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Improved Performance through Functional Finishes

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ABSTRACT

Recent commercial developments in functional finishes for cotton are discussed. Moisture management, comfort and odor are highlighted as areas of interest to the consumer, and some available products are mentioned. Results from a study of antimicrobial finishes on cotton knit fabric are given. None of the products remained effective against the chosen Gram-negative bacteria after limited number of home laundering cycles (HLTDs). However, all the treatments appeared to kill the Gram-positive bacteria after ten HLTDs. Further study is needed to identify a topical antimicrobial treatment that continues to work well after twenty-five HLTDs.

KEYWORDS: cotton, functional finishes, moisture management, comfort, antimicrobial, fluorochemical

INTRODUCTION

As consumers demand more durability and more functionality from their clothing, apparel makers must respond with garments that are technically advanced yet still soft and comfortable. Cotton can provide naturally the comfort that is expected in garments and, by finishing, protection from ultraviolet, from weather, or from odors due to microbe growth. Additional properties such as resistance to burning and freedom from wrinkles are also desirable and may be achieved with the selection of an appropriate finish. Our challenge is to broaden the range of characteristics which can be obtained with cotton without forfeiting the superior comfort properties with which cotton is endowed.

Briefly, some of the characteristics which have played a part in the success of cotton are breathability, absorbency, texture, and freedom from static. Breathability, absorbency, and texture also contribute to the comfort of cotton. Some of the finishes that are widely used to expand the appeal of cotton are wrinkle resist, softeners, and enzyme treatments. Coated and laminated fabrics have become very fashionable in some areas. Application of fluorocarbons to apparel for soil repellency, water repellency, and stain release has been limited. Although antimicrobial finishing has become popular in other countries, in the U.S., questions about regulations have restrained the use on fabrics. Other unique finish applications that may have some consumer appeal include the incorporation of scents or chemicals to remove odors and temperature regulation through phase change materials. Finally, ultraviolet-protection and flame-resistance are features that have been historically are targeted to specific markets, for instance, beachwear or protective apparel.

This paper will highlight some current developments in functional finishes and present an examination of commercial antimicrobial treatments for 100% cotton.

MOISTURE REGULATION

One new process for finishing woven fabrics has been developed by Nextec Applications, Inc. The Encapsulated Protection Inside Clothing (EPIC) process surrounds individual fibers with one of several fluoropolymers that may inhibit water absorption and provide stain resistance and water repellency. The spaces between yarns are treated with a durable silicone. According to their tests, this procedure does not adversely affect the hand or breathability of the garment. Unlike coating or laminating, the drape of the cloth is unaffected as well.

In a similar approach, Burlington Industries recently announced a new high-tech finish known as Nano-Tex that will provide water repellency, stain resistance, wrinkle resistance, and breathability.[i,ii] According to the company, the finish changes the fiber at the molecular level and is durable to at least 30 home launderings.

For a recent Premiere Vision show, Cotton Incorporated produced a brochure showcasing new finishing developments from companies around the world. Developments in the control of temperature and moisture include the use of phase change materials in foams or finishes. Shawmut Mills and Gateway Technologies are marketing “Outlast”, a foam that can be laminated to cotton and may warm or cool the wearer depending on the choice of material that is incorporated, while adding little weight to the fabric. In Japan, Shikibo offers Thermstick to produce warmth that is similar to wool. Hollow-structured cotton yarns, that are said to be light-weight and warm, are being offered by Kurabo and Nisshinbo. Another approach to moisture management, two-layered fabrics that are finished on one side with a water-repellent treatment, is being promoted by other Japanese companies.

FLUOROCHEMICALS FOR RECREATIONAL APPAREL

Some research at Cotton Incorporated has demonstrated that cotton can be made to absorb less water by treatments with fluorochemicals (FC). As seen in **TABLE I**, moisture vapor transport properties of the fabric are unaffected, and air permeability actually improved after finishing. The fabric weight may have decreased slightly due to dimensional changes caused by padding the FC onto the fabric.

TABLE I

Comfort Parameters

Parameter	Untreated Cotton Knit	FC-treated Knit
Weight (oz/yd^2)	5.82	5.16
Dry Heat Transfer ($watts/m^2$)	11.34	11.63
Permeability Index (i_m)	0.48	0.48
Frazier Air Breathability (ft^3/ft^2-min)	97.6	143.1

ODOR CONTROL

Both deodorants and reodorants are showing up in the marketplace. Virkler is offering a pigment dyeing system that includes microencapsulted scents. The odor is released by rubbing action, and twelve scents, such as orange and lemon, are available. Another encapsulated finish with aloe vera is being marketed on fabrics from Welbeck Fabrics.[iii] Shikibo, Kanebo, and others have made available products with finishes that absorb odors, such as those from sweat, and make them odorless. One type of fiber, Crabyon from Omikenshi Co., Ltd., is co-spun from regenerated cellulose and chitosan and can be blended with cotton to prevent odors by killing the bacteria that cause odors.

