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Improvement of the lightfastness of reactive inkjet printed cotton

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Abstract

This paper explores some possibilities of using UV absorbers to improve lightfastness of inkjet prints. Up to 1-class increase in AATCC lightfastness was obtained by adding a UV absorber onto a printed fabric. This means that a designer, an artist or a textile/apparel producer can double the fading resistance of inkjet printed textiles to light by a simple treatment. Both water soluble and insoluble UV absorbers with benzophenone structures were examined. The effects of UV absorbers, their concentrations and application conditions on lightfastness improvement of reactive inkjet prints are discussed.

Keywords: Lightfastness; Inkjet printing; Reactive dyes; UV absorber; Benzophenone

1. Introduction

There are normally two ways to improve lightfastness of the colors on a fabric, to select the dyes with better lightfastness, and/or to use a UV absorber. This paper explores some possibilities of using UV absorbers to improve lightfastness of inkjet prints.

As a new technology, inkjet printing attracts more and more attentions in textiles. This is mainly due to its quick response [1,2], much lower cost to produce a sample or a special customized order [3,4] than that from the traditional printing technologies, less wastes in printing [5], and requirement of much less operating skills and technologies. However, inkjet printing also has its disadvantages. Examples are its low productivity, poor color reproducibility, complicated machine maintenances, and limitations in dye selections for property improvement such as colorfastness improvement [6–12]. Without improving the current inkjet printing technology, it is difficult to predict its share of more than 30 billion square meters of annual production of printed textiles [7].

Among all the fabrics being printed, cotton (48%), rayon (13%) and cellulosic blends (19%) are 80% of the total [3]. Reactive dyes are second only to pigments for all prints [3]. In inkjet printing, reactive inks are also one of the most popular inks due to its excellent water solubility, relatively low price, high wash and crock fastnesses, and beautiful brightness. Efforts to improve the quality of reactive inkjet prints include the study on printing auxiliary chemicals, printing process and printhouse conditions [6,8,9,12–18]. Hardly any researches were reported on improving lightfastness of reactive inkjet prints on cotton or other cellulosics. To the best of our knowledge, the only efforts on lightfastness improvement of inks were on paper inks and disclosed as patents [19–21].

Compared to pigment printings, fabrics printed with reactive inks have poorer lightfastness, although the inks are easier to prepare, the cost of reactive inkjet printing is lower, the handling of the printed goods is softer, the crock or abrasion fastness is better, and the prints are brighter. The objective of this paper is to improve the lightfastness of the prints digitally produced with reactive inks. Due to the special requirement of high solubility and stability of reactive dyes in the inks, selecting dye structures with high lightfastness and at the same time

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with high solubility and stability in the ink system is a difficult approach. This leaves us with only one other approach, i.e., using UV absorbers to improve lightfastness of the prints digitally produced with reactive inks.

We report the use of UV absorbers in inks and in post-printing treatment and the effects of these treatments on lightfastness of the prints. Both water soluble and insoluble UV absorbers with benzophenone structures were examined. The effects of UV absorbers, their concentrations and application conditions on lightfastness improvement of reactive inkjet prints are discussed.

