A PRELIMINARY STUDY OF DYEING GREIGE COTTON NONWOVEN FABRICS WITH AND WITHOUT THE TRADITIONAL SCOURING AND BLEACHING PROCESSES

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Abstract

A previous study conducted at the Southern Regional Research Center had shown that certain processing metrics and conditions of hydroentangling greige (non-bleached) cotton removed almost all of the fiber's natural hydrophobic impurities, such as the waxes, and made the resulting hydroentangled fabric highly absorbent – the most desired attribute for bleaching, dyeing and/or any special wet-finishing of cotton fabrics. Under the umbrella of this uniquely novel finding, a preliminary study was conducted to convert a mechanically ginned, *pre-cleaned greige cotton lint* into two sets of light-weight (~70 g/m^2) hydroentangled nonwoven fabrics. One set was produced at the 90 Bar and the other at 125 Bar of hydroentangling (bonding) pressure at the machine's high pressure heads, while keeping all other processing conditions the same. Portions of the greige fabrics from each set were scoured only, bleached only, and scoured and bleached, using standard formulations and procedures. The Whiteness Index of the greige and treated fabrics was measured using the standard method. All the above fabric portions, i.e., those with and without the conventional chemical scouring and/or bleaching treatments, were dyed blue. The various versions of the greige and dyed fabrics were tested for their classical properties, including the Lightness measured with Hunter Colorimeter. Interestingly, the test results have shown that the whiteness of *bleached only* fabrics (*i.e., w/o the scouring process*) is slightly superior to all other versions and that the greige fabrics could even be dyed without the traditional cotton scouring and/or bleaching processes, although these dyed fabrics appeared to be slightly darker, based on the "b*" value. This article mainly describes properties of the cotton fiber used, the fiber processing metrics involved, and the evaluation of the appearance of the research fabrics. This work is continuing on a broader scale and, hopefully, will be presented in greater details in the near future.

Introduction

The ongoing research on the development of cotton-based nonwoven materials at SRRC has yielded a very interesting discovery in that the greige cotton, which naturally is hydrophobic, may be made hydrophilic during its conversion into a nonwoven fabric on an hydroentanglement system. The impacting water pressure and the resulting fiber-bonding energy seemed to be the critical parameter. A number of repeated studies and pilot plant trials that followed have validated the above referenced discovery by way of the standard absorbency (Drop) tests conducted and the quantification of the cotton wax content extracted in the hydroentanglement process (Sawhney et al., 2012).

Since greige cotton fabrics, whether woven, nonwoven, or knitted, generally must undergo the chemical process of scouring at the first opportunity, in order to make them absorbent for the downstream wet processes of bleaching, dyeing and/or any special, solution-based finishing (such as FR, AM, DP, etc.), it was encouraging to study the effects of bleaching and dyeing hydroentangled greige cotton fabrics with and without the traditional *scouring and/or bleaching* treatments. This study basically shows the results of that work.

Materials and Methods

Commercially available, mechanically pre-cleaned greige (ginned) cotton (Condon et al., 2010) used in the study was tested for its typical fiber properties, using the standard HVI and AFIS systems of determining cotton quality (Uster Technologies). Although the cotton, as received (Table I), was observed and objectively tested to be very clean and really did not require the traditional cotton cleaning operations, it, for sake of smooth fiber flow in the pilot plant, was processed through a commercial-grade cotton opening/cleaning system, a chute-fed card, a crosslapper, and a pre-needling machine to prepare suitable fibrous batt(s) for the downstream hydroentanglement system of producing nonwoven fabric structures.

Table I- Properties of the cotton used in the study.

Fiber Properties	**Pre-cleaned Raw Cotton** *Bale# 589D2215** *(Used in 50/90/90 Bar trial)*	**Pre-cleaned Raw Cotton** *Bale# 1759732** *(Used in 50/125/125 Bar trial)*	**An Equivalent Classical Raw Cotton** *(traditionally opened and cleaned in a textile mill)*
Nep count *(/g)*	180	207	384
Length – number based *(cm)*	1.93	1.88	1.95
Short fiber content— number based *(%)*	26.3	27.0	22.6
Length – wt.-based *(cm)*	2.36	2.31	2.32
Short fiber content— wt.-based *(%)*	9.7	10.0	9.2
Upper Quartile Mean Length *(cm)*	2.87	2.79	2.76
Trash count *(/g)*	0	1	34
Dust Count *(/g)*	29	19	120
VFM *(%)*	0.01	0.02	0.58

* Although two bales of cotton from the same lot were used in the study, both the bales, as seen from their quality test data in the Table above, are almost identical and, hence, should not pose any significant adverse effect or influence on the underlying process or product attributes.

