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Research Article

Modification, Blending, Characterization, and Investigation of Thermal Properties, pH Response of Chitosan-based Polymer Extracted from *Labeo rohita* Scales

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ABSTRACT

Modern shrimp farming began in India during the late 1980s in response to increasing global demand for shrimp and government policies aimed at promoting seafood exports. Corporate entities provided the necessary capital to build hatcheries, farms, and processing plants. However, a survey revealed that the major waste materials generated by these shrimp processing industries in India have become a major problem. In the present work, chitin is extracted and purified from the scale of fish *Labeo rohita* and modified into chitosan. Chitosan and polyvinyl alcohol (PVA) were blended in various ratios to prepare a composite material and films. The blended material was characterized using fourier-transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), thermogravimetric analysis (TGA), and a few other analyses to understand the polymer's nature. The work demonstrated that fish scales can serve as a valuable raw material for chitin, chitosan and these polymer-based products. Chitosan, being easily accessible, cost-effective, and biodegradable, has wide-ranging applications in fields like clinical, biomedical, food industry, pharmaceuticals, polymer industries, etc., proper preparation of chitin, chitosan and combination with suitable compounds can lead to desired outcomes.

Keywords: Chitin, Chitosan, Biodegradable polymer, Biopolymer, *Labeo rohita.*

INTRODUCTION

The growth of the modern shrimp farming industry in India during the late 1980s was a response to the surging global demand for shrimp and the government's push to promote seafood exports. With the help of corporate entities, hatcheries, farms, and processing plants were established to meet this demand. However, the industry's success came with a price. A significant amount of waste generated by shrimp processing has become a pressing issue. The fishing industry often overlooks the potential for reusing waste materials, leading to a significant portion of biomass being discarded directly into the environment without proper treatment [1-3]. Waste, in this context, refers to any unused material resulting from production or consumption processes that, if not appropriately managed, can harm the environment due to technological or market constraints. However, it is crucial to recognize that such waste holds great potential as a valuable raw material that can be utilized to produce beneficial bio-compounds [1,4].

Fish scales, shells, and shrimp waste are natural byproducts that have been used in various ways throughout history. These materials are composed of a complex matrix of biopolymers, including carbohydrates, proteins, lipids, and minerals, that confer unique physical and mechanical properties. Recent advances in biochemistry and biotechnology have opened up new avenues for exploiting the potential of these materials in diverse applications, such as food, medicine, and materials science [5,6].

Chitin is a naturally occurring biopolymer that is found in the exoskeletons of arthropods and the cell walls of fungi. Chitin is also present in the shells of crustaceans, such as shrimp, and the scales of fish. Chitosan is a chitin derivative produced by the deacetylation of chitin, a process that removes the acetyl groups from the chitin polymer. Fish scales are a rich source of chitin, and recent research has focused on developing methods to extract chitin from fish scales efficiently and cost-effectively. Chitin and chitosan have a variety of potential applications due to their unique physicochemical and biological properties. For example, chitosan has antimicrobial, antifungal, and wound-healing properties and has been used in the development of medical devices, drug delivery systems, and tissue engineering scaffolds [6-8].

In addition, chitosan has been studied for its potential use as a food preservative, as it can inhibit the growth of spoilage microorganisms and extend the shelf life of food products. Chitin and chitosan also have applications in the agricultural industry as natural pesticides and in the development of biodegradable plastics and films. Chitosan-polyvinyl alcohol blend is a biopolymer composite that is formed by blending chitosan, a biopolymer derived from the shells of crustaceans, with polyvinyl alcohol, a water-soluble synthetic polymer. The resulting blend exhibits unique physicochemical properties such as enhanced mechanical properties, increased biocompatibility, and improved cell adhesion compared to either chitosan or polyvinyl alcohol alone. These properties make the blend an attractive material. Overall, the extraction and utilization of chitin and chitosan from fish scales represents a promising area of research with significant potential for commercial applications [3,9-11].

