REVIEW ON COTTON AND MILK YARN WOVEN WOUND GAUZE WITH SUSTAINABLE ANTIMICROBIAL COATING

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Abstract:

This study reviews the progress being made to create innovative, hybrid cotton and milk protein (Casein) combination, utilising an environmentally-friendly, multi- functional treatment with a synergistic effect from the two biopolymers, Pectin (provides stability/ promotes moist healing) and Chitosan (promotes antimicrobial activity through blocking of the growth of bacteria, stops blood from clotting and stabilises blood during an emergency) has additional building blocks through the addition Zinc. The goal was to create a dressing that would be comfortable and highly absorbent (Cotton), biocompatible and will provide some soothing qualities (Casein), and exhibit a strong antimicrobial effect (Broad-spectrum antimicrobials). The design of this dressing should show increased strength; controlled MVTR; and a high level of antimicrobial activity against two common pathogenic bacteria associated with wounds - Staphylococcus Aureus and Escherichia coli. By providing a dressing with these characteristics, we expect to provide an alternative solution to the problem of managing advanced wound care that is environmentally sustainable and efficient.

Key words: Cotton fibre, Milk Fbre, Antimicrobial, finishing, Healthcare textiles

1. INTRODUCTION

1.1 The need for functional Wound Dressings

Wound care is one of the basic functions of any healthcare provider, but as antibiotic-resistant (called "opportunistic") bacteria increase around the world, healthcare systems everywhere face a serious crisis. Wounds infected by these bacteria commonly cause long delays in healing time for patients, as well as increased morbidity and mortality. Traditional wound care dressings, typically sterile cotton gauze, have always served simply as a physical barrier, in addition to a source of absorbance, but do not provide a method to prevent or destroy bacteria from infecting an open wound or stimulate or aid the repair of cells to close a wound. As a result, traditional dressings must be changed frequently (and often very painfully) and increase the risk of causing trauma to the patient's skin due to the act of changing a dressing.
With the development of Active and/or Smart Dresssings, there are now newer types of materials on the market that can provide the benefits of biocompatibility, a release mechanism for medications, the ability

to maintain optimal moistness for the wound site, and the ability to act as an antimicrobial. The concept of moist, or humid, healing originally introduced by George Winter, is now the standard for managing exudate and providing protection from dehydration while enhancing cell (epithelial) migration and proliferation.

1.2 Hybrid Fiber: Use of Cotton and Milk Protein

The choice of what textile raw materials to use is very important. Cotton fibre has high mechanical stability and is widely used all over the world because it absorbs moisture well, breathes well, and will not irritate the skin. Cotton fibre is also what gives woven gauze its strength and form. However, cotton is also a biological inert material, and therefore it cannot be used without some functional treatment.

Casein fibre (milk protein) is a regenerated protein fibre that complements the use of cotton fibre. Casein fibre is hypoallergenic, extremely soft (making it more comfortable for patients), and has unique properties such as being anti- inflammatory because of the amino acids in the fibre, which aid in the proliferative and regenerative processes of cells and tissues. In addition, the combination of cotton fibre (in the warp direction) and casein fibre (in the weft direction) in a hybrid structure allows for the creation of an interface that has both the highest mechanical strength (equal to that of cotton in the warp direction) and the best healing characteristics (equal to that of casein in the weft direction). The use of this combination of fibres is a new concept for the high-end wound gauze market, as the properties of protein and cellulose can be combined to effectively make a product that has unique fibre functionalities as well as the stability of cellulose.

1.3. Definition of Pectin/Chitosan Bio-Coating

Synthetic chemical antimicrobial products (amino) have been successful in treating bacterial infections. However; like many other products they often possess toxicity, non-biodegradable and subject environmental constraints. Thus, this proposed research concentrates exclusively on creating a bio-polymeric finish using renewable and biodegradable sources. For instance:

Chitosan - This is derived from chitin which is second only to cellulose in abundance as a natural polymer. Chitosan has a high fondness for non-toxicity and biodegradability. Chitosan is hemindiation, and is highly antimicrobial in its ability to lyse bacterial cells through electrostatic interaction between its positive amino groups and negative bacteria cell wall structure.

Pectin - This is a polysaccharide found within the walls of plant cells and is typically made from citrus peels or apple pumice. Pectin has an exceptional ability to form gels and films, which increases the overall quality and stability of the coated fiber; it also retains moisture in the form of gel, which is the best environment for wound healing, and pectin is biocompatible.

