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Bleaching Efficiency and Photostability of Wool, Wool/Cotton Blends and All-Cotton Fabric

ABSTRACT

In a followup to an investigation of the bleaching of worsted challis by the Agricultural Research Service (ARS) two-step, single-bath sequential oxidative/reductive process (full bleaching), comparative bleaching studies were carried out on another fabric type, woolen flannel. In the new studies, fabric was bleached in the individual oxidative and reductive steps of full bleaching and results were compared to those from ARS- and traditional full bleaching and to those from conventional bleaching by alkaline hydrogen peroxide. Bleached fabrics were studied for photoyellowing and phototendering following exposure to artificial sunlight. ARS and conventional peroxide bleaching produced the same levels of yellowness after photoexposure. After photoexposure, the loss in strength of the fabrics from the ARS process was substantially less than the loss in strength from conventional peroxide bleaching. In full bleaching—ARS or traditional—the reductive step contributed to significant strength loss, which was compensated by the oxidative step. As seen for all-wool, the ARS process for bleaching of cotton/wool or 100% cotton fabrics gave equivalent whiteness and yellowness values to that achieved by conventional bleaching. The bleached 50/50 union cloth with worsted wool warp and cotton weft showed significant strength loss when stressed in the warp direction while a 50/50 intimate yarn-blended fabric and a 100% cotton fabric showed no strength losses.

KEY TERMS

Bleaching
Cotton
Photoyellowing
Preparation
Wool
Wool/Cotton Blends

Previous reports and patents[1,3-14] describe a new process for achieving full bleaching (oxidative followed by reductive) of wool in a single bath. The mechanism of the conversion of the oxidative system to the reductive one by introduction of thiourea involves the transient formation of thiourea dioxide and its subsequent hydrolysis to the reducing species, sulfinate anion (SO_2^{2-}), and byproduct urea.[1] The ARS process described is a very efficient one for achievement of whiteness; it utilizes unspent peroxide and obviates the need for preparation of a second bleach bath. A typical protocol for achievement of maximum whiteness is outlined in the prior study of worsted challis.[1]

In the worsted challis study, it was found that conditions 22/16T (Table I) produced maximum whiteness. [22/16T is an abbreviation for the bleaching conditions, as follows: (a) the numbers refer to concentrations of 30% hydrogen peroxide in g/L; (b) the slash (/) separates the first from the second step; i.e., the first 60 minutes from the next 25 minutes; (c) the T stands for thiourea, which is added in an amount equivalent to 70% of the neat weight of peroxide that is used in the second step (here, the neat weight of 16g/L of 30% aqueous peroxide; the change from 22 to 16 indicates that a portion of the first bath was discarded and the residual bath was diluted to 16g/L). (d) the bath temperature is 60C (by default) in all studies discussed herein.]

Conditions 16/16T produced equivalent whiteness to conventional alkaline peroxide bleaching 22/22 [i.e., 22g/L of 30% aqueous peroxide for a full 85 minutes (single bath)]. For the present study with woolen flannel, the 16/16T and 22/22 conditions were focused upon and the individual steps were isolated such as 16-/—16g/L of 30% peroxide for 60 minutes. A complete listing of the various conditions studied is provided in Table I. The resulting sets of bleached fabrics were used for mechanical and physical testing before and following exposure to artificial sunlight.

Recent interest in wool/cotton blended fabrics led the group to incorporate these fabrics into the bleaching studies. Along with the woolen flannel fabrics, 50/50 wool/cotton blended fabrics were studied—intimate yarn-blended and union-blended—and 100% cotton fabric were studied for reference.

