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Improving reactive ink jet printing via cationization of cellulosic linen fabric

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ABSTRACT

Cellulose linen fabric samples subjected to cationization using different cationizing agents: dodecyl trimethyl ammonium bromide (DTAB), tetra methyl ammonium hydroxide (TMAH), and Quat-188, via pad batch technique, followed by ink jet printing with reactive dyes.

The %N as well as the K/S of the cationized samples was found to be depends on: (a) the nature of the cationizing agent and (b) on the time of batching. As the latter increases both of the nitrogen content and K/S increases to a maximum depending on the nature of the reagent used. Further increase in the batching time up to 30 h is accompanied by a decrease in both the %N and K/S irrespective of the nature of the cationizing agent used. Cationization improves the printability of reactive dye ink jet printed linen fabrics with no remarkable effect on the overall color fastness properties.

1. Introduction

Coloration of cellulosic fabrics with anionic dyes is still possessing some environmental concern as it consumes large quantities water, salts and energy (EPA, 1979; Green & Sokol, 1985). Cellulose fibers when immersed in water produce a negative zeta potential and most of the dye classes suitable for cellulosic fabrics are anionic in nature.

The negative charge on the fiber repels the anionic dye ions and consequently dye uptake is limited. Various studies have been performed on cellulose modification via cationization process in order to investigate the effect of cationic agents on the dyeing properties of cellulosic fibers (Chavan & Chattopadhyay, 1998; Tabba, 2000). Cationization is a novel treatment on cellulosic substrates to produce fabrics with new characteristics. The use of positively charged quaternary ammonium compounds leads to the formation of ionic bonds with negatively charged anionic groups of dyes. Cationization of cotton fabrics followed by dyeing with anionic dyes without salt was reported recently (Kamel, El Zawahry, Ahmed, & Abdelghaffar, 2009; Kamel, Mashaly, Mansour, & Haroun, 2007; Montazer, Malek, & Rahimi, 2007; Nazaria, Montazer, Moghadam, & Anary-Abbasinejad, 2011).

In recent years, ink jet printing has found increasing applications in printing textiles (Gupta, 2001; Kaimouz & Christie, 2010; Owen, 2000; Ujiie, 2006; Yuen, Ku, & Kan, 2008). The flexibility, creativity, cleanness, versatility, competitiveness, eco-friendless (Gupta, 2001; Ujiie, 2006) no restriction on repeat and no limit in colours (Owen, 2000), that ink jet offers has become a major reason to switch to new printing method.

Previous studies (Chen, Zhao, & Wang, 2004; Gorgania & Shakib, 2013; Kanik & Hauser, 2003, 2004), show that the color yield of ink-jet printing with reactive ink on cationic modified cotton is much greater than that on untreated cotton. The effect on the increase of color yield by cationic modification is greater than that by preparation with alkali, urea, and thickener. The reason for this is that the introduction of positively charged sites increases the dye uptake and dye fixation on cationised cotton.

In the present work, linen fabrics; as one of the natural cellulosic fabrics; were subjected to cationization via pad batch technique for different intervals of time using three different cationizing agents namely dodecyl trimethyl ammonium bromide (DTAB), tetra methyl ammonium hydroxide (TMAH) and Quat-188 with ink jet printing using reactive dyes. The effect of cationization on the printability of linen fabrics by ink jet printing method using reactive dyes was thoroughly investigated.

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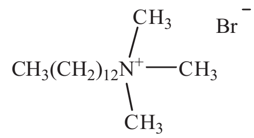
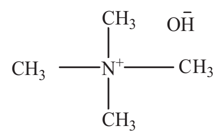
Table 1
Quaternary ammonium salts used as cationizing agents.

Symbol	Name	Structure
DTAB	Dodecyl trimethyl ammonium bromide	
TMAH	Tetramethyl ammonium hydroxide	

2. Experimental

2.1. Materials

2.1.1. Fabric

Linen fabrics, semi finished for dyeing and printing, used in this work were supplied by Textile Industries, Egyptian Co., Ointex, Egypt. Fabric specifications were weight 120 g/m^2, warp 28 threads cm^{-1}, 20 tex, weft 26 threads cm^{-1}, 20 tex.