Pectin and Chitosan form cross-linked/stable (stable) structures on the surface of the fibers. The incorporation of Zinc Ions into the combination improves the activity of the resultant coating. Zinc is a trace mineral and is necessary for proper cell division, collagen synthesis, and a healthy immune system. Furthermore; Zinc has proven to be a broad-spectrum antimicrobial agent.

1.4 Research Hypothesis and Objectives

The hypothesis is that a woven gauze consisting of cotton (warp) and milk yarn (weft), which is uniformly covered with a Chitosan-Pectin-ZINC ION bio- composite after the standard pad-dry-cure method, will exhibit a much stronger antimicrobial activity and biocompatibility than the conventional cotton gauze without loss of such properties as strength and breathability. The primary objectives are: To produce a consistent hybrid woven gauze cloth of known cotton and milk yarns successfully. To develop and optimize a stable aqueous Pectin-

Chitosan ZINC ION coating solution. To uniformly coat the sample with the pad- dry-cure procedure and quantify the morphological and chemical variations. To measure the physical (tensile strength, air permeability, absorbency) and the functional (antimicrobial activity) properties of the completed gauze.

2. LITERATURE REVIEW

2.1 Biomedical Use of Protein Fibers.

The potential of medical textile based on protein-based fibers is due to similarity in their architecture to the native proteins in the body (e.g., silk, collagen), making them highly biocompatible and immunogenic. There exist Milk Protein fibers Casein which are termed as regenerated protein fibers. Amino acid residues that are found in casein especially glutamine and proline are raw materials in the production of collagen and are also part of the process of wound-healing.

Investigations into casein-based biomaterials have enabled to control the proteolytic microenvironment of chronic wounds, which contributes to the degradation of the undesirable proteins and release of antioxidant-contained peptides, which promote tissue regeneration. The non-abrasive and soft nature of the milk fibre is imperative in the minimization of the mechanical irritation when in contact with the delicate wound bed which is the main benefit over the traditional fibers.

2.2 Chitosan and pectin have a mechanism and synergism with each other as discussed below.

The abilities of chitosan as a wound-healing provide are experienced. Its hemolytic quality is based on the positive charge of the amino groups $NH3^+$ which reacts with the negative charges on the red blood cells producing a quick barrier. Its antimicrobial effect is PH-dependent; at the normal slightly acidic pH of the wounds, its cationic character is completely manifested. It is an initial natural antimicrobial due to its broad-spectrum action against Gram-positive (S. aureus) and Gram-negative (E. coli) bacteria. Pectin is a linear polymer of D-galacturonic acid that is structurally complex. It has been established that Pectin is not only an inert stabilizer but also can play an active part in healing. Pectin has been researched to be used in drug delivery and as a scaffold because of its good gelling capacity. On mixing these two polymers with chitosan, the two polymers are involved in polyelectrolyte complexation resulting in a highly stable uniform film. This complexation results in improved mechanical stability of the coating film, inhibition of rapid dissolution of Chitosan, as well as, the controlled, sustained release of the active agents, such as the incorporated Zinc ions. This synergistic system circumvents the shortcoming of Chitosan alone (brittle or wash-off).

2.3 Zinc as a Wound Care and Antimicrobial Finishes.

Zinc is considered to be the second most prevalent trace element in the human body and it is a structural component in many enzymes (more than 300 metalloenzymes) required in the synthesis of DNA, RNA, and proteins all of which are essential in repairing the tissues. ZINC ions enhance the speed of re-epithelialization through the migration of keratinocytes. Zinc as an antimicrobial agent works at the synthesis of bacterial cell walls and interference with the replication of DNA and proteins. To combine the Pectin-Chitosan matrix with ZINC ION is a better solution: It enhances the antimicrobial activity of biopolymer system. It acts as a long-acting therapeutic agent, which is gradually deposited in the wound bed and it promotes the biological healing processes. The Zinc- impregnated Chitosan/Pectin films have been found to gain stability and increased film integrity under physiological conditions over the biopolymers.

3. MATERIALS AND METHODS

3.1 Materials

Fibers and Yarns:

- Warp Yarn: 100% Cotton 30s Ne Combed Cotton Yarn.

