle

The inward angle created by the solid surface (base line) and the interface of the tangent line, where your liquid droplets and solids interact, is known as the water contact angle. The KRUSS Tensiometer K100 MK3 is used to test this.

### Cobb test and Water Vapor Transmission Rate (WVTR) of coated Paper

The Cobb test measures the volume of water absorbed into the surface in a predetermined amount of time, often 60 or 180 sec (Cobb60 or Cobb180), by a sized (non-bibulous) paper, paperboard and corrugated fiberboard paper or paperboard sample. In  $\text{g}/\text{m}^2$ , water absorbency is expressed. We can evaluate and contrast several paper label materials using the Cobb test: A high Cobb value indicates that the label substrate has the ability to both absorb and hold moisture. The amount of water vapor that travels through a material or substance in a predetermined amount of time is called the Water Vapor Transmission Rate, or WVTR. The amount of water in weight that travels through a one square meter area in a day, measured in grams per square meter, is how data obtained from a WVTR analysis is often presented. WVTR testing is commonly used in the packaging industry to evaluate the barrier properties of materials used in food, pharmaceutical and other products. The lower the WVTR the smaller the amount of moisture passes through in a given time.

#### FTIR

The materials' absorbance spectra were captured using FTIR spectrophotometry and the KBr method. A Nicolet is 50 FTIR spectrometer was used for the analysis, which covered the wavenumber range of  $4000\text{-}400\text{ cm}^{-1}$ . Using an agate mortar, solid samples were combined with KBr at a ratio of roughly 1:300 and ground into a fine powder. In a vacuum oven, the mixture was dried for 12 hr at  $100^\circ\text{C}$ . After that, a pellet was created using about 300 mg of the dry powder and it was examined right away. At a resolution of  $4\text{ cm}^{-1}$ , the spectra were captured using a sequence of scans. The backdrop was a pellet prepared from an equivalent volume of pure KBr powder.

#### SEM

SEM is used to examine the surface morphologies and structures.

#### Thermogravimetric Analysis (TGA)

Hitachi STA7000 series simultaneous thermal analysis equipment was used to conduct Differential Thermal Analysis (DTA) and Thermogravimetric Analysis (TGA). Each sample was weighed continuously and 10-20 mg was deposited in a platinum crucible on a microbalance plate. The samples were then heated at a rate of  $2^\circ\text{C}/\text{min}$  from ambient temperature to  $800^\circ\text{C}$  while being purgeable with argon at a flow rate of  $100\text{ mL min}^{-1}$ .

## RESULTS

### Thickness

The application of coatings has notably augmented the thickness of the samples in comparison to their uncoated counterparts. Specifically, the thickness of chitosan-coated samples increased by 32%, while those coated with chitosan-shellac experienced a more substantial augmentation of 39% (Table 1). Similarly, when juxtaposed with uncoated paper samples, the thickness of chitosan-coated and chitosan-shellac-coated thin fabric surged by 46% and 42%, respectively. Notably, the thickness of chitosan-coated and chitosan-shellac-coated thick fabric demonstrated a significant increase of 60% and 52%, respectively, when compared to their uncoated equivalents.

**Table 1: Thickness of coated Paper and Fabrics.**

Sample Number	Thickness (mm)
Uncoated paper	0.17
Chitosan coated paper	0.25
Chitosan-Shellac coated paper	0.28
Uncoated thin fabric	0.40
Chitosan coated thin fabric	0.75
Chitosan-Shellac coated thin fabric	0.70
Uncoated thick fabric	0.60
Chitosan coated thick fabric	1.51
Chitosan-Shellac coated thick fabric	1.26

### Tear strength

Relative to the tear strength of uncoated samples, those coated with chitosan and chitosan-shellac experienced significant enhancements (Table 2). In comparison to uncoated paper samples, the tear strength of paper coated with chitosan and chitosan-shellac exhibited substantial enhancements, registering increases of 91% and 94%, respectively.

**Table 2: Tear Strength of coated Paper and Fabrics.**

Sample Number	Tear strength (kgf/cm)
Uncoated paper	5
Chitosan coated paper	62
Chitosan-Shellac coated paper	89
Uncoated thin fabric	5
Chitosan coated thin fabric	55
Chitosan-Shellac coated thin fabric	60.5
Uncoated thick fabric	5
Chitosan coated thick fabric	65
Chitosan-Shellac coated thick fabric	89

Likewise, when evaluated against their uncoated counterparts, chitosan-coated and chitosan-shellac-coated thin fabric demonstrated notable improvements in tear strength, with increments of 90% and 91%, respectively. Moreover, a considerable elevation in tear strength was observed in thick fabric samples coated with chitosan and chitosan-shellac, showcasing increments of 92% and 94%, respectively, compared to their uncoated counterparts. Thus the chitosan-shellac coating has significantly enhanced the mechanical strength of the fabric.

### Air permeability

Relative to uncoated paper, the application of chitosan and chitosan-shellac coatings resulted in a substantial reduction in air permeability. In contrast to uncoated paper, the air permeability of paper coated with chitosan and chitosan-shellac exhibited a notable reduction of 99%. Similarly, when compared to uncoated thin fabric, the air permeability of chitosan-coated and chitosan-shellac-coated samples decreased by 51% and 42%, respectively (Table 3). Moreover, in comparison to uncoated thick fabric, the air permeability of chitosan-coated and chitosan-shellac-coated thick fabric experienced reductions of 22% and 18%, respectively. The decrease in air permeability serves to mitigate the proliferation of microorganisms while concurrently diminishing enzymatic activity, thus fostering an extended shelf life for stored fruits and vegetables.