The greige cotton batt(s) were converted into two sets of fabrics of about the same linear density (~70 g/m^2) on a commercial-grade hydroentanglement system (Fleissner, 2009), using 90 Bar and 125 Bar of water pressure, respectively, at the high pressure heads, while keeping all other operating parameters and conditions, including the fabric drying, uniform for both sets of fabrics.

The greige fabrics were tested for their classical properties, using the standard ASTM, AATCC and other applicable test methods, including the Drop Test for absorbency (ASTM, 2008; American Association of Textile Chemists and Colorists, 2006a).

Table II – Properties of hydroentangled cotton nonwoven fabrics produced at two different energy levels.

Water Pressures (*Bar*) **Pre-wet pressure / HP-Jet-Head #1 / HP-Jet-Head #2**	**Hydraulic Energy Applied to Web** *(hp-hr/ lb of fabric)*	**Weight** *(g/m²)*	**Thick-ness** *(mm)*	**Tensile Strength MD** *(Newtons /5cm)*	**MD Elonga-tion** *(%)*	**Tensile Strength CD** *(Newtons /5cm)*	**MD Elonga-tion** *(%)*
90 Bar (*low energy*)	1.01	70.2	0.64	83.67	38.60	94.00	54.20
Std. Dev.		1.43	0.04	5.89	1.55	4.90	2.85
125 Bar (*high energy*)	1.54	70.7	0.63	101.04	38.01	133.06	44.67
Std. Dev.		1.83	0.02	1.36	1.34	3.45	0.86

A portion of the greige fabric from each set was *scoured only,* a portion was *bleached only* (i.e., w/o the conventional scouring), and a portion was *scoured and bleached,* using a jet dyeing machine (Werner Mathis USA, Inc., 2010) and conventional (chemical) formulae and procedures, Table III, as adopted in the Center's Mathis wet lab. The chemicals and the time-duration *equivalents of the scouring process* were appropriately adjusted (reduced) in the case of the *bleached only* versions.

Table III: Chemical formulations and the time durations used in the various wet processes.

	Formulation	Procedure
Scouring only	Liquor ratio: 22:1 17 L - Distilled H_2O 0.24 g/l - Triton X-100 (4.0 grams) nonionic surfactant 1.8 g/l - NaOH 50% Solution (31.0 g of caustic soda)	1) Filled the Jet with 17 liters of distilled H_2O 2) Added the chemicals 3) Scoured the fabric circulating the formulation at 100°C for 60 minutes 4) Cool Rinsing - 3 times. Filled the Jet with 17 L of distilled H_2O – circulated for 20 minutes each rinse. 5) Boiled-off at 100°C for 20 minutes of circulation 6) Neutralized with 0.25 g/l acetic acid – 2 times for 10 minutes each 7) Squeezed out excess liquid with Padder 8) Dried the fabric.
Bleaching Only	Liquor Ratio 32: 1 13 L Distilled Water 0.156G/L Triton x 100 1.99g 0.311 G/L Soda Ash 4.0g 0.311G/L Sodium Hydroxide 50% Solution 26g 1G/L Sodium Silicate 42^{Be} 13g 3G/L Hydrogen Peroxide 35% Solution 39g	1) Filled the Jet with 13 liters of distilled H_2O 2) Added the chemicals 3) Circulated for 10 minutes. 4) Raised temperature to 100°C and circulate for 60 minutes 5) Cool Rinsing - 3 times. Fill the Jet with 17 L of distilled H_2O – circulated for 20 minutes each rinse. 6) Boiled-off at 100°C for 20 minutes of circulation 7) Neutralized with 0.25 g/l acetic acid – 2 times for 10 minutes each 8) Squeezed out excess liquid with Padder 9) Dried the fabric.
Scouring and Bleaching	Liquor ratio: 22.4:1 17L - Distilled H_2O 0.125 g/l - Triton X-100 (2.2 grams) 4.0 g/l - NaOH 50% Solution (caustic soda) (68.0 grams) 0.7 g/l - $NaCO_3$ (soda ash) (12.0 grams) 1.8 g/l - Sodium Silicate 42^{Be} (31.0 grams) 7.0 g/l - Hydrogen Peroxide - 35% H_2O_2 (120.6 grams)	1) Filled the Jet with 17 L of distilled H_2O 2) Added the chemicals 3) Circulated the formulation @ 100°C for 90 minutes 4) Cool Rinsing - 3 times. Fill the Jet with 17 L of distilled H_2O – circulate for 10 minutes each rinse. 5) Boiled-off @ 100°C for 20 minutes of circulation 6) Re-filled with 17 L of distilled H_2O and check pH 7) Neutralized with 0.25 g/l acetic acid for 10 minutes 8) Rinsed - re-fill with distilled H_2O & drain 9) Squeezed out excess liquid with Padder 10) Dried the fabric.
Dyeing process	Liquor ratio: 38.9 : 1 14L - Distilled H_2O 0.128 G/L Triton x1002 - 1.79g 1.5 G/L Direct Dye Blue 78 – 21.0g 1.0 G/L Intramet Navy Blue RLL conc - 14.0g 0.514 G/L Direct Blue 160 - 7.19g 5.14 G/L Sodium Sulfate - 71.9g	1) Filled the Jet with 14 L of distilled H_2O 2) Dissolved the dye in hot water 3) Added all the chemicals over 10 minutes at room temperature. 4) Raised temperature to 100°C. 5) Added salt over 10 minutes. 6) Circulated for 45 minutes & Cool to 60° C. 7) Cool Rinsing - 3 times. Fill the Jet with 17 L of distilled H_2O – circulate for 10 minutes each rinse. 8) Squeezed out excess liquid with Padder. 9) Dried the fabric.

