An investigation of Chitosan's fiber to fabric

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***Abstract*- Chitosan produced from chitin, the second most frequently accessible polysaccharide, is a biodegradable, biocompatible polymer containing inherent antibacterial characteristics. Extensive efforts have been undertaken to turn chitosan into fibres because of its special qualities. In addition to its special qualities, chitosan is soluble in aqueous acetic acid, making solution spinning and electro spinning viable methods for producing fibres. The relatively weak mechanical characteristics and high moisture absorbency of chitosan make it unsuitable for many applications, despite significant efforts to develop chitosan fibres. The characteristics of chitosan fibres have been improved using strategies like cross-linking, mixing with natural and synthetic polymers, and other chemical alterations. In this Paper, dealt about chitosan fiber manufacturing process, properties and its application**

***Keywords*: chitosan, Chitin, wet spinning, dry spinning**

INTRODUCTION

The radulae of mollusks, the cell walls of mushrooms, algae, and fungi, as well as the exoskeletons of insects and crustaceans (including spiders, shrimp, crabs, and lobster), all naturally create chitin. 1010 tonnes of chitin are naturally created each year, with 70% coming from the ocean. Since there is a long-term prospective supply, the by-product of the fishing industry is sufficient to fulfill the enormous commercial demand for chitin and chitosan. Because chitosan is converted into sugar, it is biodegradable, biocompatible, and nontoxic, which are its key benefits.

A biomaterial with exceptional mechanical properties and a wide range of biological activity is chitosan. Due to their poor repeatability throughout product development, chitosan-derived products have a slow-growing industry [1]. The situation has changed from how first- and second-generation chitosan's were used as a biomaterial and biological functions for wastewater treatment and agricultural applications. Strong molecular structure-function relationships can be seen in the third phase of chitosan. Studies and research are currently being conducted to uncover every biological and biomedical function of chitosan, which will pave the way for the development of novel material applications. Applications for chitin and chitosan are extremely varied, and they can be used to make nanofibers, membranes, micro- and nanoparticles, scaffolds, beads, hydrogels, and sponges [2].Enzymatic synthesis of chitosan is continuously researched as an alternative to the risky procedure and lack of specificity for chitosan fictionalisation due to the growing concern about health, the environment, and economics. Additionally, new processes, devices, and designs are being developed from the beginning of the life cycle to the conclusion to practise and equip sustainability and safety in textile technology.

Chitin and chitosan chemistry

Chitin and chitosan are modified forms of cellulose, according to their chemical makeup, in which an acetamide and an amine group, respectively, take the place of the C-2 hydroxyl group. Chitosan is made from natural chitin, which is made up of units of glucosamine and N-acetylglucosamine randomly arranged along a linear polysaccharide chain. The occurrence of 100% acetylated amino groups and 100% deacetylated free amine groups in nature is extremely rare. It is possible that the chitin structure has less than 10% deacetylation (DD), whereas chitosan has between 40 and 98% DD. Chitin and chitosan's average molecular weight primarily depends on the degree of polymerization and deacetylation. In addition, the obtained qualities from various applications and goods vary based on the two criteria [3].

Additionally, based on the two factors, different applications and products acquire distinct attributes. Due to variations in the packing and orientation of the polysaccharide chain, chitin and chitosan's polymorphic structures alter. The degree of deacetylation and degree of polymerization mostly determine the average molecular weight of chitin and chitosan. Additionally, based on the two factors, different applications and products acquire distinct attributes. Due to variations in polysaccharide chain packing and orientation, chitin and chitosan's polymorphic structures alter [4].

Due to the existence of chiral glycosidic units, each individual chain rotates completely around its axis at 10.1–10.5. These units form a parallel and anti-parallel link between the C-1 oxygen atoms of one unit and the C-4 of the neighbouring unit. When those structures are characterised by X-ray diffraction and NMR spectroscopy, three different types of allomorphs: α, β, and γ form with a higher proportion of form αare found.