**Table 3: Air Permeability of coated Paper and Fabrics.**

Sample Number	Air Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min)
Uncoated paper	76.6
Chitosan coated paper	0.0782
Chitosan-Shellac coated paper	0.745
Uncoated thin fabric	895
Chitosan coated thin fabric	432
Chitosan-Shellac coated thin fabric	514
Uncoated thick fabric	399
Chitosan coated thick fabric	311
Chitosan-Shellac coated thick fabric	324

### Grams per Square Meter (GSM)

Relative to the GSM of uncoated samples, those treated with chitosan and chitosan-shellac coatings have exhibited increases in GSM. In comparison to the GSM of uncoated paper samples, the GSM of those coated with chitosan and chitosan-shellac has shown respective increases of 6% and 22% (Table 4). Similarly, the GSM of thin fabric samples coated with chitosan and chitosan-shellac has demonstrated increases of 29%



and 47%, respectively, in contrast to their uncoated counterparts. Moreover, a notable increase in GSM by 9% and 27% has been observed when comparing uncoated thick fabric with fabric coated with chitosan and chitosan-shellac, respectively. Overall, both chitosan-shellac coated fabric and paper exhibit a significant increase in GSM compared to samples solely coated with chitosan and uncoated samples.

**Table 4: GSM of coated Paper and Fabrics.**

Sample Number	Fabric Weight (g/m <sup>2</sup> )
Uncoated paper	0.75
Chitosan coated paper	0.80
Chitosan-Shellac coated paper	0.97
Uncoated thin fabric	0.65
Chitosan coated thin fabric	0.92
Chitosan-Shellac coated thin fabric	1.23
Uncoated thick fabric	1.22
Chitosan coated thick fabric	1.34
Chitosan-Shellac coated thick fabric	1.68

### Water contact angle

A significant rise in the water contact angle is revealed by the examination of the water contact angle, suggesting that the coated packing materials have improved water resistance.

The heightened water contact angle significantly contributes to the robustness and surface hydrophobicity of the packaging material. Consequently, there is a diminished permeation of water from the external environment into the packaging material, thereby reducing the requisite humidity for the proliferation of food spoilage microorganisms. Moreover, the samples treated with chitosan-shellac demonstrate a superior water contact angle compared to those coated solely with chitosan (Table 5). This underscores the heightened water resistance conferred by the chitosan-shellac coating, thereby strengthening the barrier against water infiltration more effectively.

**Table 5: Water Angle of coated Paper and Fabrics.**

Sample Number	Water Angle (°)
Uncoated paper	0
Chitosan coated paper	92.14
Chitosan-Shellac coated paper	93.95
Uncoated thin fabric	0
Chitosan coated thin fabric	90.0
Chitosan-Shellac coated thin fabric	95.97
Uncoated thick fabric	0
Chitosan coated thick fabric	87.43
Chitosan-Shellac coated thick fabric	108.48

### Cobb test and Water Vapor Transmission Rate (WVTR) of coated Paper

In comparison to samples coated solely with chitosan and uncoated samples, the results of the Cobb test and the Water Vapour Transmission Rate (WVTR) of coated paper showed that paper treated with chitosan-shellac exhibits decreased water absorption and ideal water vapour transmission (Table 6). This helps in maintaining the ideal moisture content within the package, preserving the freshness and quality of the food products. Fruits and vegetables have a longer shelf life because of the low WVTR and water absorption, which effectively reduce moisture transfer between the packaged food and the surrounding environment. This slows down deterioration processes like microbial growth, enzymatic activity and chemical reactions. Specifically, samples coated with chitosan-shellac demonstrated a significant reduction in water absorption by 66% and 45%, respectively, highlighting the efficacy of this coating in minimizing water penetration.

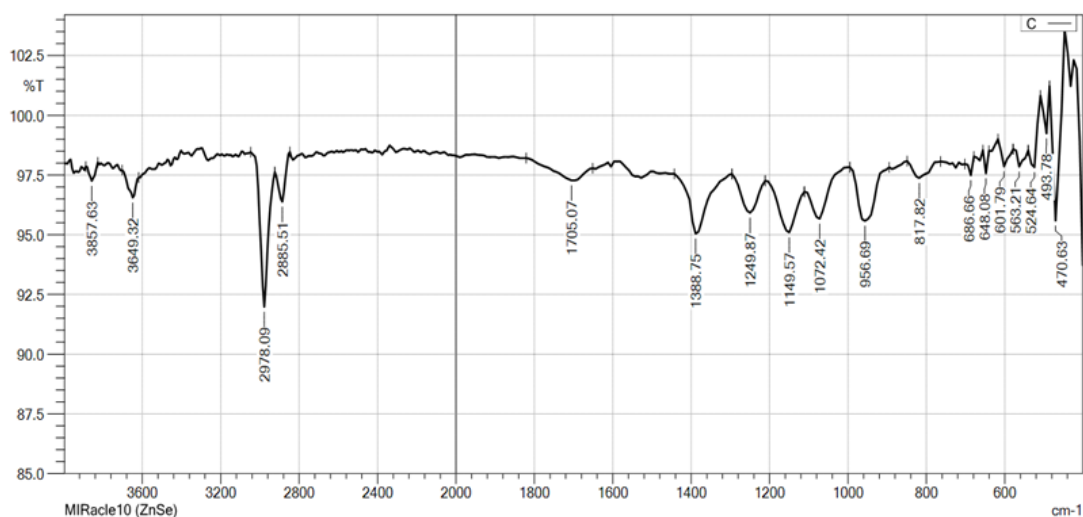
**Table 6: Cobb test and Water Vapor Transmission Rate (WVTR) of coated Paper.**

