Colour properties of cigarette smoke-exposed cotton and silk fabrics and their nicotine release

DOI: 10.35530/IT.069.04.1396

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REZUMAT – ABSTRACT

Proprietățile de culoare ale țesăturilor din bumbac și mătase expuse la fumul de țigară și eliberarea de nicotină

Expunerea la fumul de țigară a determinat modificarea culorii la țesăturile de bumbac și mătase nevopsite, printr-un efect de îngălbenire. Gradul de îngălbenire a fost mai dominant pe țesătura de bumbac. Atunci când țesăturile vopsite au fost supuse la fumul de țigară, s-a observant un efect mai pronunțat asupra țesăturilor vopsite în culori pale. Modificarea culorii a fost invers proporțională cu rezistența culorii țesăturilor vopsite. În plus, un timp de expunere mai lung a determinat, de asemenea, modificarea culorii țesăturilor, în timp ce rezistența culorii țesăturilor vopsite nu a fost afectată. Eliberarea de nicotină din țesăturile expuse la fumul de țigară în stare umedă a fost studiată în medii apoase diferite, precum apa, soluțiile tampon (pH 5,5 și 8,0) și transpirațiile artificiale (acide și alcaline), pentru a reflecta riscul potențial pentru utilizatorii de textile în ceea ce privește substanțele toxice din textilele contaminate cu fum de țigară.

Cuvinte-cheie: fum de țigară, bumbac, mătase, nicotină, vopsire

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Exposure to cigarette smoke caused colour change to undyed cotton and silk fabrics by a yellowing effect. The degree of yellowing was more dominant on cotton fabric. When the dyed fabrics were subjected to cigarette smoke, a more pronounced effect was observed on the pale shade dyed fabrics. Shade alteration was inversely related to the colour strength of the dyed fabrics. In addition, a longer exposure time also induced colour change in the fabrics while the colour strength of the dyed fabrics was unaffected. Nicotine release from the cigarette smoke-exposed fabrics in the wet state was studied in different aqueous media, viz. water, buffer solutions (pH 5.5 and 8.0) and artificial sweats (acid and alkaline) in order to reflect the potential risk to textile users of the toxicants from textiles contaminated with cigarette smoke.

Keywords: cigarette smoke, cotton, silk, nicotine, dyeing

INTRODUCTION

Cigarette smoke is a harmful source of numerous toxic substances, both volatile and non-volatile. From over 4,000 chemicals found in cigarette smoke, about 250 chemical substances have been identified as harmful and at least 69 of those chemicals are known to be carcinogenic [1]. Nicotine, tar and carbon monoxide are major substances found in cigarette smoke [2]. For textiles, exposure to cigarette smoke causes unpleasant odour and also toxicants deposited on the textiles. The adsorption of cigarette smoke depends on the chemical and physical properties of the textile fibres. Textiles produced from natural fibres exhibit higher cigarette smoke odour adsorption as compared with those from synthetics [3]. In addition, the volatile organic compounds released from natural fibres are higher than that from synthetic fibres. Also, natural fibres of plant origin emit in a different way from animal fibres [4]. Cigarette smoke deposited on cotton textile fabric was studied for its potential danger to human health, by examining permeation of textile-bound nicotine to human skin and evaluating the effect of cigarette smoke extracts from the fabric on fibroblasts, neurocytes and zebrafish embryos. It was found that about 50% of nicotine extracted into artificial sweat (pH 5.5) could permeate through human skin. Moreover, the cigarette smoke extracted into artificial sweat exhibited a concentration-dependent cytotoxicity to fibroblasts and neurocytes. It also caused a delay in development and death to zebrafish embryos. This points out a potential risk of cigarette smoke-contaminated textiles in causing an adverse effect to human health [5].

Nicotine is an alkaloid substance found as a key toxic component in cigarette smoke. It is a cause of addiction to cigarettes. With pK_a values of 3.1 and 8.0, under acidic condition nicotine is mainly in the protonated state, while under alkaline pH, it predominantly exists in the unprotonated free base form. Nicotine in its unprotonated state absorbs much more readily through the airway epithelium and increases with pH [6–8]. Nicotine has been found to cause cardiovascular disease, accelerated atherogenesis and cancers [9–10].

