Advancements in Cationic Cotton Technologies
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cottonworks.com
Type your questions in the Q&A window at any time during the webinar.

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Meet the Presenters

Matt Farrell
Textile Chemistry Research Manager
Cotton Incorporated

Esma Talu
Marketing Manager & Sustainability Manager
Dow
Advancements in Cationic Cotton Technologies
Basics of Cationic Cotton

- Cationic cotton refers to cotton that has been chemically modified to possess a permanent cationic (positive) charge.
- Concept has been researched for ~50 years.
- Ionic attraction of negatively charged dye to cationically charged cotton.
- Negates the use of salt, reduces dyestuff, reduces process consumables, and can lead to overall lower costs.
Value to the Industry

If consumption trends continue, we'll need 3x as many natural resources to produce clothing in 2050 compared to 2000.

Cationic cotton can play a key role in more sustainable textile production.
Chemistry of Cationic Cotton

Typical cationization reagent, 3-chloro-2-hydroxypropyltrimethylammonium chloride (CHPTAC) “Quat 188”

Cellulose-OH

OH-

Cellulose-O

OH-

TMA released

Cellulose-OH

OH-

TMA released

8.45% CHPTAC 4.23% CHPTAC 2.11% CHPTAC

Neutralization A

Neutralization B

Neutralization C

Synthesis of CHPTAC

Alternative non-volatile amines

- Low steric hindrance
- Minimal side reactions with EPI
- Economical

Reducing Cotton's Dependence on Water for Coloration, AATCC 2018 ICE
Molecule Comparison

**CHPTAC**
Quat 188

**CHPDMAP**
ECOFAST™ Pure Textile Treatment

- Dow was approached for interest in producing the new molecule
- Dow shared their newly patented cationization molecule, BEDQ, tradename ECOFAST™ Pure
- Also made from a non-volatile amine, bifunctional in reactivity and cationic sites
- **No odor**

![Chemical structures for BEDQ and CHPDMAP](attachment:image.png)
Testing Cationic Cotton Treatments
Dyeing Comparison

- Initial applications to confirm product efficacy and no odor
- Presented at 2018 AATCC ICE, ECOFAST™ Pure officially launched

<table>
<thead>
<tr>
<th>Conventional Dyeing</th>
<th>Reactive Dyes</th>
<th>o.w.g.</th>
<th>Sodium Sulfate</th>
<th>Sodium Carbonate</th>
<th>Sodium Hydroxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Shade</td>
<td>Black</td>
<td>3.79%</td>
<td>90 g/L</td>
<td>3.5 g/L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orange</td>
<td>0.74%</td>
<td>3.0 g/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>0.11%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reactive Dyes</th>
<th>o.w.g.</th>
<th>Sodium Sulfate</th>
<th>Sodium Carbonate</th>
<th>Sodium Hydroxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Shade</td>
<td>Black</td>
<td>2.46%</td>
<td>N/A</td>
<td>1.5 g/L</td>
</tr>
<tr>
<td></td>
<td>Orange</td>
<td>0.48%</td>
<td></td>
<td>1.75 g/L</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>0.07%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 33% Less Dye
- No Salt
- 50% Less Alkali
- 20% Time Savings
- 2 less rinses*
Dyebath Comparison

• Improved dye use efficiency and less water use in rinses
Increased Collaboration for Impact

• Cotton Incorporated and Dow have collaborated to explore and validate ECOFAST™ Pure, including comparison to Quat-188
• Analytically evaluated ECOFAST Pure vs Quat 188 in cold pad batch, pad steam, exhaust, and pad dry cure processes
  • ECOFAST Pure outperforms and improves cationization efficiency in all processes
• Evaluated nitrogen both by Kjehldahl and combustion techniques
• Evaluated effect of wet pick up on cationization efficiency
• Collaborated to build Dow’s kinetic calculator
Cold Pad Batch Comparison

Kjeldahl

$y = 0.0815 \ln(x) + 0.2468$

$R^2 = 0.9568$

$y = 0.0816 \ln(x) + 0.2177$

$R^2 = 0.9671$
Cold Pad Batch Dyeability

Is there a difference in dyeability?

With limited dyes evaluated, have not observed appreciable blocking effects.
Validating the Benefits

ECOFAST™ Pure enables...

- 90% process chemicals
- 50% dye
- 50% water
- 40% energy

Key Life Cycle Assessment Insight

- 63% GHG emissions when using ECOFAST™ Pure

Other considerations
- Optimized with pad application
- Registered at ZDHC Gateway
- Meets MRSL standards
Addressing Common Concerns with Cationic Cotton
Challenges Utilizing Pre-Cationized Cotton

- Purchasing pre-cationized fiber can be an attractive alternative to fabric treatment.
- Dark shades such as black or navy may only require a simple scour for, bright shades and/or performance requirements may dictate a bleach preparation.
  - Typical bleach formulas and processes over-activate hydrogen peroxide species causing extensive fiber damage, loss of dyeability, and low whiteness index.
- Without the ability to control the treatment levels, and in general, the cationization may work “too well” in attracting dyestuffs.
  - Quick strike of dyes onto cationic cotton can cause unlevel dyeings, splotchy appearances, and may impact fastness properties.
Investigating the Bleaching of Pre-Cationized Cotton