MATERIAL AND METHODS

Material

In the present study, chitin extraction was carried out using fish scales obtained from the local fish market of Mouda, Nagpur, Maharashtra. The scales were intensively examined and identified as belonging to the *Labeo rohita* species, commonly known as Rohu (Fig. 1).

Methods

Extraction of chitosan

The extraction and purification of chitin from fish scales involves steps like removing proteins, lipids, minerals and other impurities from the raw material. Firstly, fish scales were cleaned by removing any visible debris and dirt. The scales were then subjected to air drying for two to three days. Dried scales were then subjected to a series of chemical treatments such as deproteinization, demineralization and deacetylation.

Dried scales were deproteinized by 5% NaOH on constant heating and stirring at 100°C for 25 to 30 minutes. The samples were washed using distilled water and filtrate, then demineralized with 1.25 N HCl at constant heating and stirring at 100°C for 25 to 30 minutes.

The treated chitin was washed with distilled water. Extracted and purified chitin was then processed for deacetylation with 50% NaOH for 2 hours at constant heating and stirring at 100°C. The deacetylated chitosan was then subjected to washing, air drying and crushed in mortar and pestle and fine powder was prepared (Fig. 2).

Preparation of chitosan-PVA blend

Chitosan is a biopolymer that has been blended with polyvinyl alcohol (PVA) in various ratios to form a composite material. PVA is a synthetic polymer product of vinyl acetate polymerization followed by hydrolysis. The chitosan-PVA blend combines the unique properties of both materials to create a material with improved properties for a wide range of applications.

Characterization of the prepared chitosan

Prepared chitin and chitosan are subjected to the characterization of the chitin, chitosan and chitosan-PVA blend and have been analyzed using microscopic, spectroscopic, and gravimetric assays (Fig. 3).

RESULTS AND DISCUSSION

Investigation in the present study focused on the preparation of a blend using different concentrations of chitosan and PVA. Various analytical techniques, including fourier-transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), thermogravimetric analysis (TGA), and assessments of mechanical properties, water uptake, and tensile strength, were employed to explore and characterize the properties of these blends.

FTIR Spectroscopy

The FTIR of samples was carried out for functional group determination using an ATR mode FTIR spectrometer, IR-affinity-1, Shimadzu over 400 to 4000 cm^{-1} frequency range and chitosan-PVA Blend measurements were carried out on a (BRUKER) Instrument. The IR spectrum of chitosan, Fig. 4 A, B & C show peaks around 990 and 1120 cm^{-1} corresponding to the saccharide structure. Despite several peaks clustering in the amide peak range from 1500 to 1530 cm^{-1}, there still were absorption peaks at 1690 cm^{-1}, which are characteristic of chitin and chitosan and have been reported as an amide. The broad peak at 1040 cm^{-1} indicates the C-O stretching vibration in chitosan. Another broad peak at 3440 cm^{-1} is caused by