Sample	Coat Weight (GSM)	Cobb g/m <sup>2</sup> (1 min)	WVTR g-mm/m <sup>2</sup> day
Uncoated paper	-	88.65	1159
Chitosan coated paper	1.80	54.14	1090
Chitosan-Shellac coated paper	2.16	29.33	1013

### Fourier Transform Infrared (FTIR)

Chitosan's infrared spectra highlight a number of important characteristics. Figure 1 shows that intramolecular hydrogen bonding and N-H and O-H stretching are associated with a strong band in the 3600-600 cm<sup>-1</sup> range. Symmetric and asymmetric C-H stretching is responsible for the absorption bands located at roughly 2978 and 2885 cm<sup>-1</sup>, respectively. These bands are indicative of polysaccharides and can be found in the spectra of xylan, glucans and carrageenans, among other polysaccharides. The presence of residual N-acetyl groups is confirmed by the bands around 1705 cm<sup>-1</sup> (C=O stretching of amide I) and 1249 cm<sup>-1</sup> (C-N stretching of amide III). A band located at 1388 cm<sup>-1</sup> signifies the main amine's N-H bending.

The absorption band at 1149 cm<sup>-1</sup> is due to asymmetric stretching of the C-O-C bridge, while the bands at 1072 and 956 cm<sup>-1</sup> correspond to C-O stretching. These bands are consistent with those found in chitosan spectra reported by other researchers.<sup>[14]</sup>



**Figure 1:** Fourier Transform Infrared (FTIR) Peak Positioning Graph of Chitosan.

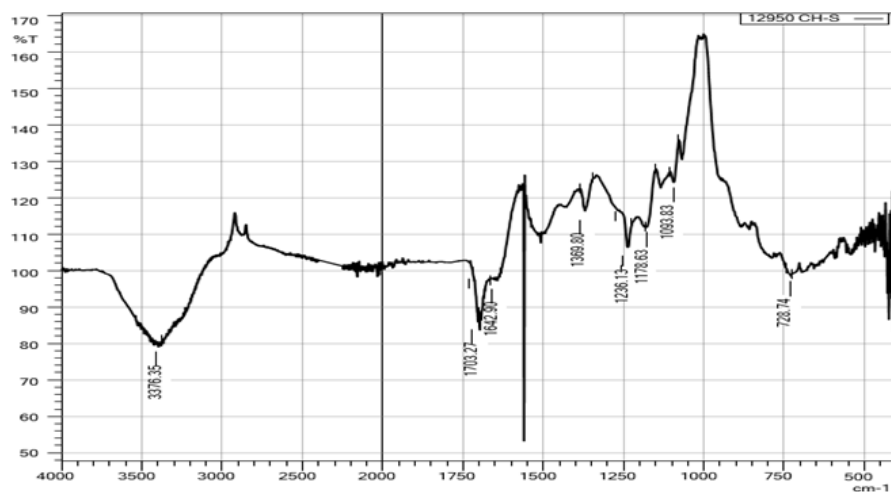
The FTIR peak positioning graph displays the FT-IR spectrum of chitosan-shellac, illustrating the following bands: NH<sub>2</sub> amine (3376), aromatic =CH (1369), alkane CH (1642), amide C=O (1703), phenol OH (1236) and amine bending NH. The FT-IR spectrum of the chitosan-shellac polymer shows bands at 1178 (amide C=O), 1519 (amide bending N-H) and 1093 (alcohol C-O) (Figure 2).

### Scanning Electron Microscope (SEM)

Using Scanning Electron Microscopy (SEM), the microstructure (surface and cross-section morphology) of the chitosan-based biocomposite fabrics is shown in Figure 3. The pure chitosan biocomposite's surface pictures demonstrate that every covering is smooth, freestanding and devoid of cavities or fissures. The dense

surface structure remained mostly unchanged with the addition of chitosan. Chitosan was evenly blended with the matrix polymer, demonstrating good liquid miscibility and no morphological changes.

Using Scanning Electron Microscopy (SEM), the microstructure (surface and cross-section morphology) of the chitosan-shellac biocomposite fabric is shown in Figure 4. Although it has a more coated structure, the chitosan-shellac blended biocomposite fabric has morphologies that are comparable to those of neat chitosan. When shellac is added to the coating, the layered structure of the chitosan matrix has a rougher surface. These results show that the fillers are evenly distributed and that shellac is compatible with the chitosan matrix. The high levels of adhesion, intermolecular binding and affinity between chitosan