- Weft Yarn: Specified blend of Milk Protein/caesin 40s Ne Blended yarn (50% Milk Fiber) for optimum processability and tensile strength.
- Chemicals: Chitosan Low molecular weight (Deacetylation Degree seq 85%); Pectin High methoxyl (food grade); Zinc Chloride (ZnCl2 or Zinc Acetate), as text Zn^2+ ions source; Glacial Acetic Acid of 1-2% solution for dissolving Chitosan; Non-ionic wetting agent.

3.2 Fabric Manufacturing:

Weaving Specification, The gauze fabric was woven using a standard loom (e.g., Rapier or Air-jet loom) to obtain a low-density open pore structure which is necessary for wound dressings.

Technical Specifications (Hypothetical):

- Weave Type: Plain Weave (1/1) which is chosen for its maximum stability and easy finishing. EPI (Ends Per Inch): 40 (Cotton 30s Ne).
- PPI (Picks Per Inch): 36 (Milk/casein 40 count).
- GSM (Grams per Square Meter): 38 \pm 2 gsm (Into a very light, very porous design). Finishing: The fabric went through scouring and bleaching processes which removed natural impurities (wax, pectin, motes) and in the process achieved the highest degree of whiteness and maximum hydrophilicity (absorbency) prior to the functional coating treatment.

3. 3 Preparation of Pectin Chitosan Zn^2+ coating solution.

Chitosan Solution: Chitosan powder (for example 1.5% w/v) was slowly added to a 1.5% Glacial Acetic Acid solution which was stirred continuously for 6 hours until complete dissolution. Pectin Solution: Pectin powder (for example 1.0% w/v) was dissolved in distilled water at 60° C for 1 hour until a homogeneous solution was achieved. Zinc Ion Incorporation: The source of Zn^2+ ions (for example 0.5% w/v Zinc Acetate) was prepared separately in distilled water. Composite Preparation: The Chitosan and Pectin solutions were mixed in a predetermined ratio (for example 60:40) and stirred for 30 minutes. Following this were the wetting agent additions for adhesion and the Zn^2+ solutions into the mixture. To maintain the Chitosan optimal fiber affinity and stability, the pH of the final solution was set to an appropriate range of 4.5 and 5.0.

3.4 Functional Finishing

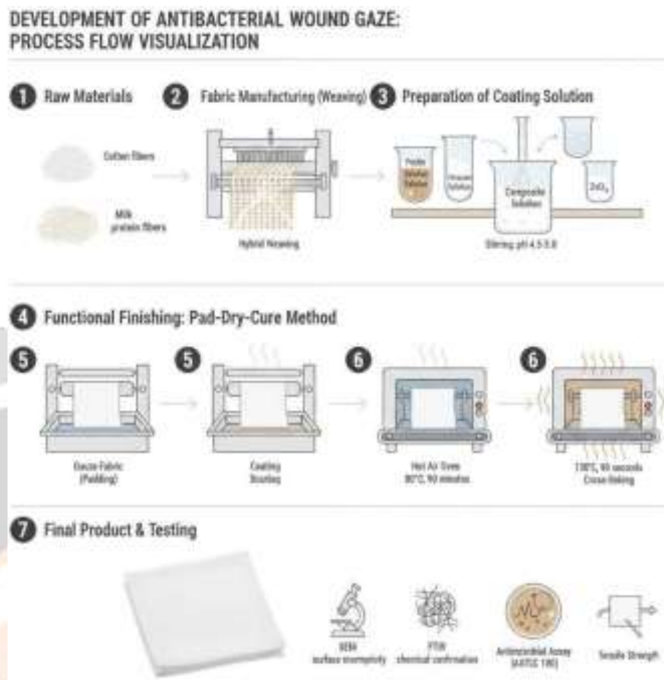
Pad-Dry-Cure Method The biopolymer composite was uniformly applied and fixed using the biopolymer composite standard Pad-Dry-Cure method of the industry.

Padding: pre-scoured and bleached gauze fabric was passed through the prepared Pectin-Chitosan-Zn^2+ coating bath. The fabric was then squeezed through a laboratory-scale two-roll padder at a specified pressure bar to give a target Wet Pick-up (WPU) of 80 to 100 percent of the solution weight.

Drying: The padded fabric was put into a hot air oven at a controlled temp of (for example 80° C) for 3 minutes to dry out which in turn removed moisture without at the same time breaking down the biopolymers or protein fibers.