Therefore, the effect of the cigarette smoke retained on cotton and silk fabrics on the colorimetric properties of the undyed and dyed fabrics was investigated in this work. Hot-dyeing reactive dyes were used for cotton, and silk was dyed with acid dyes. Nicotine

was chosen as a representative of the cigarette smoke constituents for this study. The release of nicotine deposited on the cigarette smoke-exposed fabrics was monitored in different aqueous media, viz. water, buffer solutions and artificial sweats solutions. This aimed to gain a view of possible nicotine release from cotton and silk textiles in the wet states, especially by human sweats which textiles normally encounter during their usage.

EXPERIMENTAL WORK

Materials

Scoured plain weave cotton and silk fabrics have a weight of approximately 144 g/m^2. Analytical grade nicotine was purchased from Merck. Procion H-E reactive dyes and Supralan acid dyes were kindly supplied by DyStar Co., Thailand. The cigarette used was Marlboro Red. Dypidol 101B anionic wetting agent was from Brenntag Co., Thailand. Sodium sulfate (Na_2SO_4) and sodium carbonate (Na_2CO_3) were purchased from Ajax Finechem.

Methods

1. Exposure of the fabrics to cigarette smoke

The scoured cotton and silk fabrics were cut into 10×50 cm rectangular shapes. The fabrics were oven-dried at 105 °C for 1 h and then kept in a desiccator. For each fabric exposure, fabric pieces were hung vertically in a closed acrylic box with the size of 30×30×30 cm and the distance between the smouldering cigarette and fabric of 15 cm. The exposure times studied were varied at 12, 36 and 60 min, which were equivalent to one, three and five cigarettes smoked at 25 °C. The experiment was conducted with three replicas. The whiteness and yellowness values on the exposed fabrics were then determined in comparison with the unexposed counterparts. An alteration in whiteness and yellowness of the fabrics was expressed as %ΔW and %ΔY, as shown in equations 1 and 2, respectively.

$$\%\Delta W = \left(\frac{W_0 - W_t}{W_0}\right) \times 100 \quad (1)$$

Where W_0 denotes the fabric whiteness before exposure and W_t denotes the fabric whiteness after cigarette smoke exposure for any designed times.

$$\%\Delta Y = \left(\frac{Y_0 - Y_t}{Y_0}\right) \times 100 \quad (2)$$

Where Y_0 denotes the fabric yellowness before exposure and Y_t denotes the fabric yellowness after cigarette smoke exposure for any designed times.

2. Dyeing of cotton and silk fabrics

Cotton dyeing was conducted using the hot-dyeing reactive dyes, i.e. Procion Yellow H-E6G, Procion Red H-E7B and Procion Navy H-ER 150%, at 0.5 and 4%owf for pale and heavy shade, respectively, at a liquor ratio of 20:1. Sodium sulfate at 20 g/L was used as an auxiliary to promote the dye exhaustion.The dye and sodium sulphate were added at the beginning and the dyeing was conducted at 80°C for 10 minutes. After that, the alkali, sodium carbonate at 15 g/L was added to accelerate the dye fixation and the fabrics were dyed further for 30 minutes. The dyed fabrics were then washed off in 1 g/L wetting agent at 90 °C for 20 min, rinsed and air dried. Silk fabrics were dyed with 0.5 and 4%owf Supralan Yellow 4GL, Supralan Red GWN and Supralan Blue GLW dyes, at 30:1 liquor ratio. The dyebath was set at pH 5 and sodium sulfate was added at 2 g/L. The dyeing was conducted at 95 °C for 40 minutes.The dyed silk was then rinsed with water and air dried.

3. Colourimetric determination

The colourimetric properties of the dyed fabrics were examined with a Macbeth ColourEye7000 spectrophotometer. The colour yield (K/S values) and the shade alteration (Δa*, Δb* and ΔE_{cmc} values) of the cigarette smoke-exposed dyed fabrics were measured against unexposed counterparts.