**Figure 2:** Fourier Transform Infrared (FTIR) Peak Positioning Graph of chitosan-shellac.

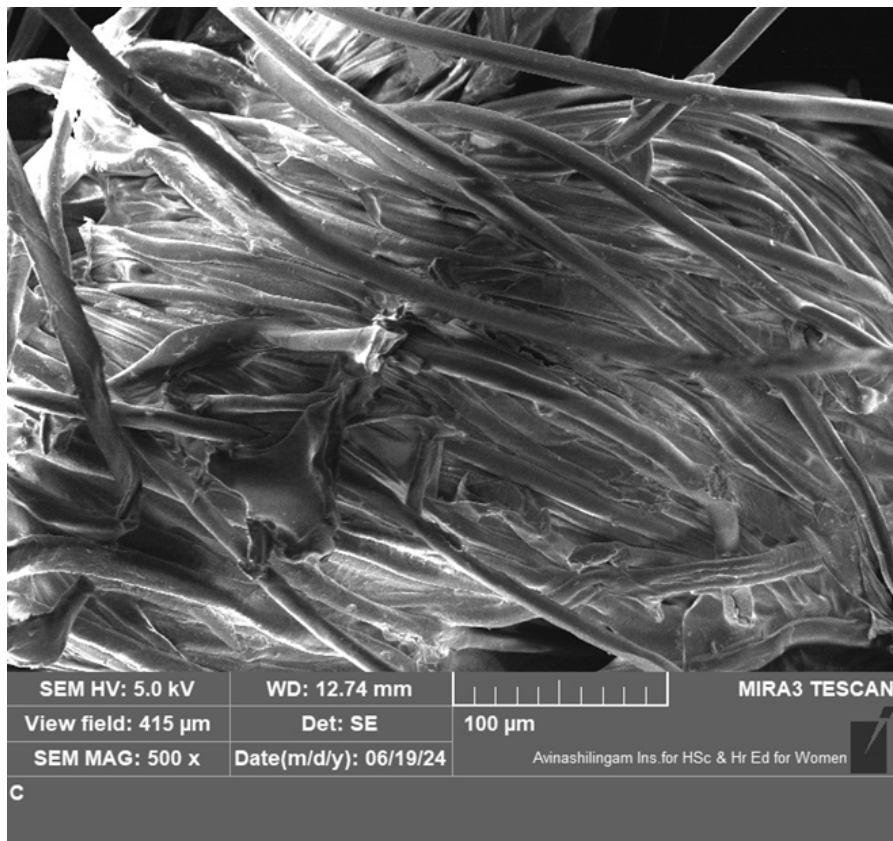


Figure 3: Morphological observation of chitosan-based coating by SEM 500X.

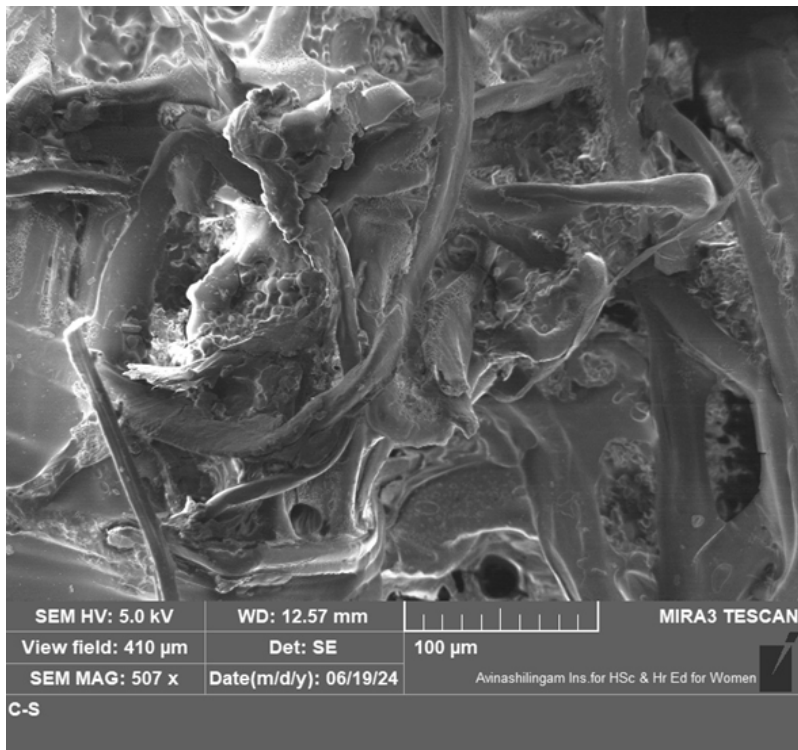


Figure 4: Morphological observation of chitosan-Shellac based coating by SEM 507X.

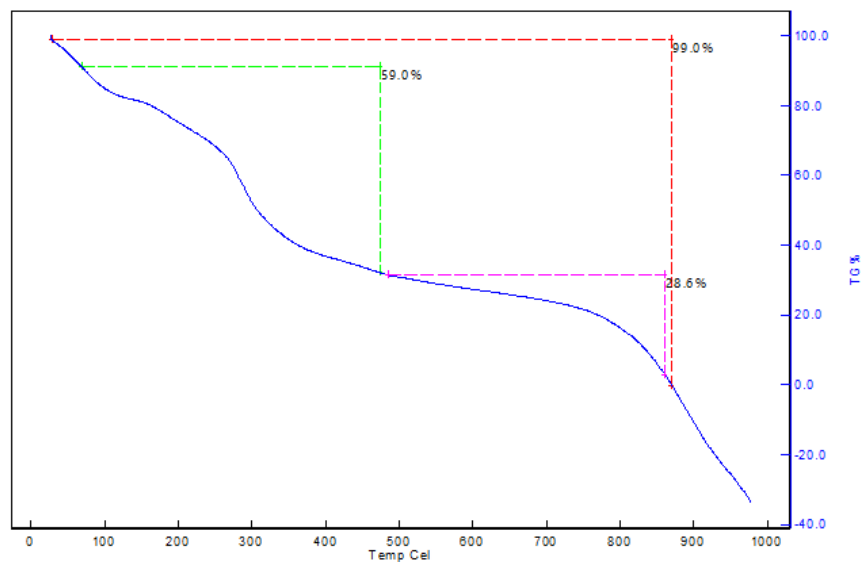
and shellac in this compatibility probably improve the biocomposite's physical characteristics.