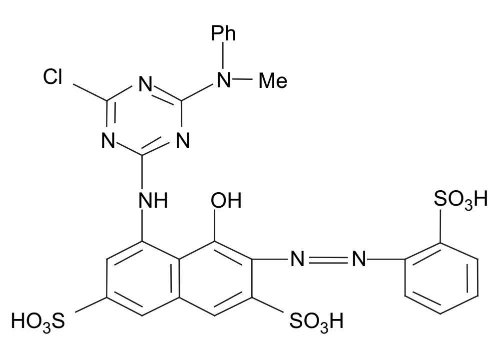
2. Methods

2.1. Materials

C.I. Reactive Red 24 (18208), a monochlorotrazinyl dye, was selected for the inks considering a variety of conditions including heat stability, storage stability, and availability [22]. The chemical constitution of Reactive Red 24 is shown in Scheme 1. Solvents for the inks were ethylene glycol and deionized water. Other chemicals used in the formulation of inks were glycerol as humectant, a non-ionic surfactant (cf. Scheme 2), as a wetting and/or emulsifying agent and a water soluble (UV-WS), and a water insoluble (UV-WI) UV absorbers (cf. Scheme 3). Both UV absorbers are benzophenone derivatives as depicted in Scheme 3. Common chemicals were reagent grade chemicals from VWR International at West Chester, PA. The dye, surfactant and UV absorbers were from textile chemical companies. The dye was purified by the reverse osmosis process by the textile chemical company, and the surfactant (10% w/v) and UV absorbers were commercial products. Bleached, mercerized and reactive inkjet printing pre-treated 100% cotton fabric of style # 419W PRE was from Test Fabrics Inc. (West Pittston, PA). AATCC (American Association of Textile Chemists and Colorists) 1993 Standard reference detergent without optical brighteners was used to wash the steamed fabrics, and to determine the colorfastness of the printed fabrics to laundering [23].

2.2. Ink preparation

For all the inks 11% (w/w) of the dye was used. This is an acceptable dye concentration for reactive inks. Concentrations



Scheme 1. Chemical constitution of the C.I. Reactive Red 24 (18208).

of 0.5, 1.0, 2.0 and 3.0% (w/w) of UV-WS and of 0.1, 0.2, 0.3 and 0.4% (w/w) of UV-WI were added into the inks based on the weight of inks. Higher UV absorber concentrations will affect the properties of the inks prepared. Based on our experience, ink viscosities between 3.5 and 4.5 cP and surface tension between 34 and 39 mN/m result in good ink performances from our inkjet printer (Epson Stylus Pro 7000, Long Beach, CA). The surface tension of the inks was measured by the capillary rise technique and the viscosity was measured by an Ostwald viscometer. The specific gravity of the ink required for the measurement of surface tension and viscosity was measured by a Picnometer. All the viscosity, surface tension and density measurements were conducted at 25 °C.

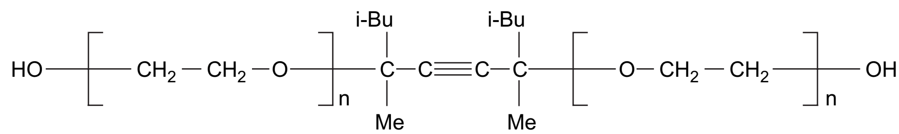
For the control ink without UV absorber, an aqueous surfactant solution was first prepared and the dye was dissolved in it, followed by the addition of ethylene glycol and glycerol. For the inks with UV-WS, the UV absorber was dissolved in surfactant–water, while the dye was dissolved in the mixture of ethylene glycol and glycerol. These two solutions were then mixed to form the ink. For the inks with UV-WI, the dye was dissolved in surfactant–water, while the UV-WI was dissolved in a mixture of ethylene glycol and glycerol. These two solutions were then mixed to form the ink. The recipes and properties of the inks used in this research are summarized in Table 1. Before use, the inks were de-aerated by a Branson Sonifier.

2.3. Printing and post-treatment

The fabric was stored in a conditioning room at 21 °C and 65% RH for at least 24 h before printing. Two of the six refillable cartridges of the Epson Pro 7000 printer were used for the research. Both of the cartridges were filled with the same test ink. The fabrics were printed either to a light shade (using one cartridge) or to a dark shade (using two cartridges). In this paper we will use "light shade" and "dark shade" to describe the two shades for all the prints. The *K*/*S* values of the light and dark shades were 4.18 and 11.80, respectively, for the control fabrics. After printing, the fabrics were steamed at 104.4 °C for 10 min based on a previous study by Yang and Naarani [8]. The steamed samples were hand washed in cold water first, followed by warm water with 0.5% w/w of the AATCC standard detergent without optical brighteners, and then with warm water until no color could be further removed from the fabric. The fabrics were then air dried and conditioned for the post-treatment and/or property evaluations.

For the study of the application of UV absorbers after printing, the fabric was first printed, steamed, washed and dried using the above conditions. The UV absorbers were padded onto the printed fabrics using two dips and two nips to reach a wet pickup of 100% by an EVAC padder. Fabrics were then dried at 90 °C for 3 min using a Flash unit air heater. The UV absorbers were applied using either an organic solvent or water.

