ENHANCING CREASE RECOVERY IN LINEN FABRIC THROUGH CITRIC ACID TREATMENT

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ABSTRACT

This work focuses on improving crease recovery in linen fabric using citric acid as a crosslinking agent and sodium hypophosphite as a catalyst. Citric acid is a non-formaldehyde-based agent widely used in the textile industry for creating crosslinks in cellulose fibres, which enhances the crease recovery of fabrics. By optimizing the treatment parameters—such as citric acid concentration, catalyst concentration, and curing temperature—the study aims to develop a sustainable and effective method for increasing the fabric's crease resistance while maintaining its physical properties, including tensile and tear strength.

Keywords: Linen fabric, Citric acid, Crosslinking agent, Box-Behnken method, Eco-friendly textile processing, Wrinkle resistance, Crease recovery.

1.Introduction:

Linen, one of the most ancient and revered textile fibres, is derived from the flax plant (*Linum usitatissimum*). It is composed of approximately 80% cellulose, with the remaining 20% consisting of pectic substances, hemicellulose, and lignin. The process of extracting linen from flax involves labour-intensive steps such as retting, scutching, and spinning. Despite the effort required, linen is highly valued for its strength, durability, and natural lustre.

For centuries, linen has been used across various cultures for garments, bed linens, and household items due to its exceptional qualities. However, one significant drawback is its tendency to wrinkle, caused by crushing during use and washing. During washing, water absorption allows cellulose molecular chains to shift in the amorphous and intermediate (non-crystalline) regions. Hydrogen bonds between adjacent hydroxyl groups stabilize the cellulose molecules in their new arrangements, resulting in persistent creases.

Linen fabric is highly prone to creasing, and once creased, the wrinkles are challenging to remove, especially when the fabric is in a dry state. Therefore, preventing the movement of cellulose chains is essential to address this issue. This is achieved using resins and polymers, which act as cross-linking agents. These agents, also referred to as *easy-care* or *durable press (DP)* finishing agents, are classified into two categories: formaldehyde-based compounds and formaldehyde-free compounds.

This research focuses on improving the crease recovery angle of cellulosic fabrics, particularly linen, by utilizing eco-friendly chemicals. While cross-linking between cellulose chains has been a widely adopted strategy, achieving a process that enhances dry crease recovery without compromising other fabric characteristics remains a challenge. Addressing this long-standing goal is critical for linen producers, aiming to combine functionality with sustainability.

2. MATERIALS AND METHODOLOGY:

2.1 Materials:

The fabric used in this study was Desized scoured, pure linen plain-woven fabrics with EPI 50, PPI 52 and GSM 180. This fabric was supplied by Master Linen Inc, Karur, Tamil Nadu.

Citric Acid (CA), Sodium Hypophosphate (SHP)

2.2 Methodology:

The fabric was pretreated in a solution containing 1% HCl for 1 hour at room temperature, maintaining a material-to-liquor ratio of 1:10. After pretreatment and drying, the fabric was padded in a solution containing citric acid and sodium hypophosphite using padding mangle machine as shown in Fig.1.The padded fabric was then dried at 80°C, followed by a curing process in curing chamber as shown in Fig.2 is carried out at 160°C, 180°C, and 200°C for 2 minutes each . Using the Box-Behnken experimental design, a total of fifteen trials were conducted.

The methodology of this research process has been highlighted in the below flow chart

Pretreated Linen fabric

↓

Treating of Linen fabric with citric acid +Sodium hypophosphite (SHP) (catalyst)

↓

Drying at 100° C for 5 minutes and curing at 160°C-200°C for 2 mins

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Testing of finished fabric

(Crease recovery angle, Tensile strength, Whiteness index, Stiffness Testing)

