FACTA UNIVERSITATIS
Series: **Physics, Chemistry and Technology** Vol. 18, Nº 1, 2020, pp. 57 - 63
https://doi.org/10.2298/FUPCT2001057M

DEGREE OF COTTON FABRIC WHITENESS OBTAINED BY THE FLUORESCENT BLEACHING AGENT UVITEX BHT AND H_2O_2[†]

UDC 677.016.262

Milena Miljković[1], Vojkan Miljković[2], Dušan Trajković[2], Sandra Konstantinović[2]

[1] University of Niš, Faculty of Sciences and Mathematics, Department of Chemistry, Niš, Serbia
[2] University of Niš, Faculty of Technology, Leskovac, Serbia

Abstract. *In this paper, the influence of the fluorescent bleaching agent, UVITEX BHT optical bleach, on the degree of whiteness of cotton fabric was examined. In the first phase of the test, the bleaching of cotton with hydrogen peroxide, as the bleaching agent, was done. In the second phase, the effect of fluorescent bleaching agent on the whiteness of cotton wool bleached in the first phase was tested. Moreover, the color strength (K/S) and CIE L*a*b* were determined using Coloreye - 3000 spectrophotometer. The whiteness degree achieved with bleaching agent UVITEX BHT was almost twice larger than the one achieved with chemical bleaching compounds. The highest whiteness index (WI) of cotton fabrics was achieved when fluorescent UVITEX BHT bleach was used in the concentration of 0.1%.*

Key words: *CIE L*a*b* parameter, color strength, fluorescent bleaching agent*

1. INTRODUCTION

Cotton is one of the most used natural textile fibers. It belongs to the genus *Gossypium* in the mallow family Malvaceae and its fibers can grow from semen of cotton. For researchers, the most important is a one-year herbaceous plant that blooms for 80-100 days from sowing. The raw cotton fiber consists of 50% cellulose, 8% waxes, 10% pectin, 13% protein, and other substances. The secondary wall contains 70% of cellulose, which depends on the degree of maturity. The tertiary layer contains protoplasmic

Received December 18th, 2020; accepted December 27th, 2020
[†] Acknowledgement: The paper is a part of the research done within the project funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Program for Financing Scientific Research Work, no. 451-03-68 / 2020-14 / 200133
Corresponding author: Milena Miljković
University of Niš, Faculty of Sciences and Mathematics, Department of Chemistry, Niš 18000, Serbia
E-mail: milenabmv@gmail.com.rs

proteins. Cellulose fiber is not a continuous monoclonal crystal, but it is a semicrystalline aggregate. The strength of the crystal is due to Van der Waals and hydrogen bonds. Waxes and pectins are responsible for the hydrophobic properties of raw cotton, while its yellowish and brownish coloration is associated with the presence of remnants of proteins and flavone pigments (Abdel-Halim, 2012; Kabir et al., 2014). Therefore, it is necessary to purify cotton fibers before bleaching, finishing, and using them (Iqbal et al., 2016). Since impurities cannot be completely removed by a chemical treatment (e.g. cooking with sodium hydroxide for over 1 h), fluorescent bleaching methods have been intensively applied in the last few years. For this purpose, fluorescent bleaching agents (FBs) that absorb the invisible long-wavelength ultraviolet light (λ=300-400 nm) and emit visible light in the wavelength range of 400 to 500 nm (blue part of the light spectrum) are used. Removal of blue-absorbing yellow impurities is the main goal of dyeing, not cleaning (Abdel-Halim, 2012; Kabir et al., 2014). Whether it is a bio- or chemical-bleaching, the process should be conducted with minimum damage to fiber. Hydrogen peroxide is a widely used bleaching agent for cellulosic and protein fibers since it is environmentally acceptable, easily available, and inexpensive (Kabir et al., 2014). However, in some cases, complete whitening with hydrogen peroxide cannot be achieved. For example, knitted cotton fabrics have almost twice higher whiteness when fluorescent brightener Periblanc BA was used in comparison with H_2O_2 (Miljković et al., 2011). The fluorescent brighteners are designed for selective emission of blue light and can be used to treat textile fibers when bleaching agents cannot achieve the required degree of whitening (Tiki et al., 2010). An important class of FBs is triazine–stilbene derivatives that are planar molecules containing a conjugated system of double bonds. Although the *trans*-isomer is found to be an active one (Kabir et al., 2014), photoisomerization occurs upon irradiation by natural light (Liu and Zhang, 2010; Fedorenko et al., 2014). So far, FBs used in the textile industry show good whiteness and fastness properties, as well as stability comparing to other whitening agents, but the isomerization represents a challenge when it needs to be prepared.