For the applications using organic solvent, UV-WS with four concentrations, 0.5, 1.0, 2.0, and 3.0% w/w, were prepared using ethylene glycol (15% w/w) and water as a solvent



Scheme 2. Chemical constitution of the non-ionic surfactant.

mixture, whereas UV-WI with concentrations of 0.1, 0.2, 0.3, and 0.4% w/w were prepared using 100% ethylene glycol. The percentage of chemicals is the weight percentage based on the weight of the total finishing bath. Since the wet pickup is 100%, this percentage of chemicals is also equivalent to the percent of chemicals based on the weight of the fabric. For the applications using water only, the UV-WS were dissolved in water directly, whereas all the UV-WI samples were dispersed in water with the help of 5% w/w of the commercial non-ionic surfactant.

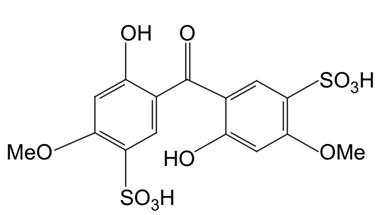
2.4. Property evaluation

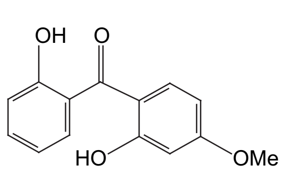
Colorfastness to light of the printed fabrics was measured according to the AATCC Test Method 16, Option E, using the Model Ci 65A Xenon Weatherometer of Atlas of Chicago, IL. Colorfastness to accelerated home laundering was evaluated by AATCC Test Method 61, Option 2A. Colorfastness to both wet and dry crockings was evaluated using AATCC Test Method 8. All the colorfastness evaluation methods could be found in the AATCC Technical Manual [23]. After being equilibrated in a conditioning room at 21 °C and 65% relative humidity for 24 h, the $L^*a^*b^*$ values and ΔE of printed fabrics were measured by an UltraScan XE spectrocolorimeter of Hunter Associates Lab Inc. using a D65 illuminant and 10° observer.

3. Results and discussion

3.1. UV absorbers in the ink

The improvement in lightfastness of the color due to the addition of both the water soluble (UV-WS) and insoluble





Scheme 3. Chemical constitution of the two UV absorbers: a water soluble UV absorber (UV-WS) (a) and a water insoluble UV absorber (UV-WI) (b).

(UV-WI) UV absorbers in the inks is depicted in Fig. 1 at different concentrations of the UV absorbers for both the light and dark shades. The best improvement was 0.5-class for the dark shade using UV-WS at 3.0% in the ink. The highest possible concentrations of the UV absorbers in the inks to assure good quality with an appropriate viscosity and surface tension as shown in Table 1 were 0.4 and 3.0% for UV-WI and UV-WS, respectively. An improvement of 0.5-class in AATCC lightfastness rating means 50% increase in resistance to fading caused by light, and is accepted as a significant lightfastness improvement in textile industry.

Although both UV absorbers at all tested concentrations improved lightfastness of the inkjet printed fabrics, most of the improvement was less than 0.5-class, especially for those with UV-WI. This was probably because of the higher concentrations of UV-WS than UV-WI investigated.

Fig. 1 also shows that both UV absorbers improve the lightfastness of the dark shade more than that of the light shade. An explanation is that the quantity of UV absorbers on fabric is directly proportional to the quantity of dyes on the fabric, since they are added into the inks. The increase in concentrations of UV absorbers on unit surface of cotton fabric decreases the strength of the incident light on the fabric surface, therefore, increases the prevention of light fading of the dyes.

3.2. UV absorbers after printing

As discussed, adding UV absorbers into inks had limited improvement in resistance of colors to light, mainly because of the limitation in the quantity of UV absorbers allowed in the inks. In order to observe better improvement in lightfastness from the use of UV absorbers, we have examined the effect of adding UV absorbers after inkjet printing as a post-treatment and present the results in Figs. 2 and 3.