- Statistical analysis of design of experiments with factors including bleach temperature, time, concentration of caustic and hydrogen peroxide and magnesium sulfate
- Responses included whiteness index, burst strength, and dyeability

<table>
<thead>
<tr>
<th>Table I. Effect of Bleaching Temperature on Cationized Cotton Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cotton Fabric</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Uncationized</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cationized</td>
</tr>
<tr>
<td></td>
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</table>

AATCC Journal of Research DOI: 10.14504/ajr.6.5.4
Key Considerations for Bleaching Pre-Cationized Cotton

- Direct input of magnesium sulfate (Epsom salt) key in quenching over activation of peroxide system
- Difficult to increase whiteness, burst strength, and dyeability responses at once
- 3-7 g/L of H$_2$O$_2$ and 0.5-1 g/L of MgSO$_4$ are suggested in consideration of all responses
- Other factors including time, temperature, and caustic determined by fabric requirements

AATCC Journal of Research DOI: 10.14504/ajr.6.5.4
**Bleaching Visualization**

Table III. Effect of MgSO₄ on Bleaching Cationized Cotton Fabric

<table>
<thead>
<tr>
<th>Bleaching Temperature</th>
<th>MgSO₄ Conc. (g/L)</th>
<th>Bath after Bleaching</th>
<th>Bleached Fabric Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% NaOH Consumption</td>
<td>% H₂O₂ Consumption</td>
<td>WI-CIE</td>
</tr>
<tr>
<td>100 °C</td>
<td>0</td>
<td>82</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>90 °C</td>
<td>0</td>
<td>72</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>41</td>
<td>18</td>
</tr>
</tbody>
</table>

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Controlling Strike Rate by Process Changes

- The influence of temperature, dye structure, and addition of soda ash on dyeing kinetics and levelness of cationized cotton were evaluated utilizing real-time dyebath monitoring.
- For most of the dyes, significantly better dyeing levelness was obtained by lowering the dyeing temperature although the strike rate was minimally slowed.
- Addition of soda ash has different effects on dyeing kinetics and levelness for different dyes.
  - For VS-MCT dyes, the addition of soda ash has a relatively small influence on the dyeing performance.
  - For MCT-MCT dyes, eliminating soda ash from the initial dyebath significantly reduced the dye strike rate and improved dyeing levelness.
Fig. 9 The influence of soda ash on the exhaustion kinetics of Everzol Red 3BS

Everzol Red 3BS (239)

Evercion Red H-E7B (141)
Controlling Strike Rate by Chemical Means

**Fig. 12** Cationic cotton fabrics dyed with different leveling agents
Key Recommendations for Strike Rate

• Naphthalene sulfonate formaldehyde condensate is key component to allow dye retardation, obtain levelness, but still obtain near complete exhaustion

• Dye exhaustion temperature as low as possible
• Add soda ash late in process
• Utilize condensate levelling agent
• Add dye in parts or progressively

Cellulose (2017) 24:3061-3071
DOI 10.1007/s10570-017-1291-0
Fig. 13 The effect of adding dyes in portions on the exhaustion of Reactive Red 239

Table 7 The effect of adding dyes in portions on dyeing cationized cotton with Reactive Red 239

<table>
<thead>
<tr>
<th>Addition of dye</th>
<th>Conc. of INVALON DAM</th>
<th>Dye exhaustion monitoring</th>
<th>Dyed cationized cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial rate (%/min)</td>
<td>Max. rate (%/min)</td>
</tr>
<tr>
<td>All in</td>
<td>No leveling agent</td>
<td>36.8</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>15.3</td>
<td>5.8</td>
</tr>
<tr>
<td>Add in 4 portions</td>
<td>No leveling agent</td>
<td>8.1</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>3.2</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Advancements in Cationic Cotton Technologies
Cationic Cotton

What is Cationic Cotton?
Cationic cotton is cotton that has been chemically modified to possess a permanent cationic, or positive, charge. Although the concept of cationic treated cotton has been available for many years, this innovative technology has continued to grow in popularity among companies exploring ways to reduce water, energy, and chemical consumption in the development of their products, while also seeking ways to increase responsiveness to consumer fashion demands with more versatile and on-trend fashion offerings.

When immersed in water, cotton naturally possesses a neutral or mildly negative charge. Common dyes used for cotton also possess a negative charge. Like common poles of magnets, the same charges repel each other. Therefore, in typical dyeing of cotton, salt and alkali are used in the dye bath to reverse the charge on cotton so that it has a positive charge, allowing the dye to react and bond to the cotton. Cationic treated cotton is chemically modified to possess a permanent cationic.

Cationic Design Possibilities
Cationic cotton technology prepares the fabric to accept a greater variety of dyes and provides for greater flexibility in the color offerings. Unique designs can be achieved by altering the level of cationization (higher = deeper color) and creating fabrics using both cationized and conventional cotton in the same fabric. Altering the level of cationization can help create tonal effects in the fabric, while blending with non-cationized yarn creates areas that do not take the dye, yielding clean crisp lines. Yarn dye effects can also be created with alternating cationic and non-cationic yarns. Cationic cotton can be used for 100% cotton or blended yarns.

Go to cottonworks.com/cationic-cotton.
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