The fabric was scoured at 100 °C. for 60 min with a solution containing 1 g/L non-ionic detergent and 2 g/L sodium carbonate, then washed thoroughly and finally air dried at room temperature.

2.1.2. Dyestuffs

Four reactive dyes were used in this work, cyan, magenta, yellow and black (four basic colors) for obtain red color, their reactive group is monochloro triazine, produced by Encad Inc., USA.

2.1.3. Chemicals

Sodium hydroxide, sodium carbonate, sodium alginate, acetic acid, and urea were of laboratory grade chemicals. Sodium alginate of medium viscosity was used under the commercial name Daicothik RE.

Cationic agents Three cationic agents were used through this study. The compound, 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (65 wt.%) is a technical grade cationic agent and was kindly supplied under the commercial name (Quat-188) by Dow Chemical Company, USA.

The other two cationic agents are cleared in Table 1 and are of fine grade chemicals.

Surfactants: non-ionic detergent, under trade name, Hostapal CV-ET, produced by Dystar, Germany was used.

2.2. Methods

2.2.1. Cationisation of linen fabric

The cationization was carried out according to the Pad-Batch method (El-Molla, El-Sayad, & El-Halwagy, 2004). The cationic reagent used at concentrations of 100 g/L with corresponding sodium hydroxide concentrations of 43.6 g/L.

The fabrics were padded through the cationization baths at aproximately 100% wet pickup, then padded fabrics were placed in plastic bags and stored at room temperature for different batching times (3, 9, 18, 24, 30 h). After the removal of the padded fabrics from the plastic bags, they were rinsed with warm water at 40 °C. To remove the unfixed and hydrolyzed cationic reagent, neutralized with 2 g/L acetic acid, rinsed with cold water and then dried at 100 °C.

2.2.2. Nitrogen content

The nitrogen content of the cationised fabric was determined by Cole and Parks modification of the micro-Kjeldal method (Vogel, 1975).

2.2.3. Digital printing

Four steps to printing cotton fabrics by digital ink jet printing; as follows.

I. Pretreatment bath:

The traditional pretreatment bath of linen (Ciba Catalog of Pretreatment of Textiles, 2000) fabric has the following recipe:

Sodium alginate 4%	150 gm/L
(Urea) hygroscopic agent	100 gm/L
Sodium carbonates	30 gm/L
Water	Y gm/L
	1000 gm/L

Padding {approx 70% pick up} and drying at room temperature.

II. Ink jet printing: The pretreated linen samples were digitally printed with ink machine, the printer which was used Encad 1500 TX, a thermal drop-on-demand, produced by Encad Inc., USA.

III. Fixation: After drying the printed fabrics, they were subjected to fixation via steaming at 105 °C for 10 min, using steaming machine, produced by Edward Kuster Machine fabric, Germany 1984.

IV. Washing Off: Washing off process was carried out as follows:

- Rinsing with running cold water.
- Soaping at 95 °C for 15 minutes, using Hostapal CV. ET 3 g/l.
- Rinsing with running cold water and finally the printed samples were dried at room temperature, and assessed for measuring the K/S and overall color fastness properties.

2.2.4. Color strength measurements

The color strength of the printed samples expressed as K/S was evaluated by light reflectance technique (Judd & Wyszecki, 1975). All the printed samples were measured using a Hunter Lab Ultra Scan PRO instrument. The K/S values represented are a mean of 5 readings for each sample

2.2.5. Fastness properties measurements

The color fastness properties to washing to rubbing to perspiration and to light fastness were carried out according to standard methods (AATCC test method 36, 1972; method 16, 2004; method 23, 1993; method 30, 1993).