Table 1
Chemical composition and properties of inks

Ink type	Chemical concentration (% w/w)						Property	
	Dye	UV absorber	Ethylene glycol	Glycerol	Surfactant	Water	Viscosity (cPs)	Surface tension (mN/m)
Control	11.0	0.0	24.0	7.0	9.0	49.0	3.8	37.5
UV-WS	11.0	0.5	17.5	6.5	9.0	55.5	4.3	36.1
UV-WS	11.0	1.0	17.0	6.5	9.0	55.5	4.3	35.0
UV-WS	11.0	2.0	16.0	6.5	9.0	55.5	4.4	35.8
UV-WS	11.0	3.0	15.0	6.5	10.0	54.5	4.2	35.6
UV-WI	11.0	0.1	20.0	7.0	10.0	51.9	3.9	35.6
UV-WI	11.0	0.2	20.0	7.0	10.0	51.8	4.0	36.0
UV-WI	11.0	0.3	20.0	7.0	10.0	51.7	4.1	35.9
UV-WI	11.0	0.4	20.0	7.0	10.0	51.6	4.1	35.0

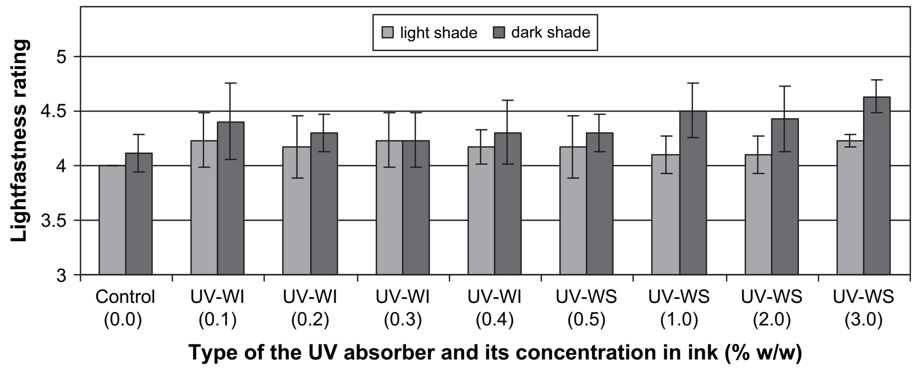


Fig. 1. Lightfastness ratings (AATCC *L*-values) of printed fabrics with two UV absorbers added into the ink. UV-WI and UV-WS are the water insoluble and soluble UV absorbers, respectively. Error bars represent ±1 standard deviation.

Fig. 2 depicts the lightfastness improvement from a post-treatment using the ethylene glycol–water solvent systems. Better improvements in lightfastness were obtained for both UV absorbers in post-treatment than in inks (cf. Fig. 1). This can be explained by the higher concentrations of UV absorbers on cotton via the post-treatment than the direct ink addition. By comparing the UV concentrations in Figs. 1 and 2, the concentrations in the direct ink addition are based on ink weight, while the concentrations in the post-treatment are based on the fabric weight. Since the ink added to the fabric during printing is much lighter than the fabric weight at the areas covered by the inks, a 0.1% UV absorber based on the weight of ink means less addition of that UV absorber onto the printed areas of a fabric than a 0.1% add-on of the same UV absorber based on the weight of the fabric. Another reason for less UV absorbers on fabrics printed by inks with UV absorbers than fabrics post-treated with UV absorbers is that fabric after printing was washed to remove unfixed dyes and chemicals added onto the fabrics during fabric pretreatment. This washing process removes some of the UV absorbers which were added onto the fabric with inks and therefore, decreases the concentration of UV absorbers on the fabrics.

An interesting observation from Fig. 2 is that the improvement in lightfastness with increasing concentrations of UV absorbers has a maximum, indicating that there is an optimum concentration for both UV absorbers. As shown, 0.2% of UV-WI and 0.5% of UV-WS are the recommendable concentrations probably. The decrease in lightfastness rating of the colors with further increase in concentrations of UV absorbers is possibly due to the additives or impurities in the commercial UV absorbers. Since the commercial UV absorbers were padded on fabrics, all the impurities were added onto fabrics at the same time. A critical amount of these impurities might generate enough free radicals under the light exposure test conditions to decrease the lightfastness of the dyes. Such an optimum improvement in lightfastness was observed again when the solvent system was changed from the ethylene glycol–water system to water only as shown in Fig. 3.