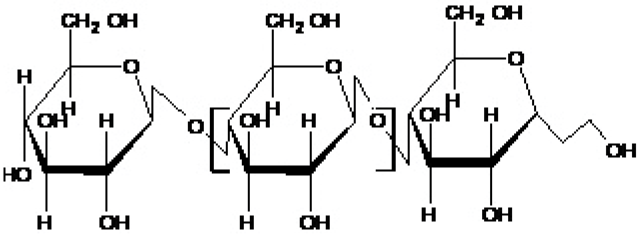

Fig 1: Chitin's molecular structure

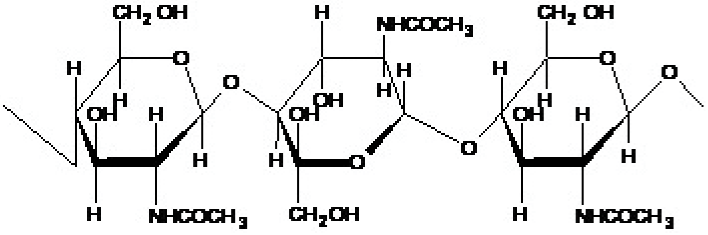

Fig 2: Chitosan's molecular structure

Fiber synthesis using chitosan

Wet Spinning

An acetylated polysaccharide is chitin. In comparison to semi-crystallized chitosan fibres, the addition of acetyl groups improves interchain forces and the proportion of crystallization, which results in greater dry and wet strength. Additionally, chitosan fibres with a higher moisture regaining capacity perform poorly in terms of building the desired strength.

Wet spinning is the most widely used technique for producing chitin and chitosan fibres. This method involves extruding viscous chitosan solution into a coagulation bath to create chitosan fibres. A viscous dope is created when chitosan dissolves in 1–10% acetic acid below pH 6.It goes through a candle system filtration unit to eliminate unwanted pollutants and a reservoir for degassing under vacuum for five hours at a pressure of about 30 mbar to ensure that the air bubble has been completely removed.

After that, the extrusion procedure begins to produce fibres, with a reservoir, a metering pump, and a spinneret making up the extrusion chamber. Under 1.5 bar of pressure, the chitosan dope is extruded into a coagulation bath. Aqueous solutions of coagulants like NaOH, KOH, cupric ammonia, alcohol/calcium chloride/acetate, NaOH-Na2SO4, NaOH- AcONa, NaOH-40% methanol, CuSO4-NH4OH, CuSO4-concentrated ammonia, etc. are present in the coagulation bath.The compounds in the tailors that were previously described serve as coagulation inhibitors. The take-up rollers, drawing system, drying rollers, and winding up are tuned in this process based on the production rate and necessary fibre qualities. Aqueous methanol and ethanol or distilled water is used to wash the extra coagulant from the fibre. Pre drying bath is another name for this washing bath. To improve the intended mechanical property in drying procedures, some extra physical and chemical processes are used [5].

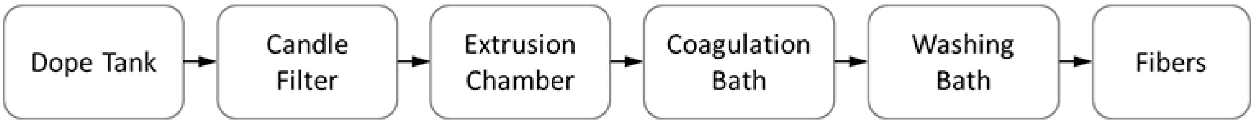

Fig 3: Wet Spinning Process

Dry Spinning

The initial concentration of the chitosan used for dry spinning should be more than or equal to 0.5% (w/w), which is the crucial concentration for chain entanglement. Chitosan is typically dispersed with acetic acid. The extrusion process comes after the process outlined above in a similar fashion. Chitosan monofilament is in contact with 125 ml of pure ammonia (20% w/w) in the gaseous state during the coagulation process. Based on the relationship between the extruder and the first roller's speed of around 3.4 m/min, the flow of gaseous ammonia is approximately 0.24 m3/h for 7.5 seconds. By keeping the speed of the first roller at 14% of its maximum, which results in a straight fibre line during coagulation, stretching is accomplished [6].