### Thermal Properties

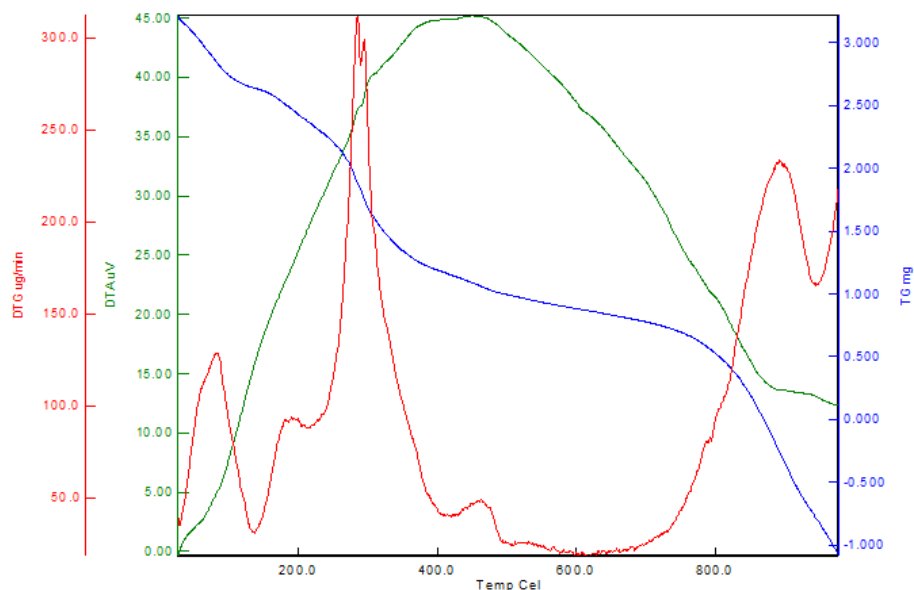
The chitosan and Chitosan-shellac biocomposite fabric's thermal stability was assessed by measuring TGA and DTG thermograms and DSC analysis. The TGA and DTG results are displayed in Figure: 5a, b. and Figure: 6a, b.

Both chitosan and chitosan-shellac biocomposite fabrics exhibit a two-stage thermal degradation process. The chitosan biocomposite fabric shows an initial weight loss at approximately 40°C due to moisture evaporation.

The onset and endset temperatures for the primary degradation are listed in Table 7. The maximum thermal degradation occurs around 880°C, resulting from the thermal decomposition of the chitosan polymer matrix. For the chitosan-shellac biocomposite fabric, the initial weight loss occurs at approximately 50°C due to moisture evaporation, with the primary degradation temperatures also detailed in Table 7. The maximum thermal degradation for this fabric is observed around 990°C, again due to the decomposition of the chitosan matrix. The inclusion of shellac increases the thermal decomposition temperature of the chitosan-based films, as shown in Table 7. The char contents at about 900°C



**Figure 5a:** Thermogravimetric analysis (TGA) of the chitosan Biocomposite fabrics.



**Figure 5b:** TG, DTG and DTA analyses of the chitosan Biocomposite fabrics.



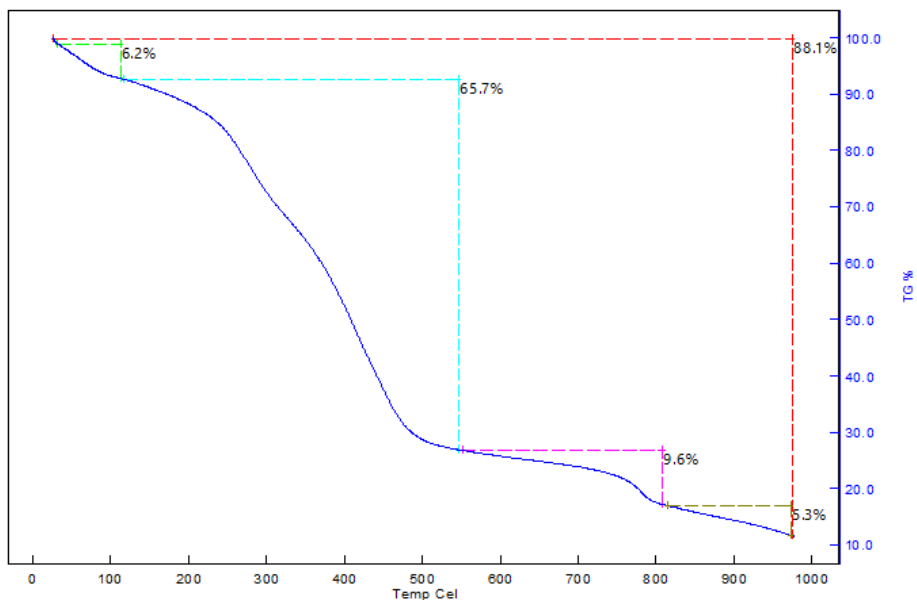


Figure 6a: Thermogravimetric Analysis (TGA) of the chitosan Biocomposite fabrics.

