

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, February 2014

Study of Antibacterial Activity of Chitosan on Lyocell and Recycled Polyester Yarns

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Abstract: Medical textiles are one of the essential materials for the production of medical garments and have been developed in the past decades. A medical textile is a type of advanced technical textile materials and is classified according to its performance and functional properties as being suitable for medical or hygienic products. Among the vast categories of medical textile products, the hospital textiles are most important and also expected to fulfill the hygienic, comfort and microbial resistance property requirements. The functional requirements of hospital textiles have led to the innovative use of a variety of natural and manmade fibers with enhanced comfort and hygienic properties in the development of new products for medical textiles. The lyocell and polyester fabrics play an important role in the hospital textiles. The new innovation of antimicrobial finishes on the fabric can minimize the transfer of microorganisms on the wearer by creating as a physical barrier. Chitosan is a natural biopolymer and it has unique properties such as biodegradability, non-toxicity and antimicrobial activity. This work is an attempt to develop hospital textiles using lyocell and Recycled polyester fibers. The fibers were converted in to different composition of yarns such as 100% Lyocell, 100% Recycled polyester, 50:50 and 70:30 Lyocell/ Recycled polyester blended yarns using short staple spinning system. The 30sNe counts of yarns were developed in each composition and the chitosan antimicrobial finish was coated on the blended yarns using pad dry cure method. The fibre and finished yarn samples were tested for fibre length, denier, yarn tenacity, yarn evenness and antimicrobial properties. The effects of antimicrobial activity of the chitosan finished yarns were assessed by standard AATCC 147 test method. The different blended yarns test results showed an higher strength and elongation and better antimicrobial activity.

Key words: Lyocell, Recycled Polyester, Chitosan, Antibacterial activity.

I. INTRODUCTION

Lyocell is the strongest and stiffest regenerated cellulosic fibre. It combines the advantages of both natural and synthetic fibers. The lyocell fibers are moisture absorbent and biodegradable. It has high dry strength than the other cellulosic's and also approaching that of polyester. Lyocell has better strength similar to polyester and stronger than cotton and all other man-made staple fibers. These properties will motivate the manufacturer and customers to make stronger yarns in blend with virtually all the other commercially available staple fibers. All man-made cellulose loses strength and modulus when wet, but lyocell is better than others. [1-3]. Polyethylene terephthalate (PET) is condensation polyester produced by the reaction of di-acid and di-alcohol. The major raw materials for the production of PET are dimethyl terephthalate (DMT), terephthalic acid (TPA) and ethylene glycol (EG). PET is a major polymer with diverse applications. The motivations to recycling of PET bottles were not only due to the results of environmental pressure to improve waste management or its slow rate of natural decomposition, but it is also economical as stated [4]. Blending of different fibres is a very common practice in spinning industries to obtain a desirable range of properties to suit end-use requirement and economic considerations [5]. Blending is performed mainly to achieve the required

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characteristics to the end product and hold down the raw material costs and achieved the effects by varying color, fiber characteristics and so on [6-7].

Tencel fiber also blends well with other natural and synthetic fibers such as cotton linen, polyester, wool adding drape, comfort and performance of the fabrics. The versatility of this fibre produces excellent fabrics for both men's and women's casual and tailored wear as well as lingerie in women, jersey and knitwear [8]. Many attempts have been made to invent new solvents to directly dissolve cellulose, and some successful results have been reported. Among these, N-methylmorpholine- N-oxide (NMMO) hydrate turned out to be the best solvent, leading to the commercial success of cellulose fibers under the trade name of Tencel by Courtaulds in 1994 [9]. Other lyocell processes include Lenzing Lyocell and TITK Alceru [10]. These processes are advantageous because they are environmentally benign, using nontoxic NMMO hydrates instead of toxic carbon disulfide, and it can be almost totally recycled. The lyocell fiber has a highly crystalline structure, good wet strength as well as excellent dry strength, it makes lyocell water-washable and it shrinks less in wetted by water and dried than other cellulose fibers such as cotton and viscose rayon [11, 12, 13, 14]. It blends well with other fibres, especially other cellulosic's. and adds strength to the final yarns and enhances the performance and aesthetic values of final fabrics.