Experimental

Materials

Oxidizing and reducing agents and auxiliary compounds are described in the previous paper.[1] Woolen flannel (Carleton Woolen Mills, Style #188), fabric weight, 11.9 oz/linear yd, was processed by carbonizing and alkaline fulling followed by scouring and acetic acid souring to pH 6.5. Also used were the following fabrics: pima cotton/wool yarn blend, 50/50 (Testfabrics Style #5400), 7 1/2-8 oz/sq yd 2 times 2 left-hand twill, scoured rinsed, dried, but unbleached and no chlorinated; cotton/wool union cloth 50/50 (Testfabrics Style #4504), 4.3 oz sq yd, plain weave, scoured, withou bleaching or chlorination; and 100% cotton print cloth (Testfabrics Styl #400U), 3.1oz/yd^2, plain weave desized, scoured, rinsed, dried, un bleached.

Methods

The previous paper[1] cites methods fc whiteness and yellowness measure ments and testing for breaking load an elongation. A load cell, Instron 251 302, 500-kg load capacity set at ful range 200kg with cross head speed 1C mm/sec, was used for these fabric Force to break was normalized to tl fabric linear density (g/cm) with sp cific stress reported as Newtons cr gram.

Table I. Bleaching Conditions, Optimization Runs on Woolen Flannel

	Step 1		Step 2		
Woolen Flannel	$[H_2O_2]$ (g/L)	t (min)	$[H_2O_2]$ (g/L)	t (min)	T (C)
0/0 (Control)	0	60	0	25	60
22/22 (Oxidative only, single bath)	22	60	22	25	60
16/16T (ARS full, single bath)	16	60	16	25	60
16/- (ARS, step 1 only)	16	60	0	0	60
22/- (Traditional full, step 1 only)	22	60	0	0	60
-/[16TD][a] (Traditional full, step 2 only)	0	0	16	25	60
22/[16TD][a] (Traditional full, steps 1 and 2; two baths)	22	60	16	25	60
16/- (Traditional full, step 1 only)	- 16	60	0	0	60
16/[16TD][a] (Traditional full, steps 1 and 2; two baths)	16	60	16	25	60

[a]Brackets indicate that thiourea dioxide (TD), not peroxide and thiourea (T), was used in these traditional full bleaching steps. To compare with the ARS processes, in which thiourea was added only in amounts equivalent to 70% of the residual neat weight of peroxide, thiourea dioxide was added only in molar amounts equivalent to the established 70% weight figures for thiourea. Thus, the ARS run 16/16T (single bath) would be equivalent to the traditional full run 16/[16TD] (two baths).

Photoyellowing and Phototendering

Photoyellowing and tendering of bleached woolen flannel were carried out in a Xenon exposure system under controlled irradiance (Atlas Ci65A Weather-Ometer) according to AATCC Test Method 16-1990, Colorfastness to Light, option E, Water-Cooled Xenon-Arc Lamp, Continuous Light with soda lime outer and borosilicate inner filters (full spectral range beginning at 310-320 nm (UV) and into the visible and infrared spectral regions). This illumination simulates outdoor natural sunlight through windowglass. The monitoring point was at 340 nm and exposure time was 80 hours. Relative humidity was maintained at 30-35% ± 5%, black panel temperature at 63 ± 1.0C, and chamber air temperature at 43 ± 2C.

Results and Discussion

Woolen Flannel Bleaching: Steps 1 and 2

As discussed earlier and shown in Table I, bleachings are identified by a coded nomenclature that indicates peroxide concentration (e.g., 22) and thiourea (T). Thiourea dioxide is abbreviated TD. Substitution of thiourea and peroxide by an equivalent amount of thiourea dioxide is indicated in brackets; thus, the ARS run 22/16T would be analogous to the traditional full bleaching 22/[16TD].

Fig. 1 shows bleaching effectiveness in terms of Whiteness Index (WI, ASTM E-313) and Yellowness Index (YI, ASTM D-1925). Note that the minimum significant difference for WI was 4.2 units and for YI, 1.6 units ($p<0.05$). In the case of traditional full bleaching (two baths), the fabrics from step 1 were rinsed, dried and wet out again for step 2 bleaching.