Major differences in light protections between using ethylene glycol–water (Fig. 2) and water (Fig. 3) systems are that UV-WI did not function when it was applied to the fabric from water and that UV-WS functioned better from water than from the ethylene glycol–water system. Applying UV-WS from water, the lightfastness of the colored fabric improved almost 1-class, much better than from the ethylene glycol–water system. This could probably be explained by the particle size of the UV absorbers on fabrics.

UV absorbers absorb incident UV light, decrease the exposure of dyes to the UV lights and, therefore, improve the lightfastness of the color. The formation of agglomerates of UV absorbers decreases the coverage of UV absorbers on fiber surfaces, therefore, decreases the prevention of light exposure to the dye molecules. UV-WI is water insoluble and therefore tends to form agglomerates in water and has less covering

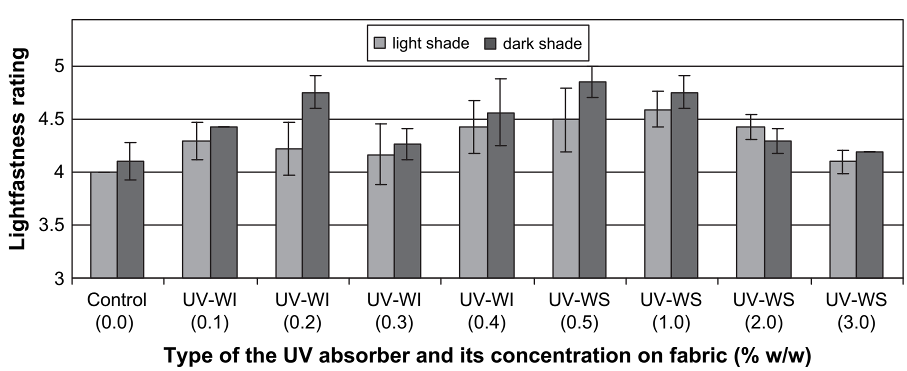


Fig. 2. Lightfastness ratings (AATCC *L*-values) of printed fabrics with two UV absorbers post-padded onto the printed fabrics using ethylene glycol as solvent. UV-WI and UV-WS are the water insoluble and soluble UV absorbers, respectively. Error bars represent ±1 standard deviation.

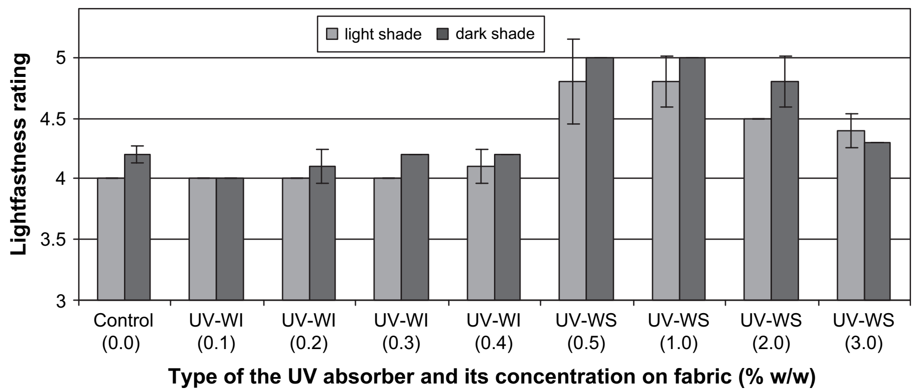


Fig. 3. Lightfastness ratings (AATCC *L*-values) of printed fabrics with two UV absorbers post-padded onto the printed fabrics using water without any other organic solvent. UV-WI and UV-WS are the water insoluble and soluble UV absorbers, respectively. Error bars represent ±1 standard deviation.

power than UV-WS on the hydrophilic cotton surface. The use of a surfactant to help improving the stability of UV-WI may accelerate the photodegradation of the dyes. Radicals formed due to the photochemical reactions of the surfactant may induce the photodegradation of the dye molecules. Therefore, as a result, there was no improvement in the lightfastness when UV-WI was used in water with the surfactant. On the other hand, UV-WS probably had less agglomeration in water than in the water–ethylene glycol system, therefore, it had better improvement to the lightfastness when it was applied from its water solution than from the ethylene glycol–water system.