Polyethylene terephthalate (PET) bottles have experienced rapid growth since the 1970s when the technique of blow moulding was introduced. Today, bottle grade PET is one of the most important packaging plastics. In 2007, the worldwide consumption of bottle grade PET was 15 million metric tons (106 metric tons or Mt) representing 8% of the total demand of standard plastics. Meanwhile, recycling of post-consumer PET bottles has become a well-established system with its own logistic chain including bottles collection, flake production and pellet production. In 2007, approximately 4.5Mt of PET bottles were collected and recycled into 3.6Mt of flakes worldwide. Recycled PET fibre accounted for approximately 8% of the world PET fibre production in 2007 [15].

Chitosan have attracted considerable interest due to their biological activities, such as antimicrobial, antitumor and hypocholesterolemic functions. Recent studies on antibacterial activity, it is more effective in inhibiting growth of bacteria. Furthermore, the antibacterial effect of chitosan is reported to be dependent on its molecular weight however, most studies involve only one or a few different molecular weights of chitosan. [16].

In this present investigation, the quality aspects of ring spun yarn with different blend ratios of lyocel and recycled polyester were analyzed and the effect of antibacterial activity in chitosan solution were investigated on lyocell and recycled polyester blended yarns against gram positive bacterial strains.

II. MATERIALS AND METHODS

Selection of Fibres

Lyocell fibre is made of cellulose and it is suitable for allergy sufferers with very high dry and wet tensile strength, soft and have excellent moisture absorbing properties. The Lyocell fiber is ecological both in terms of both raw materials (plantation, pulp) and the production process which is environmentally friendly and it has a permanent crimp which is soft and kind on the skin and the ease of care after washing and dimensional stability. Recycled polyester fiber is the environmentally-responsible alternative to virgin polyester. The process of PET bottles covert into fibres were initially stripped of their labels and caps and washed thoroughly then it was crushed and then chopped into flakes that are melted and extruded into a fiber. The end product properties are nearly identical to the virgin polyester. Hence based on literature reviews, the recycled polyester and lyocell fibres were selected for the study for developing hospital textiles.

Preparation of Yarn Samples

Yarns of 30sNe count were spun from Lyocell and Recycled polyester fibres blended with different blend ratios. The selected different blend proportions were used as follows:

- 100% Lyocell
- 100% Recycled Polyester
- 70:30 Lyocell / Recycled Polyester
- 50:50 Lyocell / Recycled Polyester

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In blending process, the lyocell and recycled polyester fibres were hand opened and sandwiched well to produce a homogeneous blend. The carded slivers were drawn on a Computerized Miniature Drawframe Machine. The draw frame slivers were drawn thrice under identical processing conditions. The linear density of finished sliver was adjusted to 3.79ktex. The drawn sliver of lyocell and recycled polyester were converted into 394tex rove by Computerized Miniature Simplex machine. The lyocell/ recycled polyester ring yarns were spun by Computerized Ring Spinning Machine with the spindle speed of 12,000 rpm. The same procedure was followed for other yarn samples.

Preparation of Chitosan Solution

Chitosan (1%) solution was prepared by mixing with acetic acid (1%) and stirred in a magnetic stirrer at 60°C till a fine homogenous suspension was formed. The mixed polymer solution was kept overnight at stand still condition to remove air bubbles formed during stirring [17].

Method of Finish Application on Lyocell and Recycled Pet Blended Yarns

The selected percentage of chitosan solution was applied on to the blended yarns with the material liquor ratio of 1:10 by pad-dry-cure method with the cross linking agent. The blended yarn samples were cut and immersed and soaked in the chitosan solution for 5min and then it was passed through a padding mangle at a speed of 15m/min with a pressure of 1 kgf/cm² to remove the excess solution. After padding, the yarns were air dried and then cured for 3min at 140°C [18]. Then the samples were tested against fibre, yarn and antimicrobial properties.