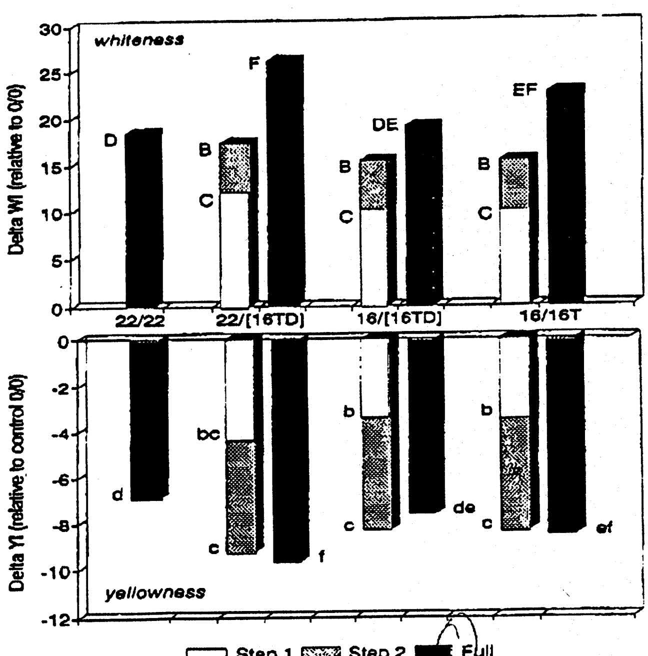

Fig. 1. Bleaching effects on woolen flannel. Abbreviations: cf. Table I. WI: whiteness index (ASTM E-313). YI: yellowness index (ASTM D-1925). Values with different letters are statistically different ($p<0.05$).

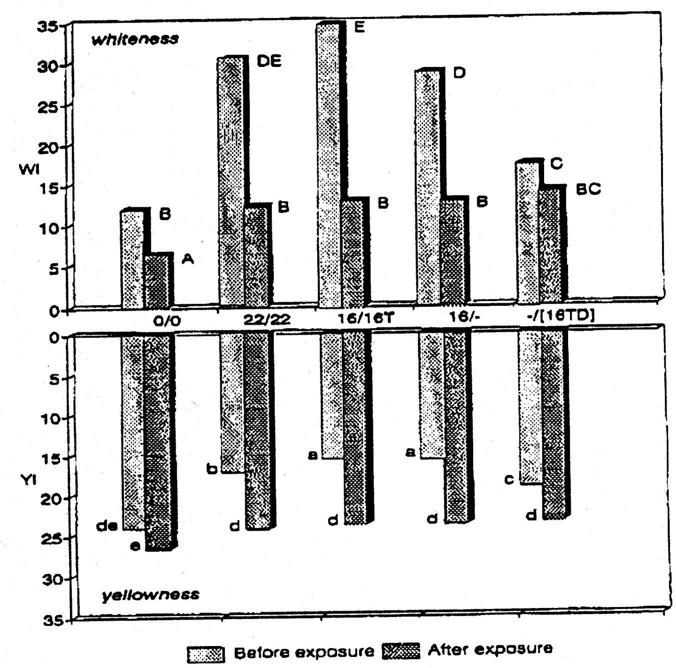

Fig. 2. Photoyellowing of bleached woolen flannel by artificial sunligh Abbreviations: cf. Table I. WI: whiteness index (ASTM E-313). YI: ye lowness index (ASTM D-1925). Values with different letters are statist cally different ($p<0.05$).