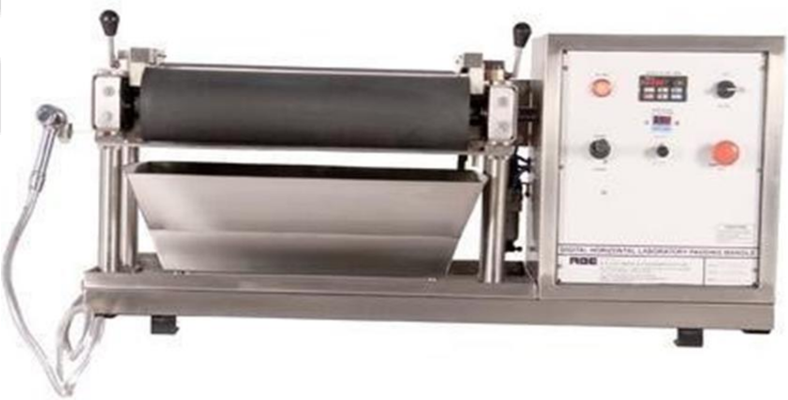

Fig.1 Padding Mangle

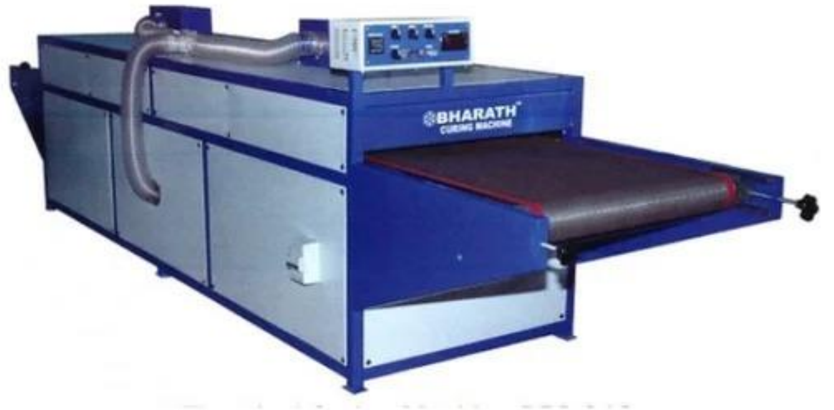

Fig.2 Curing Chamber

Statistical Analysis:

Box and Behnken method has been adopted to formulate the experimental design, in which fifteen different combinations are formed. This method also offers the advantage of being rotatable which means that the fitted model estimates the response with equal precision at all points in the factor space that are equidistant from the centre.

Experimental design:

A quarter factorial design was constructed using Minitab statistical software. The ranges of concentrations of Citric acid, Sodium hypophosphate was 15-25%, 4-6% respectively. The ranges of curing time and temperature were 160– 200 °C and 2 mins, respectively.

Details of process parameter and different levels:

Process Parameter	**-1**	**0**	**+1**
Citric Acid conc (X1), % (owf)	15	20	25
Sodium Hypophosphate(X2) % (owf)	4	5	6

Curing Temperature(°C)	160	180	200

Experimental designs:

SNO	**Concentration of Citric Acid %(owf)**	**Concentration of Sodium Hypophosphate %(owf)**	**Curing Temperature (°C)**
1	15	4	180
2	15	6	180
3	25	4	180
4	25	6	180
5	15	5	160
6	15	5	200
7	25	5	160
8	25	5	200
9	20	4	160
10	20	4	200
11	20	6	160
12	20	6	200
13	20	5	180
14	20	5	180

15	20	5	180

4.Testing:

Fifteen specimens of each of the treated sample were tested both in the warp (Wp) and weft (Wt) directions.

4.1 Crease Recovery Angle

The crease recovery of the fabrics was tested using the Shirley crease recovery tester and the value reported in this instrument was CRA according to AATCC TM 66-2017 method. The **Crease Recovery Angle (CRA)** is the value obtained using this instrument, indicating the fabric's resilience and elasticity after deformation.

4.2 Tearing Strength

The fabric sample were tested for tear strength according to ISO-13937-1, Elmendorf tearing strength tester to measure the tear strength of fabric as per ASTM D-1424-96; This standard is specifically designed for testing woven fabrics, allowing accurate determination of their tensile properties.

4.3 Tensile Strength

The tensile strength of the samples, which was measured by the ravelled strip (20 cm × 5 cm) method. The tensile strength of fabric was tested as per ASTM D-5035 method.

4.4 Stiffness Tester

The Shirley stiffness tester to measure the flexural rigidity of the fabric as per ASTM D 1388 and

4.5 Whiteness Index

spectrophotometer (data colour) to measure the whiteness index of fabric as per ASTM DE 313-67.

The mean values of the results were used for further statistical analyses and construction of the prediction models.

5.SUMMARY

This project explores an innovative approach to improving the crease recovery properties of linen fabric, a natural and widely appreciated textile known for its strength, durability, and lustrous appearance. Linen is inherently prone to creasing, which significantly limits its usability in practical applications. Traditional solutions to this issue often involve formaldehyde-based agents, which pose health and environmental concerns.

To address these challenges, the study investigates the use of citric acid, a biodegradable and non-toxic crosslinking agent, combined with sodium hypophosphite as a catalyst. This eco-friendly treatment seeks to enhance the fabric's crease recovery performance by forming crosslinks between cellulose molecular chains, thereby stabilizing the fabric structure and reducing wrinkling.

The research employs the Box-Behnken experimental design to systematically optimize key process parameters, including citric acid concentration (15–25%), sodium hypophosphite concentration (4–6%), and curing temperature (160–200°C). A total of 15 trials were conducted, allowing for a thorough evaluation of the interactions and effects of these variables on fabric performance.

Post-treatment, the fabric samples were subjected to a series of standardized tests to assess their crease recovery angle, tensile strength, tear strength, stiffness, and whiteness index. These evaluations ensure that the optimized treatment not only improves wrinkle resistance but also preserves or enhances other critical fabric properties.

The study ultimately aims to establish a cost-effective and environmentally friendly alternative to conventional formaldehyde-based wrinkle-resistant finishes. By combining sustainability with functionality, this work contributes to advancing green textile processing practices and adds value to linen fabrics, making them more suitable for modern-day applications in garments, home furnishings, and more.

CONCLUSIONS:

The study concludes that citric acid is an effective non-formaldehyde crosslinking agent for linen fabric, providing significant crease resistance while minimizing environmental impact. The optimal parameters of 15-20% citric acid, 4-6% sodium hypophosphate, and 160-200°C curing temperature produce the best combination of crease recovery, tensile strength, and whiteness retention. The process can potentially replace harmful formaldehyde-based treatments, offering both safety and effectiveness in textile finishing.

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