4. Nicotine release analysis

The nicotine content released from the fabric exposed to cigarette smoke was investigated in different aqueous media viz. water, buffer solutions and artificial sweat solutions. The scoured and oven-dried cotton and silk fabrics that had passed through the cigarette smoke exposure process were taken to determine their nicotine release ability by impregnating in 50 ml of various aqueous media: water, buffer solutions of pH 5.5 and 8 and artificial sweat solutions both acid and alkaline. The artificial sweat solutions were prepared by following the standard ISO 105/E04 method for testing acid and alkaline perspiration. The fabrics were impregnated with the solutions and incubated at 37 °C for 4 h. After that, the fabric was removed and the nicotine content in the solutions was determined by measuring the absorbance with a Specord UV/Vis spectrophotometer at 260 nm. The nicotine content was calculated from the calibration graph of standard nicotine in various aqueous media. The calibration graph of nicotine was built from the known concentration nicotine solutions and their absorbance values at 260 nm. The nicotine content of the exposed cotton and silk fabrics in various solutions was compared.

RESULTS AND DISCUSSION

1. Effect of cigarette smoke exposure on colourimetric properties of cotton and silk fabrics

As seen in Table 1, undyed cotton had a higher degree of whiteness than the undyed silk fabric, as cotton was an off-white shade, while the colour of silk fabric was pale yellow. When these fabrics were exposed to cigarette smoke, they lost their whiteness and become yellower. The degree of yellowness increased with increased exposure time. The %ΔW and %ΔY indicate the extent of the change in whiteness and yellowness, respectively; larger change accompanying the time of exposure to cigarette smoke. It is expected that the substances comprising cigarette smoke

cause yellowing to the fabrics. With more smoke exposure, the more yellowing takes place. Cigarette smoke was previously reported to yellow the hair and nails of the smoker. Yellowing was claimed to be the effect of nicotine contained in the cigarette smoke as nicotine itself is pale yellow [11].

Table 1

WHITENESS AND YELLOWNESS VALUES OF COTTON AND SILK EXPOSED TO CIGARETTE SMOKE

Fabric	Exposure time (min)	Whiteness		Yellowness	
		W_0	ΔW (%)	Y_0	ΔY (%)
Cotton	12	73.60	6.41	1.99	46.51
	36		17.22	2.02	68.97
	60		25.42	1.96	76.69
Silk	12	53.60	5.11	7.89	12.33
	36		14.26	7.75	38.97
	60		21.27	7.90	40.42

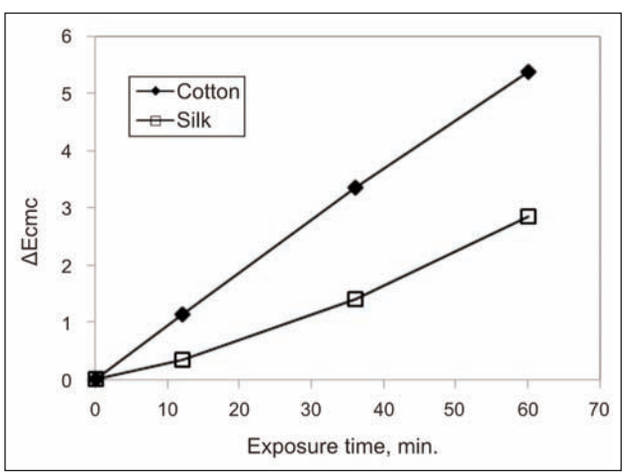

Fig. 1. Colour difference (ΔE_{cmc}) of cotton and silk fabrics exposed to cigarette smoke for various exposure times