The various versions of the greige and treated fabrics in Table III were mainly evaluated for their *whiteness* using the standard AATCC Test Method 110 (American Association of Textile Chemists and Colorists, 2006b). The Whiteness Index given in Table IV is the average of three (3) readings taken at different locations on the fabrics.

The greige and treated versions of the above fabrics were conventionally dyed with a direct blue dye, Table III - 4th section, and compared for their *Lightness* (indirect brightness) and certain classical properties, Table V. The dyed fabrics were evaluated for their "L", "a*" and "b*" values on a Colorimeter. Again, the values presented in Table V are the averages of three (3) readings taken at different locations on the fabrics.

(*Incidentally, some of the above treated fabrics are being laundered in repeated cycles and some even are being specially finished with certain FR and DP finishes and the results will be presented when the work is completed)*

Table IV: Whiteness Index of the various fabrics (before dyeing).

	Whiteness Index			
Bonding Pressure (bar)	**90**	**Std. Dev.**	**125**	**Std. Dev.**
Greige	38.08	0.45	39.34	0.86
Scoured Only	75.84	0.19	76.53	0.55
Bleached Only	91.50	0.31	91.34	0.23
Scoured and Bleached	90.34	0.83	88.78	0.18

Table V: Color values of the various dyed fabrics.

Bonding Pressure (bar)			**90**			**125**	
Color Index Value		**L**	**a***	**b***	**L**	**a***	**b***
Dyed from Greige		30.02	-0.36	-23.25	27.97	1.06	-21.31
	Std. Dev.	0.21	0.18	0.10	0.23	0.36	0.09
Scoured and Dyed Only		30.98	-0.07	-24.03	29.01	0.50	-21.99
	Std. Dev.	0.22	0.03	0.15	0.19	0.49	0.08
Bleached and Dyed Only		32.05	-0.46	-24.45	29.63	0.14	-22.27
	Std. Dev.	0.26	0.05	0.14	0.50	0.08	0.32
Scoured, Bleached and Dyed		31.91	-0.47	-24.26	29.76	0.32	-22.11
	Std. Dev.	0.06	0.18	0.03	0.33	0.04	0.23

Results and Discussion

Table I shows the properties (as measured on AFIS) of the pre-cleaned greige cotton used in the study. As seen from the trash data, the supplied fiber indeed is as clean as (if not cleaner than) any conventionally cleaned cotton at a traditional cotton user mill.

Table II shows properties of the two sets of hydroentangled nonwoven fabrics produced with different water pressures (energy levels).