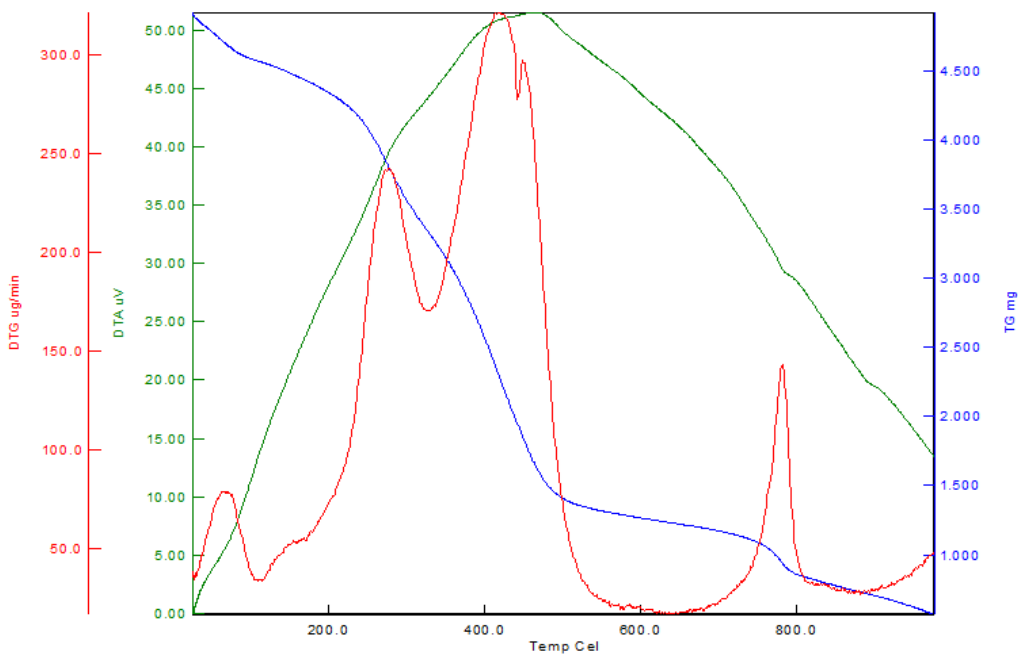


Figure 6b: TG, DTG and DTA analyses of the chitosan Biocomposite fabrics.

are 99.0% for neat chitosan and 88.1% for chitosan-shellac, likely due to non-ignitable minerals in the biopolymer. Overall, the addition of shellac enhances the thermal stability of the biocomposite fabric.

Figures 5b and 6b show the DSC spectra of the chitosan and chitosan-shellac biocomposite films. The miscibility and compatibility of the polymer's constituent parts are measured by DSC analysis. Two main peaks can be seen in the chitosan-coated fabric: one in the 50-350°C range,

peaking at about 350°C, which corresponds to the evaporation of bound and absorbed water and another in the 800-920°C range, peaking at about 850°C, which is probably related to the thermal degradation of the amine units in chitosan.

Changes were seen in both peaks for the chitosan-shellac biocomposite textiles. The first peak occurred between 0 and 80°C, reaching its highest at roughly 50°C and the second peak occurred between 220 and 550°C,

**Table 7: Thermal data for Chitosan and Chitosan-fabric biocomposite fabrics.**

Sample	Initial Decomp. Temp (°C)	Max. Decomp. Temp (°C)	Temp. (°C) of 20% weight loss at	Temp. (°C) of 50% weight loss at	Weight loss % (100°C)	Weight loss at % (450 °C)	Weight loss at % (850 °C)	Residue at % (900°C)
Chitosan	~40	880	-	490	-	59.0	28.6	99.0
Chitosan-Shellac	~50	990	110	580	6.2	65.7	9.6	88.1

reaching its maximum at roughly 240°C. A second peak was seen in the 760-820°C range, reaching a maximum at approximately 795°C. This peak is probably related to the amine units in chitosan degrading thermally.

The significant variations in the first peak's position in the nanocomposite films were likely due to different polymer interactions. These results suggest good biocompatibility between chitosan and shellac.

## DISCUSSION

The growing environmental concerns over plastic pollution have spurred the development of sustainable and biodegradable packaging materials. Chitosan and shellac are promising candidates due to their natural origin and environmentally friendly properties. The research typically reveals several key characteristics of the chitosan-shellac biocomposite films like the Mechanical Properties, where the addition of shellac generally enhances the tensile strength and elongation at break of the biocomposite fabric. In Barrier Properties the composite films show improved water vapor and gas barrier properties due to the hydrophobic nature of shellac. The thermal stability of the films is often improved with the addition of shellac. Chitosan and shellac, both biopolymers with unique properties, play crucial roles in enhancing the performance of biocomposite fabrics.

According to Ferrero and Periolatto (2017) and Korkmaz and Babaarslan (2022), chitosan, derived from crustacean shells, offers biodegradability, antimicrobial activity and functional versatility.<sup>[15,16]</sup> On the other hand, Obradovic *et al.* (2017) illustrated that shellac, when used as a matrix in composites, can significantly impact mechanical properties based on the reinforcement content and additives concentration.<sup>[17]</sup> Similar to this study, by combining these two biopolymers, researchers have achieved improved mechanical properties in biocomposites. For instance, Mubarak *et al.* (2008) attributes that the addition of urea to shellac-treated hessian cloth resulted in enhanced tensile strength, bending strength, modulus, impact strength and elongation at break, showcasing the synergistic effect of chitosan and shellac in fabricating high-performance biocomposite materials.<sup>[18]</sup>

Garavand *et al.* (2020); Priyadarshi *et al.* (2021) and Boura-Theodoridou *et al.* (2020) revealed that chitosan's usage in this field is justified because of its unique antibacterial action, which shows strong activity against bacteria, fungus and yeast. In addition, the production of antimicrobial packaging materials is made feasible by this. These findings strengthen our conclusion. Notably, they have been extensively employed in the production of edible films and coatings to lengthen the shelf life of food items.<sup>[19-21]</sup>

Obradovic *et al.* (2017) and Ghosh *et al.* (2021) developed an edible coating that has been using a nanocomposite that is created by dispersing silk nanodisks in a chitosan matrix to extend the shelf life of perishable food items. These findings support our study, when the two types of biomaterials are combined, new biodegradable materials with better qualities for a range of uses will be created.<sup>[22,23]</sup>