When compared to silk, cotton displayed a more significant change in colour; a higher percentage change in whiteness and yellowness were obtained. A marked colour change was confirmed by the colour difference values (ΔE_{cmc}) as seen in figure 1. A visibly noticeable shade difference (ΔE_{cmc}>1) appeared at an earlier exposure time for cotton than for silk and under the same exposure time, a larger ΔE_{cmc} was shown by the cotton fabric. This may be explained by two possible reasons: the first one is from the base colour of the fabric. Silk is originally pale yellow, so the yellowing caused by deposition of the cigarette smoke substances may not have as much impact on the shade change as in the case of cotton fabric, which is whiter. Another reason is that cotton fibre is likely to absorb the substances contained in cigarette smoke more readily than does silk. The more substances are absorbed, the more yellow the fibre is. This result illustrates that even for short exposure times, cigarette smoke can cause yellowing to cotton and silk fabrics to a considerable extent. Therefore, cigarette smoke not only causes unpleasant odour but also brings about an undesired yellowing of both cotton and silk fabrics even after short-term exposure. The change in the colourimetric properties of cotton and silk was also investigated on the dyed fabric at pale (0.5%owf) and heavy (4%owf) shades. Cotton fabrics dyed with Procion H-E bis-monochlorotriazine reactive dyes were exposed to cigarette smoke and the change in shade of the dyed fabrics was monitored and is illustrated in table 2. At the same applied depth (% owf), Procion Red H-E7B dye gave the highest colour strength (K/S) on cotton, followed by Procion Navy H-ER and Procion Yellow H-E6G. The fabrics dyed with Procion Yellow H-E6G showed the greatest colour differences (ΔE_{cmc}), especially the one dyed at 0.5% owf. It seems that the paler-dyed fabrics would show a greater colour change as compared with the heavier shade-dyed fabrics. Among these three reactive dyes, the Procion yellow with the least colour strength (K/S about 1 for pale depth) exhibited the largest ΔE_{cmc}. This indicates that cigarette smoke exposure can cause shade changes to the dyed cotton fabrics and the effect is more pronounced on the pale shade-dyed fabrics. Regardless of the reactive dye types used in this research, the shade change as a result of cigarette smoke exposure is inversely related to the colour strength of the dyed fabrics. The cigarette smoke showed no effect on the colour strength (K/S) of the dyed cotton fabrics, no signified change in K/S values being observed; implying no severe effect of cigarette smoke on the dye molecules during the time studied. The same trend is also observed in the case of silk fabric (table 3).

Table 2

Dye	(%owf)	K/S		λ_{max} (nm)	Δa*	Δb*	ΔE_{cmc}
		before	after				
Procion Yellow H-E6G	0.5	1.00	1.02	420	1.22	–0.11	1.08*
	4.0	4.75	4.75	420	1.66	0.04	0.70
Procion Red H-E7B	0.5	3.48	3.42	550	–1.07	0.02	0.78
	4.0	14.35	13.81	550	–1.18	–0.91	0.41
Procion Navy H-ER 150%	0.5	2.93	2.94	620	–0.20	0.64	0.65
	4.0	12.32	12.14	610	–0.13	0.19	0.59

Table 3

Dye	(%owf)	K/S		λ_{max} (nm)	Δa^*	Δb^*	ΔE_{cmc}
		before	after				
Supralan Yellow 4GL	0.5	2.07	2.06	410	0.33	-0.24	0.35
	4.0	13.47	13.14	410	0.08	-0.24	0.14
Supralan Red GWN	0.5	2.87	2.84	520	-0.55	0.62	0.33
	4.0	14.64	14.74	520	0.03	-0.2	0.12
Supralan Blue GLW	0.5	1.37	1.37	650	-0.43	1.54	1.17*
	4.0	10.60	10.62	650	-0.6	0.92	0.57