ANTIMICROBIAL REGULATION

In order to clear up the uncertainties surrounding use of antimicrobials in consumer products, the Environmental Protection Agency (EPA) issued a Pesticide Registration (PR) Notice on the Application of the Treated Articles Exemption to Antimicrobial Pesticides in February, 2000. This PR Notice explained section 25(a) of 40 CFR 152, which exempts certain treated products from the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). These “treated articles” must contain a pesticide that is registered for use on or in the product and said treatment must only be meant to protect the product. If a manufacturer wishes to make health claims for merchandise, then the “pesticide product” must be registered with EPA, which requires submission of supporting data obtained according to EPA-approved testing protocols, which at this time do not exist.

With the ruling earlier this year, much of the confusion about what product claims are allowed has been eliminated. Some examples of what may be acceptable:

- This product contains an antimicrobial agent to guard against odors.
- This product contains a preservative which protects the article itself.
- Resists odor from bacterial causes.
- Inhibits the growth of mold and mildew which may cause staining.
- Resists deterioration by mold or mildew.

Products which claim the treated article exemption may not make claims such as:

- Specific references to organisms such as *E. coli*, *staphylococcus*, *and streptococcus* which are directly related to human diseases.
- Unqualified bacterial claims and references to “germs” in any context.
- Pest-related allergen claims.
- Claims to provide a safer environment or otherwise promote a healthier indoor atmosphere.

ANTIMICROBIAL DURABILITY

Incorporation of antimicrobial (AM) finishes may be done by exhaust or pad-dry-cure methods, depending on the chemistry involved. Many of the AM agents on the market contain cationic functional groups that provide the material with good durability to home laundering. However, these groups are also responsible for the efficacy of the finish and may be blocked by anionic laundering agents. Therefore, Cotton Incorporated decided to conduct a laundering study of commercially available AMs for 100% cotton to evaluate the efficacy after multiple home launderings.

EXPERIMENTAL APPROACH AND RESULTS

Five manufacturers of AM products were contacted to obtain samples and application information for finishing a basic cotton interlock fabric. The fabric – a 24 cut interlock knit made from ring-spun, 100% cotton Ne$_C$ 40/1 yarn – was scoured, bleached and finished with optical brightener. **TABLE II** outlines the methods and conditions used for application.

TABLE II

AM Application Conditions

Sample ID	**Pad/Exhaust**	**Bath Conditions**	**Drying Conditions (^{o}F)**	**Concentration (%owf)[1]**
A	Pad	<120^{o}F, pH 6	250	0.8
B	Exhaust	110^{o}F	Air dry	0.7
D	Exhaust	80^{o}F	320	2.0
E	Pad	104^{o}F, pH 7	250	2.0
F	Exhaust	104^{o}F	250	1.0
G	Pad	150^{o}F, pH 7	250	5.0
H	Exhaust	100^{o}F	250	1.0
Control	Pad	75^{o}F	250	Water only

[1] owf = on weight of fabric

After drying and curing, where applicable, the edges of each test piece were serged. Each treatment was washed as a separate load according to AATCC 124. Additional prepared knit fabric was used to bring the wash load weight up to four pounds. Samples for testing were removed from the dryer after one, five, and ten home laundering-tumble dry (HLTD) cycles. Testing was also performed on the unwashed fabric. All samples were tested according to AATCC 100 at NAMSA and the results for *S. aureus* are given in TABLE III. Additionally, the Dynamic Shake Flask Test (Dow Corning Test 0923) was used to evaluate the bound AMs (A,B,D, and E) and the control after zero, one, and five HLTDs, and those results are listed in TABLE IV for *K. pneumoniae*. The control sample is identified by letter "C". The sample identification codes consist of the number of HLTD cycles before AM testing followed by the letter code for the treatment.