3. Results and discussion

As previously mentioned, the aim of the present work is to investigate the effect cationization of linen fabrics on its printability with ink-jet printing using reactive dyes. Hence, samples of linen fabrics were subjected to react with three different cationizing agents DTAB, TMAH and Quat-188 via pad-batch method. After which, the catinized linen fabrics were allowed to be printed with ink jet printing method using reactive dyes, according to the procedure indicated in the experimental section. Before printing the cationized fabrics were analyzed for nitrogen and after ink jet printing, these fabrics have been assessed for K/S and overall color fastness properties. Given below the results obtained along with the appropriate discussion.

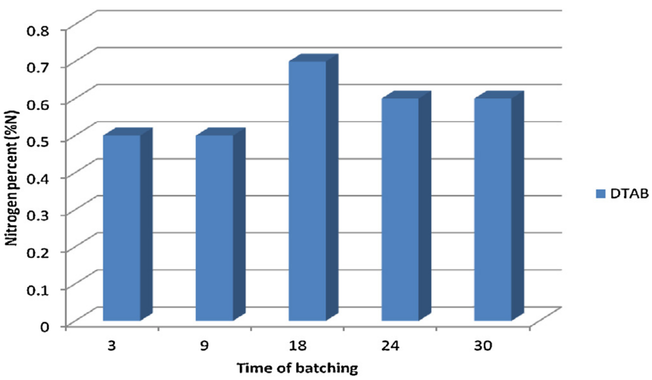


Fig. 1. Effect of batching time on the %N of the DTAB cationized linen fabrics.

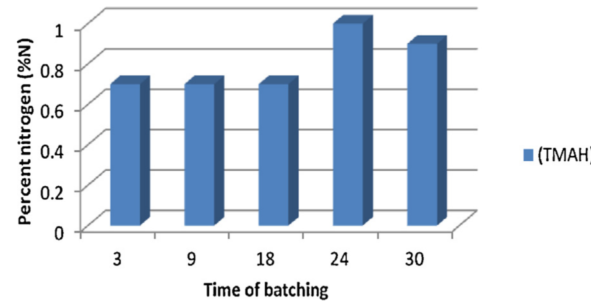


Fig. 2. Effect of batching time on the %N of cationized linen fabrics on using TMAH.

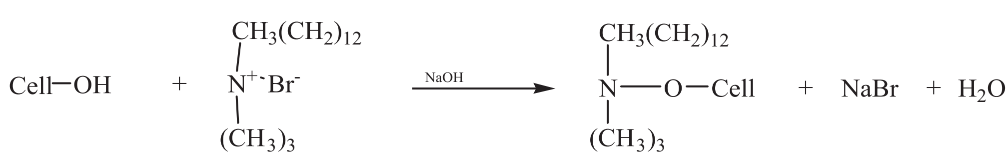
3.1. On using DTAB

Samples of linen fabrics were subjected to cationization using dodecyl trimethyl ammonium bromide (DTAB) via pad batch method for different intervals of time (3, 9, 18, 24 and 30 h).

The modified fabrics were subjected to analysis for percent nitrogen %N and the results were illustrated in Fig. 1.

It is clear from Fig. 1 that, the DTAB can easily reacts with the linen fabric to increase its %N, and this increase was due to the increase in batching time, it was found that as the time of batching increases the %N of linen fabrics increases too, till a detected time which is 18 h of batching, while increasing the time of batching more than 18 h causes a reverse action.

Increasing the %N of treated fabric samples means that the cationization reaction was carried out successfully in the alkaline medium as it is clear from the following equation:



It is clear from Fig. 1 that, as the time of batching increases from 3 up to 18 h the %N increases regularly from 0.5 to 0.7, indicating that more molecules of DTAB react with the hydroxyl groups in linen fabric causes in the %N.

The data also reveal that increasing the time of batching more than 18 h i.e. 24 and 30 h is accompanied by a decrease in the %N, this may be due to uncompleted reaction of the fabrics with the cationizing agent. Where some molecules of (DTAB) can undergo hydrolysis and hence become unable to react with hydroxyl groups of linen fabrics. Also increasing the time of batching more than 18 h may hydrolyze some of the reacted DTAB molecules under the action of alkali and batching for relatively long time.