Assessment Properties of Fibre, Yarn and Antibacterial Properties

Fibre Testing

The selected lyocell and recycled polyester fibre samples were tested (BISFA 1998 & ASTM D-3822-07) under the following parameters namely fibre length, denier, strength and fineness using high volume instrument (HVI). The working principle of High Volume Instrument systems are similar to the fibre bundle strength tester and The time for testing per sample is 0.3 minutes. The Lyocell and Recycled Polyester fibres were tested and average values were calculated and represented.

Yarn Testing

The different proportions of blended yarns were tested for single strand strength and breaking extension using Instron tensile tester according to ASTM standard. The 500 mm test specimens being elongated and rate of extension was adjusted to maintain the time of breaking of the specimen with in 20±2s. The breaking strength and breaking extension were averaged from 200 observations for each yarn sample. Yarn irregularity was also determined by an Uster Evenness Tester (UT-III).

Assessment of Antibacterial activity on Lyocell / Recycled Polyester Blended Yarns

AATCC-147-1998 (USA): Qualitative Antibacterial Assessment of Diffusible Antibacterial Agents (“Quick Method”) – Agar Diffusion Test

25ml of nutrient agar was prepared and sterilized at 121°C for 15 minutes. Petri plates were autoclaved in hot air oven at 121°C for 30 minutes. 20ml of Nutrient agar was poured into each of these plates and were allowed to solidify. A series of 8 test tubes containing 4.5ml of sterile water was taken and 0.5ml of culture from nutrient broth containing the chitosan treated 100% lyocell yarn sample was transferred aseptically into the first test tube. Serial dilution was carried out until its reduced dilution was 10⁻⁸. 100 micro liters of 10⁻⁸ diluted culture was taken aseptically and poured onto the petri plates. This was spreaded by using L rod. The plates were incubated at 37°C for 16-18 hours [19]. Similar procedure was carried out for all other yarn samples.

III. RESULTS AND DISCUSSION

a . Fibre properties

The lyocell and recycled polyester fibers test results are listed in the Table I and Fig 1. The test results showed that the recycled polyester fibre has high tenacity and linear density than lyocell fibre. The results of fibre properties of both samples showed no significant difference in breaking elongation.

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TABLE I

Properties of lyocell and recycled polyester fibers

Fibres	Length (in mm)	Fibre Fineness (in Denier)	Tenacity (in g/denier)	Breaking elongation (in %)
Lyocell	38	1.25	3.81	10.41
Recycled Polyester	38	1.43	5.27	10.41

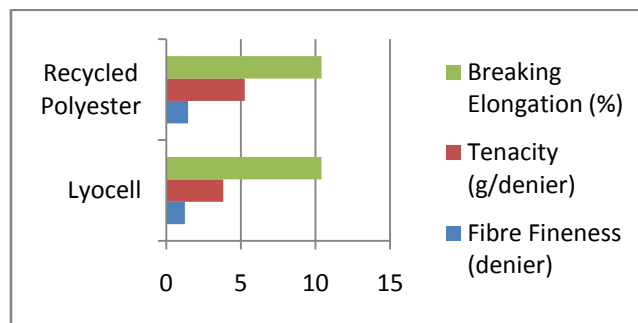


Fig. 1 Properties of lyocell and recycled polyester fibers

b . Yarn characteristics

The chitosan antimicrobial treated Lyocell and Recycled Polyester (100% Lyocell, 100% Recycled Polyester, 70:30 Lyocell / Recycled Polyester, 50:50 Lyocell / Recycled Polyester) blended yarns test results are shown in Table II and Fig 2. From the Table-II, the results chitosan treated of 50:50 Lyocell / Recycled Polyester blend proportion showed higher strength and elongation than 100% Recycled Polyester. The both Lyocell (100%) and Lyocell / Recycled Polyester (50:50) yarn samples showed the same results of breaking elongation because of finish application.