Although the UV absorbers were padded on the fabrics, using a spray after inkjet printing should also provide the same effects. This means that an artist or a designer with no textile finishing knowledge or equipment also will be able to improve the lightfastness of his/her work by spraying some UV absorbers to the fabric after printing.

3.3. Colorfastness to laundering and crocking

Colorfastness to accelerated home laundering and to crocking of the control and the prints with UV absorbers, either added directly in the ink or padded onto the fabric using the ethylene glycol–water as a solvent are compared in Tables 2 and 3, respectively. As shown, colorfastnesses of the prints with UV absorbers, i.e., the color change of the printed fabrics themselves and the staining to the multifibers from the laundering test, as well as the wet and dry crockings, was the same as that of the control. These results indicated that adding both UV absorbers, either directly into the inks or padded onto the printed goods, did not affect the wash and crock fastnesses of the prints.

Table 2
Colorfastness to accelerated home laundering

UV absorber (% w/w)	Color change L/D[a]	Staining					
		Acetate L/D	Cotton L/D	Nylon L/D	Polyester L/D	Acrylic L/D	Wool L/D
UV absorbers added into inks (% w/w in ink)							
UV-WI (0.1)	4.6/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.2)	4.5/4.6	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.3)	4.5/4.4	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.4)	4.5/4.4	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (0.5)	4.5/4.6	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (1.0)	4.4/4.4	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (2.0)	4.5/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (3.0)	4.7/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV absorbers padded onto fabrics after printing (% w/w on fabric)							
UV-WI (0.1)	4.5/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.2)	4.4/4.7	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.3)	4.4/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WI (0.4)	4.4/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (0.5)	4.6/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (1.0)	4.4/4.7	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (2.0)	4.4/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
UV-WS (3.0)	4.6/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
Control (0.0)	4.7/4.5	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0

[a] L = light shade; D = dark shade.

Table 3
Colorfastness to crocking

UV absorber (% w/w)	Crock fastness	
	Dry crocking L/D[a]	Wet crocking L/D
UV absorbers added into inks (% w/w in ink)		
UV-WI (0.1)	4.9/3.1	3.7/3.3
UV-WI (0.2)	4.2/3.3	4.2/3.5
UV-WI (0.3)	4.4/3.6	4.4/3.5
UV-WI (0.4)	4.2/3.9	4.2/3.8
UV-WS (0.5)	3.8/3.3	4.0/3.7
UV-WS (1.0)	4.0/4.2	4.0/3.7
UV-WS (2.0)	3.7/3.4	3.9/3.4
UV-WS (3.0)	3.7/3.2	4.0/3.5
UV absorbers padded onto fabrics after printing (% w/w on fabric)		
UV-WI (0.1)	3.8/3.2	3.7/3.6
UV-WI (0.2)	3.5/3.4	3.7/3.6
UV-WI (0.3)	3.8/3.6	4.0/3.8
UV-WI (0.4)	4.1/3.9	4.0/4.0
UV-WS (0.5)	4.1/3.8	4.0/3.7
UV-WS (1.0)	4.0/3.8	4.1/3.8
UV-WS (2.0)	3.8/4.0	3.9/3.9
UV-WS (3.0)	3.9/3.6	4.0/4.1
Control (0.0)	4.3/3.4	4.0/3.5

[a] L = light shade; D = dark shade.