Fig. 1: Source of chitin used in present work

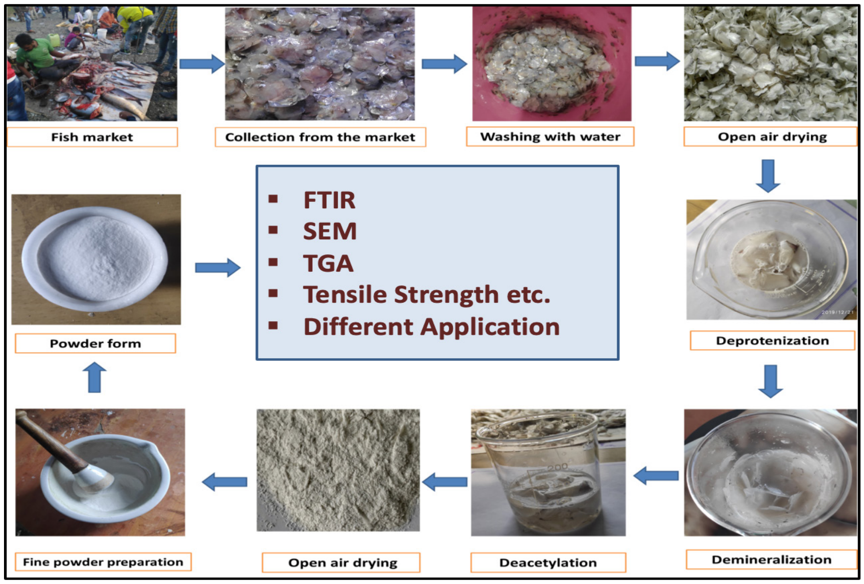

Fig. 2: Method of extraction of chitin and preparation of chitosan from fish scales

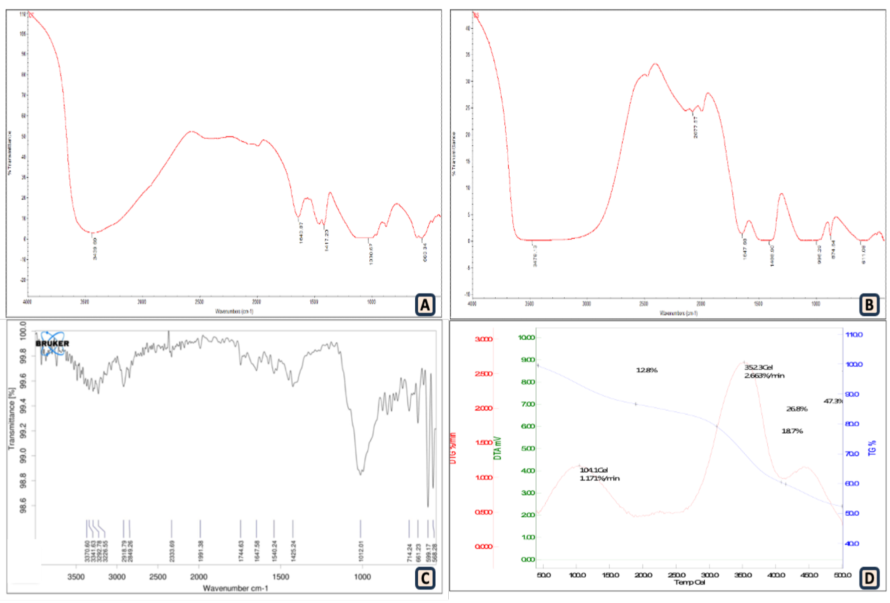

Fig. 3: The FTIR spectrum of extracted [A] Chitin, [B] Chitosan, [C] Chitosan-PVA Blend, [D] Thermogravimetric analysis (TGA^0) of Chitosan-PVA Blend

amine N-H symmetrical vibration, which is used with 1690 cm^{-1} for quantitative analysis of the deacetylation of chitosan. The IR spectrum of the chitosan–PVA film is different from that of the chitosan because There are two distinguishing peaks at 1425 and 1540 cm^{-1} formation of the NH_3^+.

Thermal Stability (Thermogravimetric Analysis)

A thermal analyzer TG-DTA 7200 (Hitachi, Japan) was used by TGA to evaluate the thermal stability of the materials. The TGA data depicted in Fig. 3D reveal the presence of water molecules, as indicated by a distinct peak at approximately 100°C. Furthermore, upon analyzing the data, it becomes apparent that there is a slight decrease in mass relative to temperature, specifically up to 300°C (as depicted by the blue line) (Fig. 3D). However, beyond this threshold, a significant decline in mass is observed, suggesting stability up to 300°C. The differential thermogravimetry (DTG) graph further corroborates these findings, highlighting that the maximum weight loss occurs at 352°C. These intriguing results shed light on the behavior of the sample, providing valuable insights into its thermal properties.

SEM Analysis

The films cast using chitosan-PVA blend in different ratios were characterized. The surface area of the polymer films is in different resolutions Fig. 4. The chitosan-PVA blend was analyzed using scanning electron microscopy, revealing that chitosan and PVA are well dispersed in the prepared blend.