Different optical tools are used for optical bleaching of the same materials by different methods. The operation of optical brighteners depends on the pH, the temperature of the fleet, the addition of electrolytes, and the possible heat treatment of the material. One common characteristic of optical brighteners is that they have at least 4 conjugated double bonds or aromatic rings, or both. For optical bleaching, the styrene derivatives are most frequently used, particularly those that are derived from 4,4'-diaminostilbene-2,2'-disulfonic acid.

In this work, the influence of hydrogen peroxide and fluorescent bleaching agent, such as UVITEX BHT optical bleach, on the degree of whiteness of knitted cotton fabric was examined. Chemical bleaching with hydrogen peroxide was performed by using the single-bleaching method of exhaustion and dual bleaching method. The parameters such as CIE (*Commission Internationale de l'Eclairage* – International Commission on Illumination) whiteness index (WI), CIE tint, and color strength values (K/S) of the treated and untreated knitted cotton fabric were determined.

2. MATERIALS AND METHODS

2.1. Materials

Raw unpacked cotton knitwear with reddish shade (under protected designation 10954/S of the "Nitex" company, Niš, Serbia), composed of 100% cotton, was used. A suspension of cotton (10 g) in water (200 cm^3) was prepared. The volume of 5-12 cm^3 of 35% H_2O_2 (v/v), as a chemical bleaching agent, was added. UVITEX BHT (Ciba-Geigy, Basel, Switzerland) was added as a fluorescent bleaching agent in the amount of 0.1%, 0.5%, 1% (1:20). ALVIROL NMB, a solution of carboxylic acid derivatives and polyphosphates, was used as the water softener. ALVIRON GBU, an aqueous solution of lipids, ester oils, and natural emulsifiers, was used and added in a quantity of 1-2 g/dm^3 for bleaching and 1-3 g/dm^3 for coloring. LAVAN OLKC, a combination of selected anionic surfactants, non-ionic surfactants, and natural solvent components, was used as a soap. It has a positive effect on the removal of grease, oils, waxes, and is added in the amount of 0.5-2 g/dm^3 for bleaching. An aqueous microemulsion of lipids, ester oils, and natural emulsifiers, TC-STABILIZER OS, was used as a stabilizer. It was added in the amount of 0.5-1 g/dm^3 for bleaching.

2.2. Exhaustion

The mass of 50 g of raw cotton knit and 1000 cm^3 of water was put into the AHIBA TEXOMAT and 1 g/dm^3 of ALVIRON NMB, 2 g/dm^3 of LAVAN OKC, and 2 g/dm^3 Na_2CO_3 were added. After the fleet was heated for 10 min at 50 ºC, the temperature was raised to 98 ºC for 15 min, and it was flushed constantly for 45 min. The sample was washed with a suitable LAVAN OLKC agent, neutralized with 1 g/dm^3 CH_3COOH, washed several times with warm and cold water (40 ºC / 20 ºC), and dried at room temperature.

2.3. Bleaching with hydrogen peroxide

Two methods of chemical bleaching with hydrogen peroxide were used: single-bleaching method of exhaustion and dual bleaching method of exhaustion.