3.4. Effect of UV absorbers on shade of the prints

UV absorbers, especially at high concentration, are yellowish in color, therefore, adding UV absorbers onto inkjet printed fabrics, especially through high concentration pad-application after printing, will change the color of the printed fabrics. The comparisons of the colors of the prints with and without UV absorbers are presented in Table 4. As shown, the higher the concentration of UV absorbers, the more the changes of colors of the prints. When UV absorbers were added into the inks, the maximum color differences were from the fabrics with 3.0% UV-WS based on the weight of the inks, with ΔE of 2.79 and 2.45 for the light and dark shades, respectively. When UV absorbers were padded onto the printed fabrics, the maximum color differences were also from the fabrics with 3.0% UV-WS based on the weight of the fabric, with ΔE of 8.61 and 7.55 for the light and dark shades, respectively. The change of shades due to the addition of UV absorbers indicates that a calibration of shades is necessary for the production of inkjet prints from a designed pattern if UV absorbers are used.

4. Conclusions

Using UV absorbers, both water insoluble and soluble, could improve the lightfastness of inkjet printed cotton fabrics with reactive inks. The water soluble UV absorber had better lightfastness improvement than the water insoluble UV absorber based on the conditions examined. UV absorbers could be added onto fabrics either from using the inks with the UV absorbers or from the post-printing treatment. Due to the limited amount of the UV absorbers that could be added into the inks without affecting the ink delivery and shelf-life, adding UV absorbers through post-treatment provided better protection to the prints. A simple padding or perhaps, spraying of a water soluble UV absorber from water to the printed fabric could provide about a 1-class improvement in lightfastness. This means that a designer, an artist or a textile/apparel producer can double the fading resistance of a reactive inkjet printed fabric to light by a simple treatment. A recommended concentration of 0.5% of the water soluble UV absorber or a 0.2% of the water insoluble UV absorber based on the weight of the fabric is recommended for the post-treatment. Higher concentrations of the UV absorber will decrease the improvement in lightfastness. If water insoluble UV absorbers have to be used, they should be used from a solution, not a dispersion, to maximize their protection of reactive inks from fading caused by UV lights. UV absorbers, especially at high concentration, are yellowish in color, therefore, a calibration might be necessary for color matching.

Table 4
Influence of UV absorbers on shades of printed fabrics

	Light color				Dark color			
	L^*	a^*	b^*	ΔE	L^*	a^*	b^*	ΔE
UV absorbers added into inks (% w/w in ink)								
Control (0)	59.48	56.94	3.71		50.10	63.89	13.82	
UV-WS (0.5)	58.61	57.18	3.88	0.92	49.50	64.39	14.24	0.89
UV-WS (1.0)	58.07	57.25	3.91	1.46	49.13	64.56	14.61	1.42
UV-WS (2.0)	57.53	57.84	3.79	2.15	48.87	64.83	14.31	1.63
UV-WS (3.0)	56.95	58.07	3.40	2.79	47.92	63.94	14.92	2.45
UV-WI (0.1)	59.24	56.68	3.84	0.38	50.49	63.08	13.73	0.90
UV-WI (0.2)	59.19	56.80	3.65	0.33	50.06	64.18	12.98	0.89
UV-WI (0.3)	59.06	56.94	3.35	0.56	49.72	64.37	14.19	0.72
UV-WI (0.4)	59.02	56.37	3.70	0.74	49.28	62.78	12.75	1.74
UV absorbers padded onto fabrics after printing (% w/w on fabric)								
Control (0)	59.48	56.94	3.71		50.10	63.89	13.82	
UV-WS (0.5)	55.24	58.94	5.61	5.06	46.49	65.14	16.42	4.63
UV-WS (1.0)	54.01	59.63	5.98	6.50	45.73	66.38	15.94	5.46
UV-WS (2.0)	53.94	60.37	6.17	6.96	44.57	66.83	17.05	7.05
UV-WS (3.0)	52.51	60.82	6.95	8.61	44.80	67.39	17.90	7.55
UV-WI (0.1)	57.48	57.16	4.82	2.30	49.09	64.28	14.72	1.41
UV-WI (0.2)	56.18	58.30	5.24	3.88	47.82	65.33	15.18	3.02
UV-WI (0.3)	56.25	58.13	5.08	3.70	47.21	65.14	15.97	3.82
UV-WI (0.4)	55.18	59.43	5.72	5.36	46.83	65.95	16.28	4.59

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