Figures 1 and 2 below are of significantly great interest. As seen in figure/slide 1, a water drop dropped on the surface of the "*low pressure/energy*" fabric continued to stay as a round drop almost indefinitely, while a water drop dropped on the (*high pressure/energy)* fabric, Figure 2, instantly dispersed within a second. We believe that this particular phenomenon is a significant milestone and perhaps a technological advance in the development of nonwoven products based on *greige* cotton.

Figure 1 – A drop of water that almost indefinitely sits on the hydrophobic surface of the greige cotton nonwoven fabric bonded at 50/90/90 of water pressures.

Figure 2 – A water drop that instantly diffuses (in less than 1 second) on the hydrophilic surface of the greige cotton nonwoven fabric bonded at 50/125/125 of water pressures.

Table IV shows each Whiteness Index of the various treated versions of the two sets of fabrics. As seen, there is little difference in the whiteness of the various treated fabrics. This reveals that the greige cotton nonwoven fabrics may not need scouring before bleaching. The bleached-only fabrics show satisfactory whiteness. In fact, the whiteness test data show that the *bleached-only* fabrics in both the sets are slightly superior in whiteness and that the fabric made with the 125-Bar of water pressure in each set seems to be even whiter. This is a significant development in that the greige cotton nonwoven fabrics may be bleached without the traditional chemical scouring process that is costly, time-consuming, and ecologically-sensitive.

Table V, along with Figure 3, shows Lightness of the various dyed versions of the fabrics. As seen, all the samples dyed reasonably well. Again, the slightly greater "L" values of the only *bleached & dyed* fabrics indicate slightly superior color brightness. The *greige-dyed* and the *scoured-dyed* samples, as seen in Figure 3, however, reflect a little darker blue color, which, as reflected by their relatively lesser negative "b*" value, Table V, somewhat contradicts the norm, since the lower negative value of "b*" generally indicates less blue tint. Also, the *greige-dyed* *version* of the 90-Bar fabric apparently did not dye as well as the 125 Bar version, perhaps because of its original lack of wet-ability and absorbency, which somehow improved during the *hot* dyeing process. The bleached & dyed fabric (*w/o scouring*), produced with the 125-Bar water pressure, seemed to have dyed the best and had acceptable color brightness, as well. It may be mentioned that the textile industry worldwide uses and disposes more water and effluents, respectively, than any other manufacturing industry. Thus, eliminating or even reducing the cotton scouring process alone for certain cotton-based nonwoven products may considerably contribute to substantial economic savings and environmental advantages, overall.