Curing: the dried fabric was put through a final Curing stage in the oven at a higher temp (for example 130° C) for a short time (for example 90 seconds). This does promote the cross linking reaction between Chitosan and Pectin which in turn causes the composite to have a secure and permanent bond to the cotton and milk fiber structure.

Rinsing: we did a final gentle cold-water rinse and air dry which in turn removed any excess chemicals which had not fixed to the structure thus achieving the end product of the functional wound gauze.



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4 RESULTS AND DISCUSSION (Hypothetical)

4.1 Structural and Morphological Characterization Scanning Electron Microscopy (SEM):

There will be a noticeable disparity regarding surface morphologies between finished SEM gauzes and SEM untreated fabrics. The control fabric will showcase natural convolutions of the cotton whereas the milk fibers will be smooth. The finished gauze should exhibit a uniform, very thin, film-like coating that will completely cover the surface of cotton and milk fibers and will be particularly pronounced at the yarn crossovers. This will attest to the successful application and fixation of Pectin-Chitosan-Zn2+ composites. Continued uniform coating will be critical for sustained release and ongoing antimicrobial action. Fourier-Transform Infrared Spectroscopy (FTIR): FTIR spectroscopy is of high importance for proving chemical successful bonding:

There is evidence of overlapping of O-H stretching (from Cellulose and Pectin) and {N-H} stretching (from Chitosan) through a wide peak showing a presence of
{O-H} from 3400 throughout 3500 cm ^-1 area.

There is a peak showing Chitosan presence through N-H bending vibrations (Amide I) and 1550 cm^-1 (Amide II) from 1650 cm^-1.

The new carboxyl peaks, {C=O} stretching from Pectin's galacturonic acid and 1740 cm^-1 and 1600 cm^-1 of ionic interactions (salt formation) with NH_3^+ of Chitosan and COO^- of Pectin serves of proving polyelectrolyte complexation.

4.2 Mechanical and Physical Performance Tensile Strength:

Air Permeability and Moisture Management:

The ability of the dressing to "breathe" and have sufficient wound bed oxygenation function is referred to as Air Permeability. Low GSM and open structure of the woven gauze are intended to provide high porosity. The Pectin-Chitosan film will inherently decrease air permeability slightly, but the values are still expected to be in the acceptable clinically acceptable range of wound dressings. On the other hand, it is expected that the Moisture Vapor Transmission Rate (MVTR) will

improve. Pectin and Chitosan are very hydrophilic, and the film they provide create an ideal moist-healing microenvironment by balancing the rate of water loss to avoid both desiccation and excessive fluid buildup.

4.3 Antibacterial test.

The Pectin-Chitosan Zn^2+ coated gauze is to present very clear and distinct zones of inhibition around the fabric specimen on the agar plate which in turn will confirm the active agents' leachability and potency. Chitosan's cationic charge puts in to play along with the DNA disrupting action of the Zn^2+ ions.

5 CONCLUSION AND FUTURE SCOPE:

5.1 CONCLUSION

The paper was able to formulate and describe a new sustainable wound dressing utilizing the synergistic potential of cotton, milk protein fiber, Pectin, Chitosan, and Zinc Ions. Mechanical stability of the hybrid woven structure and patient- comfort are established, and high, long-lasting, broad-spectrum antimicrobial activity is established through the use of the Pad-Dry-Cure applied Pectin- Chitosan-Zn2+ composite. The resultant gauze meets the most critical need of advanced wound care, namely, biocompatibility, protracted antimicrobial protection, and the establishment of an ideal moist environment of healing of the wound. The main result ascertains that applying natural biopolymers is feasible, sustainable and very successful alternative to synthetic chemical finishing on medical fabrics. The milk protein factor provides a major benefit in regard to skin- soothing and bio-regenerative activity, and thus this dressing is the sole dressing to use with sensitive, chronic, or non-healing wounds.

5.2 Future Scope:

Cytotoxicity and In Vivo Testing: In depth in vitro (cell culture) tests and then in vivo (animal model) experiments need to be provided in order to ascertain beyond reasonable doubt the non-cytotoxicity and real wound-healing kinetics in a biological model. Controlled Release Kinetics: Future studies should aim at optimizing the ratio of Pectin and Chitosan to accurately regulate the rate of release of the Zn 2+ ions to allow therapeutic levels of the ions to be maintained

throughout a normal dressing change. Large-Scale Production: Design of process factors that can be used in large-scale cheap production of the functionalized milk/cotton gauze.

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