In the first phase of dual bleaching, 50 g of cotton knitted fabrics and 1000 cm^3 of water (1:20) were put into the AHIBA TEXOMAT device after which 2 g/dm^3 ALVIRON GBU, 4 g/dm^3 Na_2CO_3, and 5 cm^3/dm^3 of H_2O_2 were added. After heating for 10 min at 50 °C, the temperature was raised to 98 °C for 5 min and it was kept constant for 30 min. The washing and neutralizing processes were done as in the exhaustion section. In the second phase, 50 g of whitened cotton knitwear from the first phase and 1000 cm^3 of water were added (1:20) into the AHIBA TEXOMAT device, along with 2 g/dm^3 ALVIRON GBU and the fleet was heated for 10 min at 40 ºC. Additives, such as 7 cm^3/dm^3 NaOH and 12 cm^3/dm^3 H_2O_2 (35%, v/v) were added and the fleet was heated for another 10 min at 40 °C. The sample was washed with LAVAN OLKC agent, several times with (hot (70 °C) and cold (50 °C)) water, neutralized with 0.5 cm^3/dm^3 CH_3COOH, washed again with warm (40 °C) and cold (20 °C) water and dried at room temperature. In the method of one-way bleaching, with peroxide, 50 g of cotton knitted fabrics and 1000 cm^3 of water (1:20) were put into the AHIBA TEXOMAT device and treated with 1 g/dm^3 TC-STABILIZER OS, 2 g/dm^3 LAVAN OKC, 4 g/dm^3 NaOH and 5 cm^3/dm^3 H_2O_2 (35%, v/v). The sample was heated for 10 min at 50 °C, after which the

temperature was increased to 98 °C for 5 min and it was flushed for a constant 30 min. The washing, neutralizing, and drying processes were done as in the previous section.

2.4. Optical whitening with fluorescent bleachers UVITEX BHT

The 5 g of a sample was overflowed with 100 ml of water (1:20). Fresh solutions of fluorescent bleaching agents were made (0.1%, 0.5%, 1.0% UVITEX BHT). Three samples, previously chemically bleached with hydrogen peroxide, were placed in separate cylinders of the AHIBA TEXOMAT device and 0.1%, 0.5%, or 1.0% solutions of UVITEX BHT fluorescent bleach were added in the amounts of 5 cm^3, 25 cm^3, and 50 cm^3. After the fleet was heated for 30 min at 40 °C, the temperature was increased to 98 ºC and kept constant for 60 min. The samples were washed with a suitable LAVAN OLKC agent, several times with water (warm 70 °C / cold 50 °C), neutralized with 0.5 cm^3/dm^3 CH_3COOH, washed several times with warm 40 °C / cold 20 °C water and dried at room temperature.

2.5. Test methods

CIE whiteness index (WI) and tint value (T) were determined by using Color-Eye 3000 spectrophotometer at the standard illuminant D65 (Ice-Texicon, d/8, D65/10°). The color strength (K/S) was calculated using the Kubelka-Munk equation (Miljković et al., 2011):

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \tag{1}$$

where R is the reflectance of the dyed fabric at the wavelength of the maximum absorption and K/S is the ratio of the absorption coefficient (K) at the maximum wavelength (λ_{max}) and the scattering coefficient (S).

The white sample is not different from other colored samples. The illuminated white sample absorbs a part of the incidental depression, and the rest is reflected. The white color is represented by CIE LAB coordinates L* (lightness), a* (red-green chromaticity index), b* (yellow-blue chromaticity index), C* (chroma), and H* (hue), which were also measured. White balance is used for numerical evaluation of the whitewash. Some samples may have the same degree of whiteness, but they differ in tone: neutral, green, or red.

CIE whiteness index (WI) and tint value (T) are calculated as follows:

$$WI = Y + 800(0.3138 - x) + 1700(0.3310 - y) \tag{2}$$

$$T = 900(0.3138 - x) - 650(0.3310 - y) \tag{3}$$

3. RESULTS AND DISCUSSION

The degree of whiteness increases with the increase of the concentration of FBs, but when the maximum is reached, the degree of whiteness falls regardless of the content of FBs. The increase in the degree of whiteness after the achieved maximum concentration is the result of the capturing effect of the FB concentration. The influence of cotton treatment on K/S, WI, and T values is given in Tables 1 and 2.