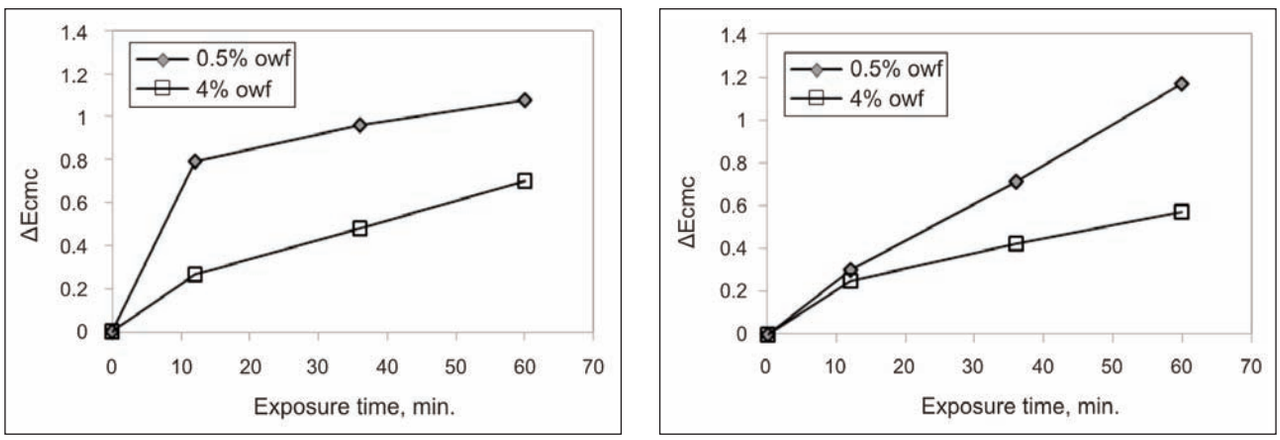

Fig. 2. Colour difference (ΔE_{cmc}) of the dyed cotton and silk fabrics at different cigarette smoke exposure times: *a* – Cotton, Procion Yellow H-E6G; *b* – Silk, Supralan Blue GLW

Supralan Blue GLW, which provided the weakest colour strength on silk, showed the highest colour differences,while the colour strength of the dyed silk fabric was unaffected by cigarette smoke.

The ΔE_{cmc} values of cotton dyed with Procion Yellow H-E6G and silk dyed with Supralan Blue GLW were examined over various cigarette smoke exposure times and the results are depicted in figure 2, *a* and *b*, respectively. Longer exposure times caused higher colour differences (ΔE_{cmc}); in particular the 0.5%owf-dyed fabrics. This study confirms that exposure of cotton and silk textile fabrics to cigarette smoke, even for a short period of time, can cause shade alteration to both undyed and dyed fabrics, especially those with pale shade, irrespective of the types of dyes used in this study. Furthermore, a stronger colour change effect tends to occur with cotton fabric.

2. Nicotine released from cigarette smoke-exposed cotton and silk fabrics

Nicotine is the main substance contained in cigarette smoke; therefore, it was chosen as a representative of cigarette smoke substances and its content was monitored in the different media viz. water, buffer solutions (pH 5.5 and 8) and artificial sweat solutions (acid and alkaline conditions). The amount of nicotine released into water from cotton and silk fabrics increased along with the longer exposure times as seen in figure 3. Cotton fabric released more nicotine into water compared to silk fabric. This supports the colour change results discussed in the previous section. Larger colour change on cotton is presumably due to higher cigarette smoke substances (including nicotine) absorbed onto cotton fabric; therefore, more yellowing is noticed and the nicotine content released is also higher as compared to silk. However, another factor influencing the release of nicotine is its affinity towards cotton and silk. If nicotine is strongly bound onto the fibres, it will not be released easily. Affinity of the substances contained in cigarette smoke to cotton and silk is believed to depend on the different

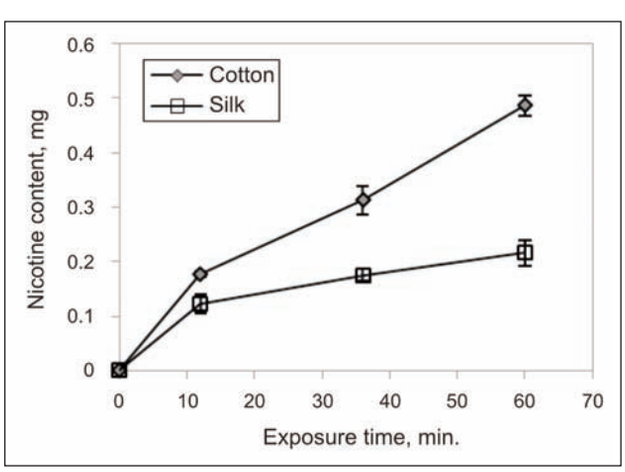

Fig. 3. Nicotine content released into water from the fabrics at different cigarette smoke exposure times