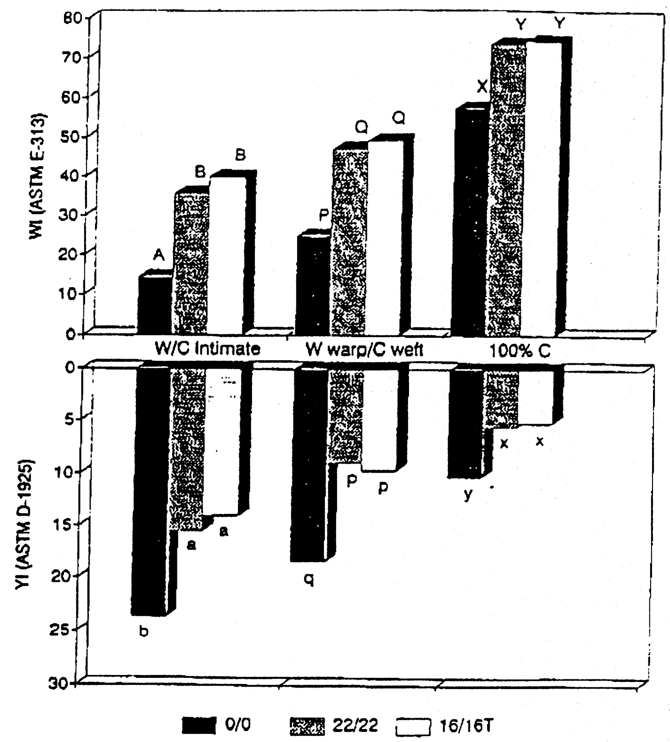

Fig. 3. Bleaching effects on wool/cotton fabrics. Abbreviations: 0/0, 22/22, 16/16T, cf. Table I. W/C Intimate, 50% wool/50% cotton fabric of intimately blended yarn; W warp/C weft, 50% wool/50% cotton union-blended fabric (all wool warp and all-cotton weft); 100% C, 100% cotton fabric. Values with different letters are statistically different ($p<0.05$).

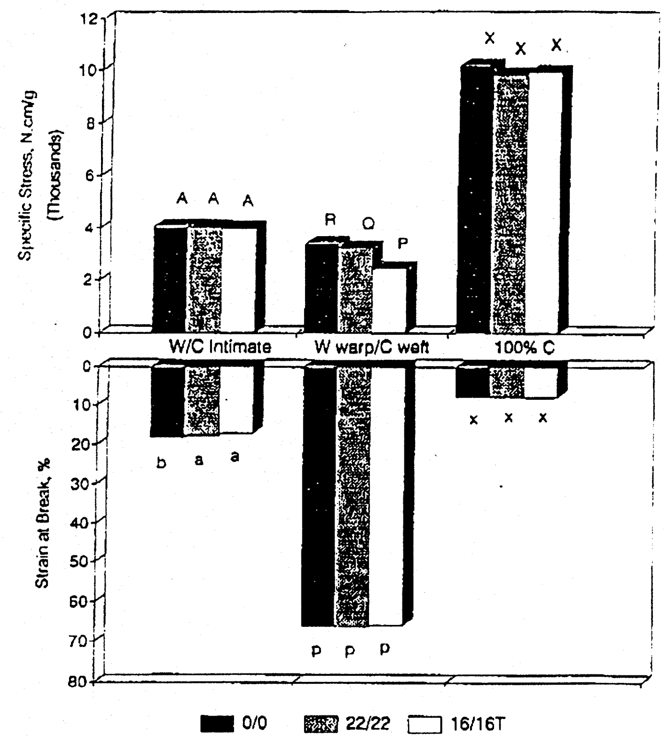

Fig. 4. Tensile properties of wool/cotton fabrics. Abbreviations: 0/0, 22/22, 16/16T, cf. Table I. W/C Intimate, 50% wool/50% cotton fabric of intimately blended yarn; W warp/C weft, 50% wool/50% cotton union-blended fabric (all wool warp and all-cotton weft); 100% C, 100% cotton fabric. Values with different letters are statistically different ($p<0.05$).

From the wool challis study[7] it was observed that similar fabric whiteness resulted from conventional runs 22/22 and the ARS runs 16/16T. In the present study on woolen flannel, runs of 16/16T were used as the ARS-bleached comparison. This time results of runs 16/16T and 22/22 were similar, but not statistically identical; runs 16/16T's whiteness just surpassed 22/22's by a statistically significant difference. Furthermore, statistically similar results are now seen between traditional full bleaching, runs 16/[16TD], and its parallel protocol, ARS runs 16/16T. The ARS process, of course, offers the added advantage of a single bath for full bleaching.

The WI for runs 22/[16TD] was significantly higher and the YI significantly lower than 22/22; this is not surprising, for in the wool challis study, ARS-bleached runs 22/16T surpassed the whiteness of runs 22/22.