The treated cationized linen fabrics were then adjusted to printing with reactive dyes by ink jet printing technique in order to investigate the effect of cationization batching time on the K/S of the printed fabrics.

It is clear from the data of Table 2 that all the cationized linen fabrics acquire K/S higher than that of the untreated one. Furthermore as the %N of the cationized linen fabrics increases, the K/S increases. Whereas the %N increases from 0.5 (3 h batching) to 0.7 (18 h batching) the K/S also increases from 2.52 to 3.71. The current data is expected, since as the %N increases, the positive charge on the linen fabric surface increases and hence its affinity to attract the negatively charged dye molecules increases which facilitate the reaction between the dye molecules and the linen hydroxyl groups.

3.2. On using TMAH

Linen fabrics are adjusted to batching for different periods of times after treating with TMAH as a cationic agent according to the procedure detailed in the experimental section. At this end the cationized linen fabrics were assessed for measuring %N. TMAH reacts with linen hydroxyl under the catalytic action of sodium hydroxide as follows:

Table 2
Color strength and overall fastness properties of ink jet printed cationized linen fabrics using DTAB.

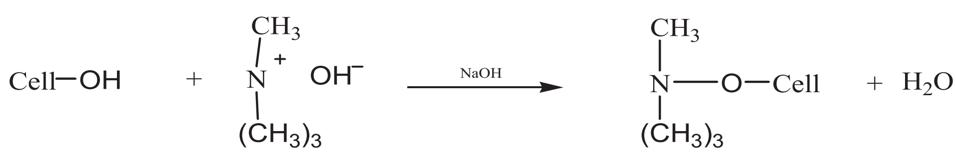
Cationic agent used	Time of batching (h)	K/S	Washing fastness		Rubbing fastness		Perspiration fastness				Light
							Acidic		Alkali		
			St.	Alt.	Dry	Wet	St.	Alt.	St.	Alt.	
Untreated sample	–	1.61	3–4	4	1–2	1–2	1–2	1–2	2	2	4
Dodecyl trimethyl ammonium Bromide (DTAB)	3	2.52	4–5	4–5	1–2	2	2	2	2–3	3	5
	9	2.73	3–4	4	1–2	2	2–3	3	2	2	4–5
	18	3.71	4	4	2	2	3	3	2	2	4–5
	24	2.87	4–5	4	1–2	2	2–3	2	1–2	2	5
	30	2.52	4–5	4–4	2–3	2	2–3	2	2–3	3	5

St., staining; Alt., alteration.

Table 3
Color strength and over all fastness properties of ink jet printed cationized linen fabrics using TMAH.

Cationic agent used	Time of batching (h)	K/S	Washing fastness		Rubbing fastness		Perspiration fastness				Light
							Acidic		Alkali		
			St.	Alt.	Dry	Wet	St.	Alt.	St.	Alt.	
Untreated sample	–	1.61	3–4	4	1–2	1–2	1–2	1–2	2	2	4
Tetramethy ammonium hydroxide (TMAH)	3	3.78	4	4	3	3	2	2	3	2	5
	9	4.20	4	4	2–3	3	2	2	2–3	3	5–6
	18	3.15	4–5	4–5	1–2	2	2–3	3	3	2	4–5
	24	3.99	4–5	4	2–3	3	2	2	2	2	5
	30	4.20	4	4	1–2	2	1–2	2	1–2	2	5

St., staining; Alt., alteration.



3.3. Cationization with TMAH

It is clear from Fig. 2 that increasing the time of batching causes an increase in the %N of the cationized linen fabrics. The current data is expected, since increasing the batching time facilitate and increase the chance for the reaction between the hydroxyl groups and TMAH under the catalytic action of the sodium hydroxide.

Comparing Figs. 1 and 2, it is easily notice that samples cationized with TMAH acquire higher %N values compared with their corresponding samples cationized with DTAB, this may be due to the highly ionization and reactivity of TMAH compared with DTAB.

It is also noticed from Fig. 2 that increasing the time of batching more than 24 h is accompanied by a decrease in the %N. The same phenomenon was observed in case of using DTAB and can interpret on the same bases as previously mentioned.