To prevent un-stretching, it's crucial to keep the speed exactly the same. To maintain a stretching ratio of 1:12 to the produced monofilament, a second, faster roller is employed. When drying, hot air approximately 110°C is passed via a 65 cm oven with an air flow of 1.5 m3/h, and monofilament is retained in the oven for around 10 s. The chitosan fibre is then treated for a week in wet air with a circulation temperature of 25°C and a water content of 55% w/w before final storage [7].

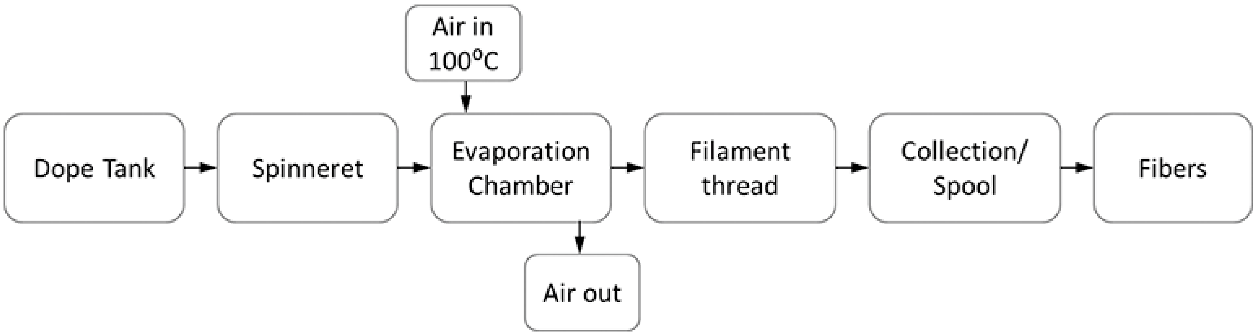

Fig 4: Dry Spinning Process

Properties of Chitosan Fiber

Chitosan's performance is influenced by a number of factors, including the degree of deacetylation (DDA), average molecular weight (MW), polydispersity (MW/MN), crystallinity, and acetylation pattern. Based on the chitin supply and hydrolysis techniques, chitosan has a wide range of MW, DDA, and crystallinity. Chitosan's molecular weight (MW) can range from 30 kDa to far above 1000 kDa. Since chitosan typically has a DDA of over 70%, it can dissolve in aqueous acidic solutions. Chitosan's poor solubility in commonly diluted acids is caused by higher crystallinity, which restricts the processing options for chi-tosan. In general, random deacetylation can decrease crystallinity and lower MW to increase a substance's solubility in solvents. As a result, the extraction method for chitosan affects its characteristics.

The concentration of alkali, temperature, reaction time, and chitin structure are the variables influencing the characteristics of chitosan in the extraction process. Alkali is used in the treatment procedure to remove the chitin protein and acts as a catalyst for the deacetylation process. Chitin is typically deacetylated with 40% aqueous alkali, typically sodium hydroxide, at 100–120 °C for 1-3 h to produce 70–85% deacetylated chitosan. Deacetylation advances quickly, reaching 70% after the first hour of alkali treatment in a 50% NaOH solution at 100 °C, but it then slows down, reaching 80% in 5 h. Further alkali treatment does not appreciably increase deacetylation; instead, it just damages the molecular chain.

The nitrogen in chitosan, the deacetylated derivative of chitin, is in the form of primary aliphatic amino groups following extraction treatment. Since chitosan is soluble in acidic solutions, it is possible to manipulate how much of it dissolves in water and organic solvents by adjusting the solution's temperature, pH, ionic strength, concentration, and solvent. Materials with negative charges may be able to interact with chitosan because the amino groups in chitosan possess a positive charge below pH 6.5.