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TABLE II
Characteristics of lyocell and recycled polyester yarn samples

Parameters	Lyocell 100:0	Lyocell / Recycled polyester 70:30	Lyocell / Recycled polyester 50:50	Recycled polyester 100:0
Count (Ne)	30	30	30	30
Breaking Elongation (%)	7.11	8.23	7.14	9.66
Tenacity (g/denier)	16.21	14.66	17.11	12.86
Twist per cm	8.66	8.66	8.66	8.66
RKM value	22.85	19.94	18.42	24.77

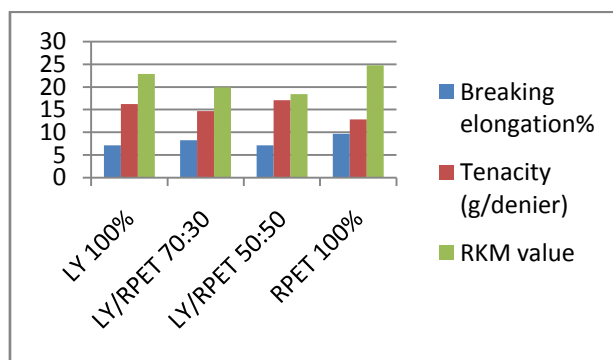


Fig. 2 Characteristics of lyocell and recycled polyester yarn samples

c. Antimicrobial activity

The agar diffusion test results of yarn samples for antimicrobial effectiveness against standard test cultures namely *Staphylococcus aureus* bacterial organisms are presented in the Table III and Fig 3. As can be seen, after incubation the plates were observed for bacterial growth. Then the numbers of colonies were counted for each plate. The plates showed the zone of inhibition of different yarn samples such as Lyocell / Recycled Polyester 50:50 blend (18mm) and 100% Lyocell (24mm) 70:30 Lyocell / Recycled Polyester blend (20mm) and 100% Recycled Polyester (15mm) against *Staphylococcus aureus* positive bacteria. The plate results proved that the 100% lyocell chitosan treated yarn sample do not support the bacterial growth to larger extent when compared to the other yarn samples.

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TABLE III
Antibacterial activity of Lyocell and Recycled Polyester Yarn Samples

Blended Yarn samples	Antibacterial activity against <i>Staphylococcus aureus</i> positive bacteria in (mm)
Lyocell 100:0	24
Lyocell / Recycled polyester 70:30	20
Lyocell / Recycled polyester 50:50	18
Recycled polyester 100:0	15

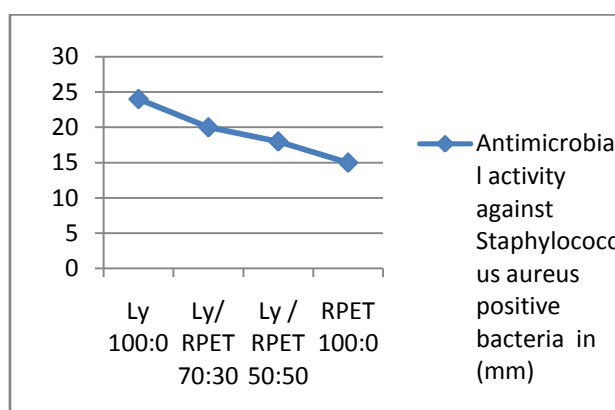


Fig.3 Antimicrobial activity of Lyocell and Recycled Polyester Yarn Samples

IV .CONCLUSION

The Lyocell and Recycled Polyester both the fibres and yarn blends showed better strength and elongation property. The Recycled Polyester has comparatively higher tenacity where as Lyocell and Recycled Polyester has almost similar breaking elongation. All the developed chitosan treated blended yarn samples has better antimicrobial activity. In general, the ring yarns made from lyocell and its blend with recycled polyester fibre are stronger and more extensible. From the test results, it concluded that the developed blended lyocell and recycled polyester yarns will be more suitable for developing hospital textiles due to its higher strength and breaking elongation property. This research work will lay a foundation for wealth out of waste materials from new innovative products for different end uses.

ACKNOWLEDGMENT

We thank the Management of Kumaraguru College of Technology and TIFAC-CORE in Textile Technology and Machinery, Kumaraguru College of Technology, Coimbatore, India for their endless support rendered to test the samples.

International Journal of Innovative Research in Science, Engineering and Technology

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