It is clear from the data of Table 3 that increasing the time of batching using TMAH is accompanied by an increase in the K/S of the printed goods. Whereas the %N increases, the K/S increases too.

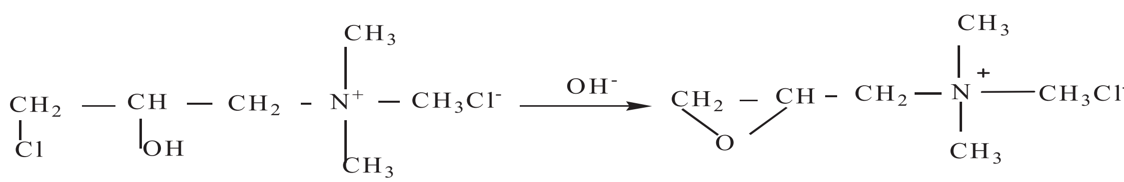
It could be safely concluded from the data of the color strength values that cationization either by TMAH or DTAB enhances greatly the color yield of linen fabrics printed via ink jet with reactive dyes. This is expected since pretreatment with cationic reagents introduces cationic groups into the linen fabrics, thus improving both substantivety and reactivity of the latter toward attraction and reaction with reactive dyes.

It is also clear from the data of Table 3 that batching the TMAH treated linen fabrics for 24 h is sufficient to acquire a higher K/S values while increasing the time of batching more than 24 h, i.e. for 30 h is accompanied by a decrease in the K/S of the printed goods.

3.4. On using Quat-188

Fig. 2 shows the effect of batching time of the treated linen fabrics with Quat-188 on the %N of the cationized samples.

Quat-188 be a 2,3-epoxy propyl trimethyl ammonium chloride (I) (Rupin, 1976). This reactive material is prepared in situ by reaction of the reaction of 3-chloro-2-hydroxypropyl-trimethyl ammonium chloride (II) (Quat-188) with alkali according to the following equation:



(II) (I)

Formation of epoxy radical under alkaline condition

Epoxy radical of 3-chloro-2-hydroxy propyltrimethyl ammonium chloride (Quat-188) can react with cellulose under alkaline conditions as shown in the following equation:

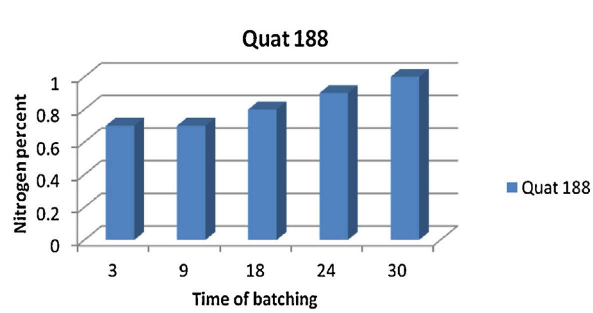
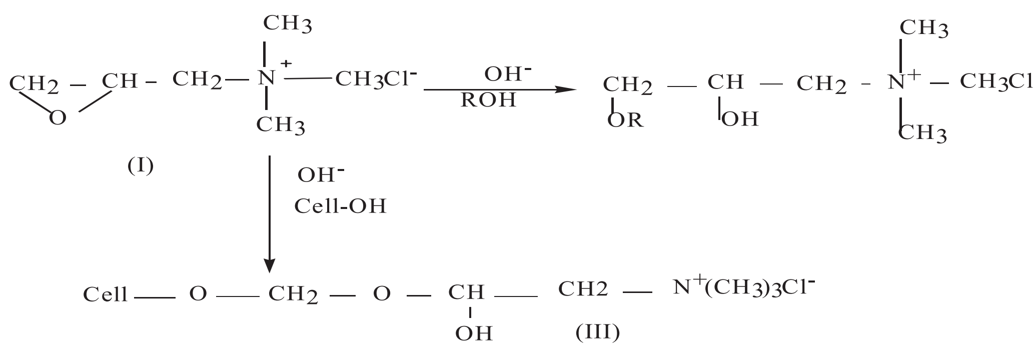


Fig. 3. Effect of batching time on the %N of cationized linen fabrics on using Quat-188.