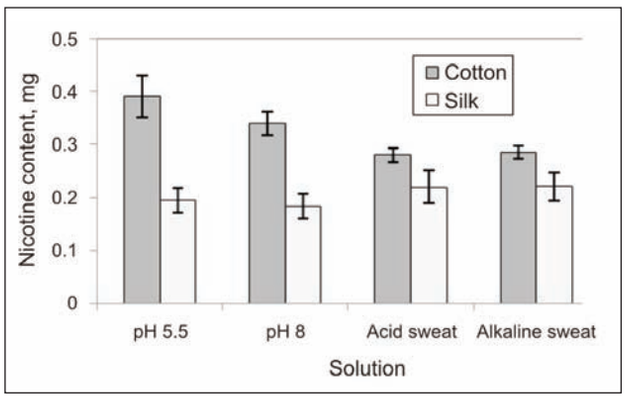

Fig. 4. Nicotine content released into buffers and artificial sweats from the fabrics at 36 min exposure time

natures of these fibres. Nevertheless, the results obtained in this study show corresponding results of colour change and nicotine content.

Nicotine released into buffer solutions at pH 5.5 and 8.0 was determined in comparison to the artificial sweats, in both acid (pH 5.5) and alkaline (pH 8.0) conditions. Figure 4 shows that cotton fabric released more nicotine than did silk into both buffer solutions and the artificial sweats. Cotton and silk released more nicotine into the acidic buffer (pH 5.5) than into the alkaline buffer solution. pH has been reported to influence the ionisation of nicotine [7]. With a pKa of 8.0, nicotine is in its ionised form under acidic pH, while it appears in unprotonated form under alkaline conditions. In artificial sweats, less nicotine was released from the cotton fabrics into both acid and alkaline sweats as compared with the release into buffer solutions, even though it was conducted at the same pH values. The amount of nicotine released was previously reported to be solvent-dependent. More nicotine detached from cotton textiles into phosphate buffer solution than into artificial sweats [5]. The substances contained in the artificial sweats may interfere with the release of nicotine from the fabrics. NaCl can cause a salting-out effect in aqueous nicotine solution, even at small added quantity, consequently lowering nicotine solubility, which can affect the amount of nicotine detected. In the case of silk, a marginal increase in nicotine content released was observed in the artificial sweats as compared with the pH buffer solutions[12–13]. This differing nicotine release from cotton and silk is relevant to the distinctive properties of the fibres.

This study reveals that substances contained in cigarette smoke, including nicotine, can be released from cotton and silk fabrics into human sweats within relatively short times. This nicotine-containing sweat can pose a potentially harmful effect to human health depending on the conditions of smoke exposure and the releasing ability of the fabrics. Permeation through human skin of nicotine extracted into sweat has previously been reported and its toxicity mentioned [5]. Therefore, cotton and silk textiles exposed to cigarette smoke can be a source of toxicants to textile users.

CONCLUSIONS

Exposure to cigarette smoke caused colour changes to undyed and dyed cotton and silk fabrics, with cotton showing a higher degree of colour differences. The shade of the dyed fabrics changed markedly with longer exposure time to cigarette smoke, while the colour strength of the dyes was unaffected. The nicotine content released by cotton into the aqueous media was found to be higher than that by silk; the results agreed with the colour change results. Also, the nicotine content increased with the exposure times. The release of nicotine into artificial sweats implies that cotton and silk textiles contaminated with toxicants from cigarette smoke may pose a harmful effect on human health.

ACKNOWLEDGEMENT

The authors are indebted to Kasetsart University Research and Development Institute for financial support. Special thanks are given to the Center for Advanced Studies in Nanotechnology for Chemical, Food and Agricultural Industries, Kasetsart University, Thailand.

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