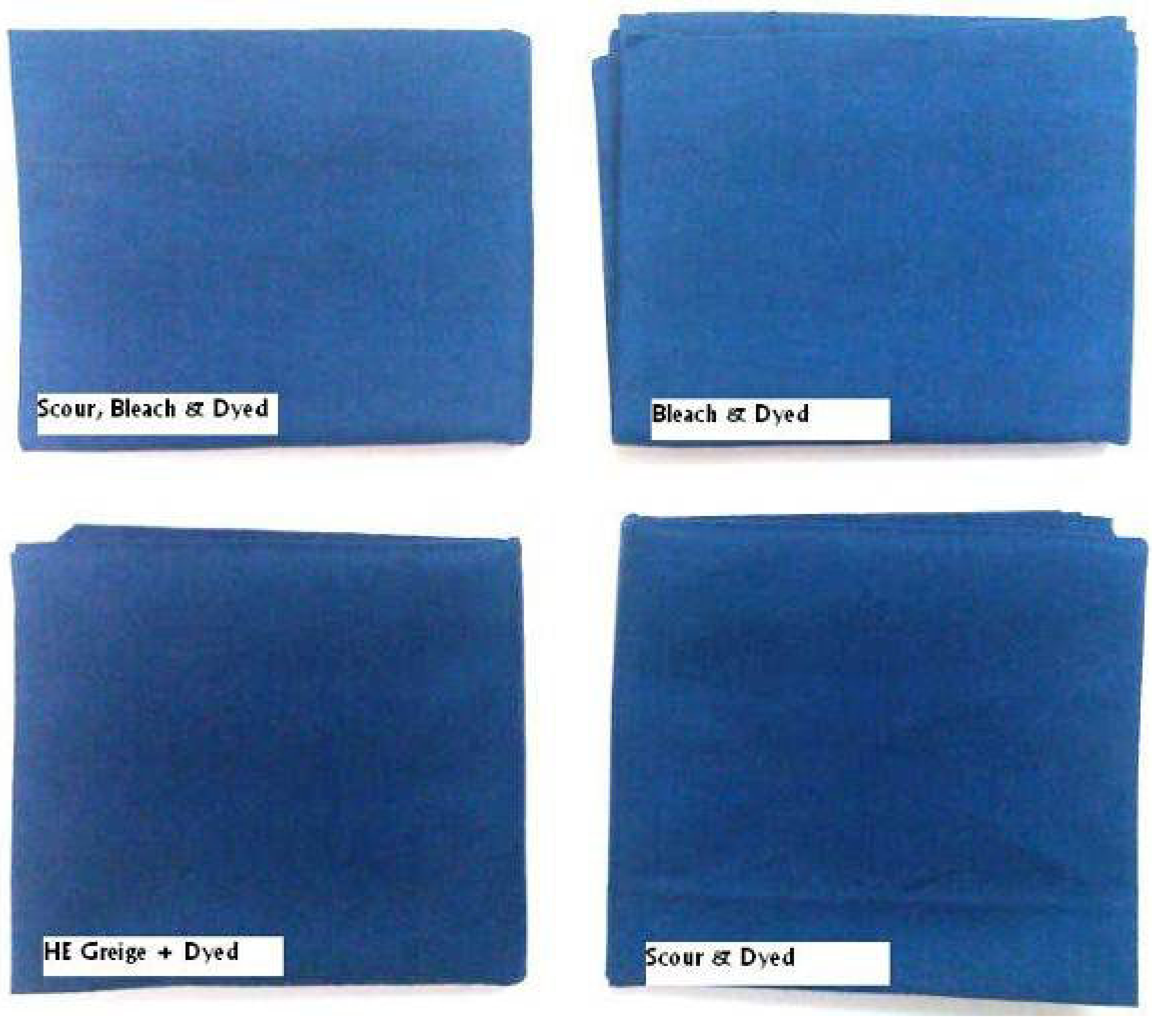

Figure 3: The digital appearance of the various dyed versions of the fabrics.

Table VI shows a few classical properties of the various versions of the dyed fabrics. The results are satisfactory for the basic fabric structures.

Table VI: Classical Properties of the dyed versions of the hydroentangled cotton nonwoven fabrics.

Water Pressures Pre-wet pressure / HP-Jet-Head #1 / HP-Jet-Head #2 (*Bar*) Sample dyed from:	**Hydraulic Energy Applied to Web** *(hp-hr/ lb of fabric)*	**Weight** *(g/m²)*	**Thick-ness** *(mm)*	**Tensile Strength MD** *(Newtons /5cm)*	**MD Elonga-tion** *(%)*	**Tensile Strength CD** *(Newtons /5cm)*	**MD Elonga-tion** *(%)*
50/90/90 greige	1.01	63.9	0.88	61.77	31.80	66.28	46.87
Std. Dev.				3.87	1.89	9.66	2.61
50/125/125 greige	1.54	60.5	0.50	83.78	33.20	82.24	41.80
Std. Dev.				6.71	1.73	16.16	2.47

Conclusion

A study was conducted to determine if the hydroentangled greige cotton nonwoven fabrics produced at different hydro-energy levels could be satisfactorily bleached and dyed without the traditional cotton scouring process that is essential to remove the fiber's inherent wax content before any wet finishing of the fabric can be done. A mechanically pre-cleaned (at the gin) *greige* cotton was processed and converted into hydroentangled nonwoven fabrics, using two (*low and high)* levels of bonding water pressure (energy levels) on a commercial-grade system. The fabrics were bleached and dyed with and without the traditional scouring treatment. Results have shown that the greige fabrics indeed can be bleached and even dyed satisfactorily without the traditional scouring process which is costly, cumbersome and eco-sensitive. Elimination or even reduction of the scouring process and the associated costly chemicals and time involved in the process are expected to offer a significant benefit to the development of cotton-based nonwoven products requiring bleaching and/or dyeing.

Acknowledgments

The authors would like to thank the National Program Leader, the Mid-South Area Director, and the Southern Regional Research Center Director of the Agricultural Research Service of the U.S. Department of Agriculture for providing the necessary support for the project presented here. They would also like to thank Messrs Pablo Ali Salami, Lucien Duplessis, Adrian Mejia and Farrell Screen, whose hands-on workmanship significantly contributed to the success of the project.

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Note

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