Table 1 K/S values in function of wavelength λ in the case of using H_2O_2 as the cotton bleaching agent

Fabric	Values								
Untreated cotton fabric	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.450	0.362	0.288	0.232	0.187	0.148	0.118	0.095
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.077	0.062	0.052	0.044	0.037	0.031	0.026	0.023
Scoured cotton fabric	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.303	0.248	0.203	0.168	0.142	0.119	0.101	0.086
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.073	0.062	0.054	0.047	0.041	0.036	0.032	0.028
Fabric bleached with H_2O_2 (I step)	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.067	0.04	0.031	0.026	0.023	0.021	0.017	0.016
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.014	0.013	0.012	0.12	0.011	0.011	0.01	0.009
Fabric bleached with H_2O_2 (II step)	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.021	0.004	0.011	0.01	0.009	0.008	0.008	0.007
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.005

The largest increase in the whitening index (WI) occurs after the chemical bleaching of the washed fabrics with H_2O_2. As expected, a further rise in WI value occurs after the second degree of bleaching with H_2O_2 exhaustion (Table 2); this sample had the lowest K/S values (Table 1) and the smallest redness.

After bleaching with FBs, the WI of cotton fabric sample has been significantly increased, for dual bleaching and one-bleaching by exhaustion. The lowest EI and K/S values and the smallest reddish ink are generally obtained for cotton fabrics bleached with FB after bleaching by the dual-use exhaustion method (Tables 3 and 4).

Table 2 White balance (WI) and tint values (T) for 100% cotton knitwear treated with hydrogen peroxide by the method of dual and one-belt exhaustion

Treatment	WI	T	*L**	*a**	*b**	*C**	*H**
Untreated cotton fabric	-10.74	-10.97 reddish	84.88	2.34	15.44	15.62	81.40
Scoured cotton fabric	12.48	-8.01 reddish	85.51	1.82	11.05	11.20	80.67
Bleached fabric with H_2O_2 (two bath exhaustion, I step)	66.08	-1.58 reddish	93.32	0.06	3.83	3.83	89.14
Bleached fabric with H_2O_2 (two bath exhaustion, II step)	80.75	-0.62 reddish	95.39	0.03	1.73	1.73	91.07
Bleached fabric with H_2O_2 (single bath exhaustion)	60.32	-1.75 reddish	93.48	-0.14	5.16	5.16	91.57

K/S, WI, and T values depend on the FB concentration. For samples bleached with FB, WI decreases slightly with an increase in FBs concentration of 0.1 to 0.5% and reaches a minimum, and the K/S value is the lowest at a concentration of 0.5%. A further increase in concentration from 0.5 to 1.0% leads to a slight increase in WI.

Table 3 White balance (WI) and tint values (T) for 100% cotton knitwear treated with hydrogen peroxide by the dual and one-belt exhaustion method

UVITEX BHT content, %	Values								
0.1	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.252	0.007	0.000	0.003	0.007	0.009	0.010	0.010
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.010	0.009	0.009	0.009	0.009	0.009	0.008	0.008
0.5	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.123	0.009	0.002	0.006	0.009	0.010	0.010	0.010
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.009	0.009	0.009	0.008	0.008	0.008	0.007	0.007
1.0	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.211	0.007	0.000	0.004	0.009	0.011	0.012	0.012
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.011	0.011	0.010	0.010	0.010	0.009	0.009	0.009

Table 4 The degree of whiteness (WI) and tint values (T) for cotton fabrics treated with UVITEX BHT after bleaching with hydrogen peroxide using a dual-weight method of exhaustion

UVITEX BHT content, %	WI	T	*L**	*a**	*b**	*C**	*H**
0.1	88.82	-2.27 reddish	93.37	1.60	-1.08	1.94	325.98
0.5	78.65	-2.56 reddish	93.77	1.22	1.34	1.81	47.65
1.0	86.90	-2.47 reddish	93.51	1.62	-0.63	1.74	338.81

The value of K/S samples of cotton fabrics bleached with FBs after chemical bleaching with a one-batter method of exhaustion is given in Table 5, and WI and T values in Table 6.