In the examples in which the results from the isolated runs were considered additive (i.e., steps 1 and 2), those results always indicated less whiteness than what was achieved by the parallel full runs (ARS single-bath or traditional dual bath treatment). This apparent synergistic effect was not seen in the yellowness values of Fig. 1.

Photoyellowing and Phototendering

Some of the fabrics of Fig. 1 were subjected to 80 hours of simulated sunlight to determine the effect of bleaching on photoyellowing. The results on the whiteness and yellowness indices are illustrated in Fig. 2. Inspection of the whiteness data shows that all the bleached samples, with the exception of runs -/[16TD], the isolated reductive step 2, experienced a greater loss of whiteness than the unbleached control, 0/0. However, there were no significant differences in the final WI among all the bleached samples. Therefore, the ARS process 16/16T not only was comparable in bleaching efficiency to the conventional peroxide-bleached process 22/22; it also was comparable in its aftereffects of exposure to light.

Inspection of the yellowness data shows a similar pattern. There was a greater increase in yellowness for all bleached samples than the increase for the control sample. Furthermore, the same final YI was achieved for all exposed bleached samples, and slightly (though statistically significant) less than the control.

In general, after 80 hours exposure to simulated sunlight, all the benefits of bleaching were lost. This was the case for all the bleached samples.

The mechanical properties of these same bleached fabrics were investigated before and after exposure to light. Results are shown in Table II. After photoexposure, bleached fabrics lost more strength than the unbleached fabrics. The effects of photoexposure from the individual oxidative (16/-) and reductive (-/16TD) steps are compensating and result in less strength loss for ARS-bleached fabrics (16/16T) when compared to fabrics bleached by the conventional alkaline process (22/22).

After photoexposure, fabrics bleached by the ARS and conventional processes lost less strain (extension) than the unbleached fabrics. Again, a

Table II. Effects of Photoexposure on Bleached Woolen Flannel

Condition	Strength Loss, %	Strain Loss %
0/0	6.1	4.5
22/22	17.1	3.6
16/16T	10.8	3.4
16/-	7.7	0.0
-/[16TD]	16.3	7.6

compensating effect was found in 16/-for -/[16TD] and resulted in approximately equivalent percent strain losses for ARS- and conventional alkaline-bleached fabrics.

Wool/Cotton Blended and All-Cotton Fabrics

Bleaching

For all three fabric types tested—the 50% wool/50% cotton fabric of intimately blended yarn (W/C Intimate), the 50% wool/50% cotton fabric of all-wool warp and all-cotton weft (union blend, W warp/C weft), and the 100% cotton (100% C)—the conventional bleaching runs (22/22) and the ARS bleaching runs (16/16T) gave the same whiteness and yellowness indices (Fig. 3).

Mechanical Testing

In Fig. 4, a strength loss was observed in the ARS-bleached union fabric in the wool warp direction relative to the conventionally bleached fabric. This is consistent with what was reported in the prior paper[1] for all-wool fabric. Bleaching regimen had no effect on the all-cotton fabric. Neither did it have an effect on the intimate yarn blend. In the latter case, cotton is acting as a reinforcing fiber; it is the stronger of the two fibers. Its tenacity is 46 g-wt/tex vs. wool's 12.[15] This is corroborated by the absolute stress figures, where the values for the 50% blend are approximately half those of the all-cotton fabric.

In contrast to the stress values, the extension at break values favor wool. The value for wool is 42.5% vs. cotton's 6.8%.[15] In Fig. 4, the beneficial effect of blending cotton with wool is seen in the intimate yarn blend, but is most prominent in the union fabric when stressed in the wool direction.

Conclusions

These studies have focused on properties of fabric—woolen flannel, wool/cotton, and cotton—that result from bleaching to equivalent whiteness using the ARS process (16/16T) or conventional peroxide bleaching (22/22).