Table 4
Color strength and over all fastness properties of ink jet printed cationized linen fabrics using Quat-188.

Cationic agent used	Time of batching (h)	K/S	Washing fastness		Rubbing fastness		Perspiration fastness				Light
							Acidic		Alkali		
			St.	Alt.	Dry	Wet	St.	Alt.	St.	Alt.	
Untreated sample	–	1.61	3–4	4	1–2	1–2	1–2	1–2	2	2	4
Quat	3	4.41	4	4	2	2	2	2	2	2	5–6
	9	3.71	4	4	2	2	2–3	3	2–3	2	5–6
	18	4.13	4	4–5	2	2	2–3	2	3	3	5–6
	24	4.84	4–5	4	2–3	3	3	3	1–2	2	5–6
	30	4.27	4	3–4	2	2	2–3	2	2	2	5–6

St., staining; Alt., alteration.



Cationisation of cellulose using 2,3-epoxy propyl trimethyl ammonium chloride under alkaline condition

As a result of this reaction, linen will have cationic dye sites in a form of quaternary ammonium compound which is covalently bounded to its polymer chains, causes an increase in the %N. It is clear from Fig. 3 that as the time of batching increases, the %N also increases, where the highest %N obtained on using Quat-188 as a cationic agent compared with the samples cationized using, either DTAB or TMAH.

The higher %N obtained on using Quat-188 may be due to the highly reactivity of the ethylene oxide group found in Quat compared by the bromide or even the hydroxyl group in DTAB and TMAH respectively. This could be associated with greater availability of the cationic reagent molecules in the vicinity of linen cellulose at a longer time of batching to the formal. It is understandable that the hydroxyl groups of cotton cellulose are immobile and their cationization relies on the availability of the cationic reagent molecules in their proximity to move and react with the former.

Table 4 also comprises the color fastness properties, i.e. the color fastness to rubbing, to washing and to perspiration. It is clear from the data that increasing the time of batching of the treated linen fabric with Quat-188 from 3 to 24 h is accompanied by an increase in the K/S values. Further, increase in the time of batching up to 30 h is accompanied by a decrease in the K/S values.

As previously mentioned Quat-188 is an aqueous solution of N-(3-chloro-2-hydroxy propyl) trimethyl ammonium chloride that can react with cellulose in the presence of alkali by forming ether linkages with the latter, this reaction leads to the formation of cationic sites on the linen surface fabric which in terms could attract the dye molecule from the fine film of the ink jet printed fabric and hence during steaming facilities its mobility and diffusion from the fiber surface into the fabrics to form the covalent bond with the fabric.

It is clear from Tables 2–4 that the overall color fastness properties i.e. the color fastness properties to rubbing, perspiration, washing and light of all the samples in question acquire acceptable color fastness properties, which ranges from good to very good, and it is also obvious that neither the cationic agent type nor the batching time cause a remarkable influence on the printed fabrics except that of the untreated sample, i.e. cationization causes an increase in the fastness properties of the samples regardless the kind of cationic agent and also the time of batching. This may be due to the formation of the fine printed film of the ink jet printing technique which in terms made something like preparing the fabric in a good form (with the small particles of the dye molecule diffuses from the nozzles of the machine) in order to facilitate its diffusion and interaction after that into the fabric during steaming leads to good fastness properties.

4. Conclusion

The %N of the cationized linen fabrics depends on: (1) the nature of cationizing agent and (2) on the time of batching. As the time of batching increases, the %N increases to reach a maximum (depending on the nature of cationization agent), after which its decreases.

The K/S of the inkjet printed cationized linen fabrics depends on the %N of the sample where, its increases by its increase.

At a constant batching time the K/S of the cationized samples follows the order: samples cationized by Quat-188 › samples cationized by TMAH › samples cationized by DTAB.

Cationization of linen followed by inkjet printing using reactive dyes has a remarkable effect on the overall color fastness properties.

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