Table 5 K/S values of cotton fabrics treated with UVITEX BHT in a concentration of 0.1, 0.5, and 1%, after bleaching with a single-beam method of hydrogen peroxide emission as a function of wavelength λ

UVITEX BHT content, %	Values								
0.1	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.318	0.025	0.005	0.012	0.016	0.017	0.018	0.017
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.015	0.014	0.013	0.012	0.012	0.011	0.011	0.010
0.5	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.174	0.026	0.012	0.017	0.018	0.017	0.016	0.014
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.013	0.011	0.010	0.010	0.009	0.008	0.008	0.007
1.0	λ/nm	400	420	440	460	480	500	520	540
	K/S	0.281	0.025	0.006	0.013	0.017	0.018	0.018	0.016
	λ/nm	560	580	600	620	640	660	680	700
	K/S	0.015	0.013	0.012	0.012	0.011	0.010	0.009	0.008

Table 6 The degree of whiteness (WI) and tint value (T) for cotton fabrics treated with UVITEX BHT after bleaching with hydrogen peroxide using a one-batter method of exhaustion

UVITEX BHT content, %	WI	T	*L**	*a**	*b**	*C**	*H**
0.1	104.9	-1.24 reddish	94.79	1.67	-3.93	4.27	293.04
0.5	94.72	-1.31 reddish	94.77	1.18	-1.68	2.06	304.99
1.0	102.3	-1.60 reddish	94.41	1.80	-3.54	3.97	296.92

The highest WI values are achieved at a concentration of 0.1% of FB. A further increase in the concentration of FBs caused a drop in WI, the minimum value was at a concentration of 0.5% FBc and then the WI values were increased and the mean values were obtained at concentrations of FB 1%. The reddening levels are decreasing with increasing concentration of FB, and the minimum is at FB concentration of 1%.

REFERENCES

Abdel-Halim, E.S., 2012. Carbohydr. Polym., 88, 1233–1238. doi:10.1016/j.carbpol.2012.01.082

Fedorenko, E.V., Mirochnik, A.G., Beloliptsev, A.Y., Isakov, V.V., 2014. Dyes Pigm., 109, 181–188. doi:10.1016/j.dyepig.2014.04.016

Iqbal, M.I., Nazmul Islam, G.M., Ke, G., Chowdhury, S., 2016. Analysis of the effect of optical brightening agent (OBA) on whitening index of different cotton fabrics, The 7th Cross-Strait Conference on Textiles, Wuhan Textile University China, FMP-O-07.

Kabir, S.M.F., Iqbal, M.I., Sikdar, P.P., Rahman, M.M., Akhter, S., 2014. Eur. Sci. J., 10, 200–210.

Liu, J., Zhang, G., 2010. Int. J. Polym. Mater. 60, 199–211. doi:10.1080/00914037.2010.504170

Miljković, M.N., Purenović, M.M., Novaković, M.K., Ranđelović S.S., 2011. Hem. Ind., 65, 257–261. doi:10.2298/HEMIND100810061M

Tiki, A., Amin, A., Kanwal, A., 2010. Pak. Text. J., 59, 42–43.

STEPEN BELINE PAMUČNE TKANINE DOBIJENE IZBELJIVANJEM POMOĆU FLUORESCENTNOG SREDSTVA UVITEKS BHT I H_2O_2

U ovom radu analiziran je uticaj fluorescentnog sredstva za beljenje, UVITEKS BHT optičkog belila, na stepen beline pamučne tkanine. U prvoj fazi izvršeno je beljenje pamuka vodonik-peroksidom kao sredstvom za izbeljivanje, a u drugoj fazi praćen je uticaj fluorescentnih sredstava za beljenje na belinu pamučne tkanine, koja je u prvoj fazi beljena hemijskim sredstvom. Snaga boje (K/S) i CIE L a* b* parametri određeni su pomoću spektrofotometra* Coloreye – 3000. *Stepen beline postignut sredstvom za izbeljivanje UVITEKS BHT gotovo je dvostruko veći nego stepen beline ostvaren hemijskim jedinjenjima za izbeljivanje. Najveći stepen beline (WI) pamučne ostvaren je pri koncentraciji fluorescentnog izbeljivača UVITEKS BHT od 0,1%.*

Ključne reči: *CIE L*a*b* parametri, jačina boje, fluorescentno sredstva za beljenje*