This study unveils the application of chitosan and chitosan-shellac coatings which significantly enhanced the properties of paper and fabric samples. Coated samples exhibited increased thickness, tear strength and Grams per Square Meter (GSM), with chitosan-shellac providing slightly greater improvements than chitosan alone. Additionally, air permeability was substantially reduced, aiding in the preservation of packaged goods by limiting microbial growth and moisture transfer. The water contact angle, Cobb test and Water Vapor Transmission Rate (WVTR) results showed improved water resistance and moisture control in coated samples. Fourier Transform Infrared (FTIR) analysis and Scanning Electron Microscope (SEM) imaging confirmed the structural and chemical compatibility between chitosan and shellac, while thermal analysis demonstrated enhanced stability, with chitosan-shellac offering superior performance. According to scanning electron microscopy, the matrix coated the fibers more effectively than the particles, which improved mechanical performance and adhesion. A crucial factor was the reinforcement's shape; longer fibers oriented in the direction of pull offered superior mechanical resistance compared to fillers made of particles. Overall, chitosan-shellac coatings significantly improved the mechanical, barrier and thermal properties of packaging materials.

The interaction between chitosan and shellac in biocomposite fabrics leads to a material that is robust, flexible and effective as a barrier, with antimicrobial properties and enhanced thermal stability. These interactions make the biocomposite fabric highly suitable for sustainable packaging applications, providing an environmentally friendly alternative to conventional plastic packaging while meeting the functional requirements of modern packaging materials.

## CONCLUSION

The development of chitosan-shellac based biocomposite fabrics presents a promising solution to the environmental challenges posed by conventional plastic packaging. By leveraging the unique properties of both chitosan and shellac, researchers can create materials that are not only sustainable but also possess superior functional characteristics for various packaging applications.

The long-term stability of the biocomposite materials, the scalability of the production method and the optimization of the composite formulation could all be subjects of future study. The chitosan-shellac biocomposite fabric has a variety of packaging uses, including food packaging (its antimicrobial and barrier qualities help prolong the shelf life of food products); pharmaceutical packaging (pharmaceuticals benefit from its biodegradability and biocompatibility); and cosmetic packaging (cosmetic products suit the biocomposite's natural and non-toxic nature).

## FUTURE RECOMMENDATIONS

Several recommendations can be made to enhance the understanding, development and application of these materials like optimization of formulation for blend ratios and to investigate a wider range of chitosan-shellac blend ratios to determine the optimal composition for specific applications. We can explore the use of various additives and plasticizers to improve flexibility, strength and barrier properties without compromising biodegradability. Advanced characterization techniques may be applied to study the mechanical and barrier property enhancement through the use of cross linking agents to enhance the mechanical strength and barrier properties of the biocomposite and how to incorporate nanomaterials such as clay, graphene oxide, or cellulose nanocrystals to further improve the mechanical and barrier properties. Degradation studies can be conducted for comprehensive biodegradation studies in various environmental conditions (soil, water, compost) to understand the decomposition behavior and to

evaluate the lifecycle analysis. Functional properties and application-specific research on food packaging can be conducted to test the biocomposite fabric with various food products to evaluate its performance in real-world packaging scenarios, including shelf life extension and sensory properties and to explore the use of the biocomposite for packaging sensitive pharmaceutical and cosmetic products, focusing on its protective and compatibility properties.

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## CONFLICT OF INTEREST

There is no conflict of interest among authors.

## ABBREVIATIONS

**WVTR:** Water vapor transmission rate; **GSM:** Grams per square meter; **TGA:** Thermogravimetric analysis; **DTA:** Differential thermal analysis; **SEM:** Scanning electron microscope; **FTIR:** Fourier Transform Infrared Spectroscopy.

## SUMMARY

The research on “Characteristics of Chitosan-Shellac Based Biocomposite Fabric for Packaging” investigates the potential of combining chitosan and shellac to create a biodegradable packaging material. The study explores the mechanical strength and flexibility of various chitosan-shellac blend ratios, aiming to identify the optimal composition for packaging applications. The effectiveness of the biocomposite in providing barriers against moisture and gases is assessed, which is crucial for maintaining the quality and shelf life of packaged products. These techniques are used to study the material properties in detail, including the effects of crosslinking agents on enhancing the biocomposite's properties. In summary the research aims to develop an environmentally friendly, high-performance biocomposite fabric for sustainable packaging solutions.