Specifically, studies on wool flannel allowed a look at the effect of the individual steps in the ARS two-step process. The cumulative results in whiteness for steps 1 and 2 were more than additive; empirically there seemed to be a synergism in running full (2-step) bleaching, whether by the traditional way (runs 16/[16TD]) or by the ARS process (16/16T).

These studies also permitted an examination of the propensity of the unbleached and bleached fabrics toward photoyellowing and phototendering. Regardless of the bleaching protocol and the resulting whiteness level thus achieved, subsequent exposure to light reduced whiteness to the same final value. Analogous results were seen for yellowness levels. Light exposure also induced phototendering for all fabrics studied, whether bleached or unbleached, but the loss in stress was less for the ARS-bleached samples (16/16T) than for the peroxide-bleached ones (22/22) of equivalent whiteness.

Studies on the wool/cotton blends and on 100% cotton showed the versatility of the ARS bleaching process toward a cellulosic fiber and its blends with wool. Again, for each fabric type, runs 16/16T and runs 22/22 gave equivalent whiteness and yellowness values. Stress and strain were retained for these fabrics, except for the union blend; that blend, when stress was applied in the wool warp direction, showed an unexplainable loss in strength with the ARS bleaching process.

Note that all-cotton cloth is traditionally bleached by hypochlorite, not peroxide. The same standard cotton print cloth that we used in the current study may be ordered already hypochlorite-bleached (Testfabrics, #400). Its WI has been reported as 87,[16] which is slightly whiter than the mid-70 values reported in this work. Nevertheless, hypochlorite cannot be used to bleach wool/cotton blends, because it severely damages the wool fiber.

These studies have demonstrated the applicability of the ARS bleaching process to a broader scope of fabrics and fiber types. Based on earlier work,[1] the user of the ARS process might se lect ARS conditions for equivaler whiteness to conventional peroxid bleaching for the resultant softer hanc By analogy, the user could expect t achieve enhanced whiteness and softe hand by applying the modified AR process 22/16T.

Acknowledgments

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References

1. Marmer, W. N. et al., *Textile Chemist an Colorist*, Vol. 26, No. 5, May 1994, p19.
2. Duffield, P. A., *IWS Technical Informatio Bulletin*, 1986, p9.
3. Arifoglu, M., W. N. Marmer and C. M. Car: *Textile Research Journal*, Vol. 60, 1990, p31
4. Arifoglu, M. and W. N. Marmer, *Textile Re search Journal*, Vol. 60, 1990, p549.
5. Arifoglu, M. and W. N. Marmer, *Proceeding of The 8th International Wool Textile Researc Conference*, Christchurch, New Zealand, Feb ruary 1990, Vol. IV, p330.
6. Arifoglu, M. and W. N. Marmer, *Textile Re search Journal*, Vol. 62, 1992, p123.
7. Arifoglu, M. and W. N. Marmer, *Textile Re search Journal*, Vol. 62, 1992, p94.
8. Arifoglu, M. and W. N. Marmer, *U.S. Pater 4,961,752*, October 9, 1990.
9. Arifoglu, M. and W. N. Marmer, *U.S. Pater 5,103,522*, April 14, 1992.
10. Arifoglu, M. and W. N. Marmer, *U.S. Pater 5,017,194*, May 21, 1991.
11. Arifoglu, M. and W. N. Marmer, *U.S. Pater 5,084,066*, January 28, 1992.
12. (a) Arifoglu, M. and W. N. Marmer, *New Zealand Letters Patent 232,161*, February 4 1993; (b) Arifoglu, M. and W. N. Marme *Australian Letters Patent 618,874*, May 4 1992.
13. Arifoglu, M. and W. N. Marmer, *U.S. Pater 5,264,001*, November 23, 1993.
14. Arifoglu, M. and W. N. Marmer, *Europea Patent Office Application 90902431.7*, Janu ary 19, 1990.
15. Meredith, R., *Journal of the Textile Institute* Vol. 36, 1945, pT107.
16. Kottes Andrews, B. A., *1989 Book of Paper AATCC International Conference & Exhib tion*, Philadelphia, p179.