Applications of Chitosan Fiber

Chitosan textiles can be applied to medical care to offer patients and carers constant, secure protection. Chitosan textiles can be used as materials for daily dressing and bedding or as essential components for long-term wound care for patients with skin trauma, especially those who are bedridden and at risk of developing bedsores or those with low immunity. This is because such textiles control bacterial growth and hasten wound healing. Additionally, using long-term antibiotics or silver fungicides can have negative effects that chitosan fabrics can prevent or lessen. To accommodate various requirements, the proportion of chitosan fibres to other fibres can be adjusted to manage the antibacterial effect.

Additionally, military and space activities require chitosan fabrics. The delicate balance of microbes is even more crucial in space due to the hostile environment. Microorganisms that are either too many or too few can be dangerous. An infection risk exists when the number of germs is excessive. Additionally, bacteria's unchecked proliferation and mutation in space could endanger people and other creatures travelling with them. Immune diseases or compromised immune function may result from an abnormally low microbial population. The number of microorganisms may be continuously maintained by using chitosan fabrics in ship interiors and clothes, which is advantageous for the health of shipborne employees.

Chitosan also has antifungal properties, making it particularly effective for textiles used in bedding, home décor, and personal hygiene items. However, the lack of brightness or whiteness in chitosan fibres inhibits consumer adoption of chitosan textiles [8][9].

Conclusion

Chitosan may be blended with traditional textile fibres like wool, cotton, silk, and polyester with ease and with strong interactions thanks to its structural features. Chitosan can be used as a finishing agent or fibre modifier to create functional textiles with antibacterial, anti-wrinkle, colouring, and antistatic qualities. The use of chitosan in the textile industry not only enhances the functionality and value of fabrics but also encourages the effective exploitation of natural resources.

REFERENCES:

1. Santos-Moriano P, Fernandez-Arrojo L, Mengibar M, Belmonte-Reche E, Peñalver P, et al. (2018) Enzymatic production of fully deacetylated chitooligosaccharides and their neuroprotective and anti-inflammatory properties. Biocatal Biotransformation 36(1): 57-67.
2. Kim SK, Abe S, Ishihara K, Adachi M, Ahn BN, et al. (2018) Antioxidant effects of phlorotannins isolated from Ishige okamurae in free radical mediated oxidative systems. In: Healthcare Using Marine Organisms. Springer Boca Raton, FL, USA, pp. 1-6.
3. Moattari M, Kouchesfehani HM, Kaka G, Sadraie SH, Naghdi M, et al. (2018) Chitosan-film associated with mesenchymal stem cells enhanced regeneration of peripheral nerves: A rat sciatic nerve model. J Chem Neuroanat 88: 46-54.
4. Hamedi H, Moradi S, Hudson SM, Tonelli AE (2018) Chitosan Based Hydrogels and Their Applications for Drug Delivery in Wound Dressings: A Review. Carbohydr Polym.

5. Ding F, Li H, Du Y, Shi X (2018). Recent advances in chitosan-based selfhealing materials. Res Chem Intermed: 4827-4840.
6. Moattari M, Kouchesfehani HM, Kaka G, Sadraie SH, Naghdi M (2018) Evaluation of nerve growth factor (NGF) treated mesenchymal stem cells for recovery in neurotmesis model of peripheral nerve injury. J Craniomaxillofac Surg 46(6): 898-904.
7. Lee EJ, Huh BK, Kim SN, Lee JY, Park CG, et al. (2017) Application of materials as medical devices with localized drug delivery capabilities for enhanced wound repair. Prog Mater Sci 89: 392-410.
8. Vidyavathi M, Farhana SKM, Sreedevi A (2018) Design and Evaluation of Lentil Seed Extract Loaded Bio Scaffolds for Wound Healing Activity. Biomed Pharmacol J 11(1): 503-511.
9. Xue Luo and Li Li, Chitosan’s Wide Profile from Fibre to Fabrics: An Overview, DOI: 10.5772/intechopen.76196.