## REFERENCES

1. Muller J, Quesada AC, González-Martínez C, Chiralt A. Antimicrobial properties and release of cinnamaldehyde in bilayer films based on polylactic acid (PLA) and starch. *Eur. Polym. J.* 2017;73:316-25. doi:10.1016/j.eurpolymj.2017.09.009.
2. Awulachew M T. A review of food packaging materials and active packaging system. *International Journal of Health Policy and Planning*, 2022;1(1):28-35. doi.org/10.33140/ijhpp.01.01.03.
3. Alemu D, Getachew E, Mondal A K. Study on the Physicochemical Properties of Chitosan and their Applications in the Biomedical Sector. *Int. J. Polym. Sci.* 2023. doi.org/10.1155/2023/5025341
4. Rasha Elsabagh, Samar S, Ibrahim, Elsayed M, Abd-Elaaty, Ahmed Abdeen, *et al.* Chitosan edible coating: a potential control of toxic biogenic amines and enhancing the quality and shelf life of chilled tuna filets. *Frontiers in sustainable food systems*, 2023;7doi: 10.3389/fsufs.2023.1177010.
5. Akash Kumar, Sangeeta, Yadav, Jhila Pramanik, Bhagavathi Sundaram, Sivamaruthi, *et al.* Chitosan-Based Composites: Development and Perspective in Food Preservation and Biomedical Applications. *Polymers*, 15. doi: 10.3390/polym15153150.
6. Juan, Camilo, Zárate-Moreno, Diana, Marcela, Escobar-Sierra, Rigoberto, Rios-Esteva. Development and Evaluation of Chitosan-Based Food Coatings for Exotic Fruit Preservation. *Biotech*, 2023;12(1):20. doi: 10.3390/biotech12010020.
7. Nuria, Muñoz-Tebar, José, Ángel, Pérez-Álvarez, Juana, *et al.* Chitosan Edible Films and Coatings with Added Bioactive Compounds: Antibacterial and Antioxidant Properties and Their Application to Food Products: A Review. *Polymers*, 2023;15(2):396. doi: 10.3390/polym15020396.
8. Khubiev O, Anton R, Egorov, Anatoly A, Kirichuk, Victor N, *et al.* Chitosan-Based Antibacterial Films for Biomedical and Food Applications. *International Journal of Molecular Sciences*, 2023;24(13):10738. doi: 10.3390/ijms241310738.
9. Nandkishore Thombare, Saurav Kumar, Usha Kumari, Priyanka Sakare, Raj Kumar Yogi, Niranjan Prasad, *et al.* Shellac as a multifunctional biopolymer: A review on properties, applications and future potential, *International Journal of Biological Macromolecules*, 2022;215:203-223 doi.org/10.1016/j.ijbiomac.2022.06.090.
10. Ata Aditya, Wardana, Laras, Putri, Wigati, Fumina, *et al.* Functional enhancement of hydroxypropyl cellulose-based bionanocomposite films incorporating chitosan nanoparticles. *International Journal of Food Science and Technology*, 2022;58(2):907-20. doi: 10.1111/ijfs.16071.
11. Chandrasekar M, Senthilkumar K, Senthil Muthu Kumar, Thiagamani, Sabareesh Radoor, Jyotishkumar, *et al.* Chitosan-Based Hybrid Nanocomposites for Food Packaging Applications. 2020;327-46. doi: 10.1201/9780429322129-12.
12. Ravi Ram Narayanan, SabaMaanvizhi. Applications of chitosan derivatives as adjuvant for nanoparticles based vaccines. *Infectious disorders drug targets*, 2022; 23(3) doi: 10.2174/1871526522666220922102621.
13. Vño AB, Ramasamy P, Shanmugam V, Shanmugam A. Extraction, characterization and *in vitro* antioxidative potential of chitosan and sulfated chitosan from Cuttlebone of Sepia aculeate Orbigny. *Asian Pacific Journal of Tropical Biomedicine*, 2012;2:S334-S341doi:10.1016/S2221-1691(12)60184-1.
14. Queiroz M, Melo K, Sabry D, Sasaki G, Rocha H. Does the Use of Chitosan Contribute to Oxalate Kidney Stone Formation? *Marine Drugs*, 2014;13:141-58. doi.org/10.3390/md13010141.
15. Franco Ferrero, Monica Periolatto. Chitosan Coating on Textile Fibers for Functional Properties. 2017;165-97. doi: 10.1002/9781119441632.CH69.
16. Ahmet Korkmaz, Osman Babaarslan. Chitosan added composite viscose yarn and its potential application for denim fabric development. 2023;30(1):93-98. doi: 10.15240/tul/008/2023-1-017.
17. Obradovic J, Petibon F and Fardim P. Preparation and Characterisation of Cellulose-Shellac Biocomposites. *Bioresources*, 2017;12(1):1943-59. doi: 10.15376/BIORES.12.1.1943-1959.
18. Mubarak A, Khan, Sushanta, Ghoshal, Ruhul, A, Khan, Shamim-Ara, Pervin, Ahmed, Mustafa. Preparation and characterization of jute fiber reinforced shellac biocomposites: effect of additive. *Chemistry and Chemical Technology*, 2008;2(3):231-4. doi: 10.23939/CHCHT02.03.231.
19. Garavand F, Cacciotti I, Vahedikia N, Rehman A, Tarhan Ö, Akbari-Alavijeh S, *et al.* A comprehensive review on the nanocomposites loaded with chitosan nanoparticles for food packaging. *Crit. Rev. Food Sci. Nutr.* 2020; 62:1383-1416. doi: 10.1080/10408398.2020.1843133.
20. Priyadarshi R, Roy S, Ghosh T, Biswas D, Rhim J-W. Antimicrobial nanofillers reinforced biopolymer composite films for active food packaging applications-A review. *Sustain. Mater. Technol.* 2021;321:e00353. doi: 10.1016/j.susmat.2021.e00353.
21. Boura-Theodoridou O, Giannakas A, Katapodis P, Stamatis H, Ladavos A, Barkoula NM. Performance of ZnO/chitosan nanocomposite films for antimicrobial packaging applications as a function of NaOH treatment and glycerol/PVOH blending. *Food Packag. Shelf Life.* 2020;23:doi:
22. Ghosh T, Mondal K, Giri BS, Katiyar V. Silk nanodisc based edible chitosan nanocomposite coating for fresh produce: A candidate with superior thermal, hydrophobic, optical, mechanical and food properties. *Food Chem.* 2021;360:130048. doi: 10.1016/j.foodchem.2021.130048.
23. Obradovic J, Petibon F, Fardim P. Preparation and characterization of cellulose-shellac biocomposites *BioRes.* 2017;12(1):1943-59. doi: 10.15376/biores.12.1.1943-1959.

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