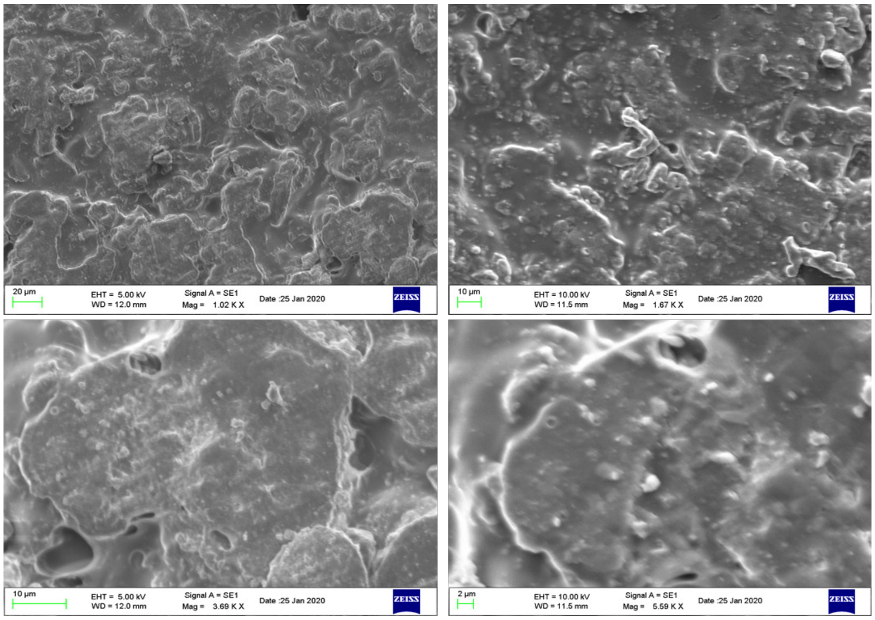

Fig. 4: Chitosan-PVA blend under SEM

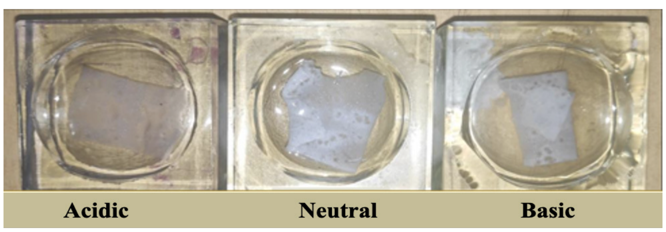

Fig. 5: pH-response and water uptake

pH response

The experiment aimed to assess the water uptake and pH response of the films Fig. 5. They were subjected to immersion in buffer solutions with pH values near 1, 7, and 13 for 18 hours. To evaluate the effects, the initial weight of the films was measured, and the final weight was determined after drying them with a paper towel. The results indicated that when exposed to basic pH and neutral pH conditions, the films absorbed water and exhibited an increase in weight. However, under acidic H, the structure of the polymer film was disrupted, suggesting an inability to maintain its integrity.

CONCLUSION

In the present study, fish scale wastes were used to obtain chitin and, correspondingly for the production of chitosan by employing different techniques. The chitosan produced by the deacetylation of chitin was observed to have many important properties. This study showed that various chitin and chitosan products can be generated using fish scales as founding materials. Chitosan is an easily accessible, cheap and biodegradable natural source. Chitosan and PVA are two biodegradable polymers that have been blended in various ratios to form a composite material. Then, the chitosan and blended films were investigated using FTIR, SEM, and TGA and checked for other mechanical properties of these blends. Thus, having a proper method of preparation with appropriate conjugation will certainly deliver the desired products. This study reveals that chitosan blends have wide applications in clinical, biomedical, pharmaceutical, food industries, etc.

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CONFLICT OF INTEREST

There is no conflict of interest.

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