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TABLE III

AATCC 100 Test Results (CFU/sample) vs. *S. aureus*

	Organism Count (CFU/sample)		
Sample ID	**Zero Contact Time**	**24 Hour Contact Time**	**Percent Reduction**
0-C	1.1E+05	5.1E+03	97.10%
1-C	2.7E+04	5.0E+02	99.88%
5-C	2.5E+03	1.0E+03	99.67%
10-C	2.5E+03	1.6E+04	80.31%
0-A	1.0E+05	1.0E+02	99.92%
1-A	9.0E+04	1.0E+02	99.92%
5-A	6.8E+04	1.5E+04	86.24%
10-A	6.3E+04	1.5E+02	99.87%
0-B	1.2E+05	4.0E+02	99.70%
1-B	1.0E+05	2.5E+02	99.80%
5-B	5.0E+04	3.5E+02	99.65%
10-B	3.8E+04	1.5E+02	99.85%
0-D	2.3E+04	1.0E+02	99.88%
1-D	4.9E+04	8.5E+02	99.10%
5-D	1.4E+04	1.0E+02	99.87%
10-D	4.5E+03	6.4E+03	99.22%

	Organism Count (CFU/sample)		
Sample ID	**Zero Time**	**24 Hour**	**Percent Reduction**
0-E	2.0E+03	1.0E+02	99.87%
1-E	9.0E+04	2.0E+02	99.83%
5-E	3.1E+04	1.0E+02	99.89%
10-E	2.2E+04	2.0E+02	99.78%
0-F	6.8E+04	1.0E+02	99.87%
1-F	4.1E+04	3.7E+02	96.13%
5-F	8.0E+04	1.0E+02	99.69%
10-F	1.5E+03	2.9E+03	96.41%
0-G	1.0E+03	1.0E+02	99.86%
1-G	1.6E+04	1.0E+02	99.87%
5-G	1.1E+04	1.0E+02	99.87%
10-G	5.0E+03	1.6E+03	98.06%
0-H	5.2E+04	1.0E+02	99.90%
1-H	2.8E+04	3.7E+03	95.60%
5-H	2.1E+04	2.0E+02	99.75%
10-H	2.5E+03	4.0E+02	99.51%

TABLE IV
Dynamic Shake Flask Test Results vs. *K. pneumoniae*

	Organism Count (CFU/ml)		
Sample Identification	**Zero Time**	**1 Hour**	**Percent Reduction**
0-A	11000	10	99.9
1-A	11000	7200	31.43
5-A	11000	7600	27.62
0-B	9700	3600	99.9
1-B	11000	7500	31.43
5-B	11000	6000	27.62
0-C	12000	9100	17.27
1-C	11000	9500	9.52
5-C	11000	10000	4.76
0-D	12000	10	99.91
1-D	11000	6600	37.14
5-D	12000	6700	39.09
0-E	11000	10	99.9
1-E	9900	8500	14.57
5-E	12000	6300	42.73
K. pneumoniae only	10000	12000	0.00%

Against *S. aureus* in the Dynamic Shake Flask test, none of the bound agents remained effective after one HLTD. In the AATCC 100 test against *S. aureus*, all treated samples were 99% effective after ten HLTDs. However, the control samples demonstrated an unexpected reductive effect against that bacterium. In order to identify the reason for this apparent efficacy, additional AM tests were performed using control fabrics that had been extracted with hot water in a beaker. The extracted fabrics showed no reduction of *S. aureus* bacteria after 24 hours. This result suggests that some chemical remaining on the fabric after preparation was responsible for the antimicrobial effect of the control fabric. Although this effect causes difficulty with the interpretation of the treated sample data at zero, one, and five launderings, the data at higher numbers of HLTDs should be valid since the responsible agent is removed by water. Therefore, it is likely that all of the products in the study are still effective against *S. aureus* after ten HLTDs.

In the AATCC 100 test with *K. pneumoniae*, only Products E, F, and G retained efficacy after one HLTD cycle, with only D and H also producing 99% reduction of bacteria before washing. No effect was observed for treatment A or B. However, product A was initially successful in the Dynamic Shake Flask Test and product B demonstrated some effectiveness. Both unwashed D and unwashed E samples killed 99% of bacteria in that test. Significant decreases in efficacy were present for all AMs after just one wash when tested by the Dynamic Shake Flask test.

The differences in the results of the two types of tests with the same bacterium may be due to the contact time interval allowed or the dynamic nature of the Shake Flask test. Further testing would be needed to be sure of the cause. Overall, the results seem to indicate a very limited effectiveness against gram negative bacteria, such as *K. pneumoniae*. Effectiveness against gram positive bacteria is retained after multiple home laundering cycles.

[i] DNR, July 5, 2000.

[ii] WWD, June 29, 2000.

[iii] Inside Fashion, August 1-15, 2000.