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Amine salts-activated systems for one-step bleaching of cotton fabrics

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ABSTRACT

In this paper triethanolamine salt-catalyzed sodium chlorite bleaching system was used to bleach plain weave cotton fabric in one step. Different triethanolamine salts, including those derived from organic acids and mineral acids were tried for activating sodium chlorite decomposition during the bleaching reaction. All bleaching trials were carried out keeping fixed sodium chlorite concentration. The concentration of triethanolamine hydrochloride, as an example for the triethanolamine salts was varied to show the effect of the activator concentration on the final fabric degree of whiteness. The optimum triethanolamine hydrochloride concentration, required for activating sodium chlorite decomposition was found to be 10 mmol/l and based on that, this concentration was applied for other organic and inorganic triethanolamine salts to show the effect of nature of the activator on the final degree of whiteness. The results showed that salts prepared using mineral acids have activation potential better than those prepared using organic acids.

1. Introduction

Naturally occurring fibers still contain coloring materials even after scouring processes and the cause of this color is the naturally occurring pigments present in the fiber structure. Also color may come from different contaminations occurring during the processing of natural fibers like for example, oils and greases coming from the processing equipments. In order to produce white fabrics, one should remove the coloring matter in a process called bleaching, using either oxidative or reductive bleaching agents, which destroy the coloring matter, giving rise to white fabrics with minimum fiber degradation.

Different consecutive chemical treatments and operations are carried out with the aim of improving the performance properties of natural fibers. These operations include, respectively, desizing processes (either chemical or enzymatic) (Abdel-Halim, El-Rafie, & Kohler, 2008; Abdel-Halim, Emam, & El-Rafie, 2008a; Chand, Nateri, Sajedi, Mahdavi, & Rassa, 2012; Peng et al., 2010; Wang, Yu, & Zhong, 2012), scouring processes (alkaline and enzymatic) (Abdel-Halim, Fahmy, & Fouda, 2008; Abdel-Halim, Konczewicz, Zimniewska, Al-Deyab, & El-Newehy, 2010; Abdel-Halim, 2012a, 2012b; Abdel-Halim & Al-Deyab. 2012; El Shafie, Fouda, & Hashem, 2009; Tanapongpipat, Khamman, Pruksathorm, & Hunsom, 2008) and bleaching processes (Abdel-Halim, Abdel-Mohdy, Al-Deyab, & El-Newehy, 2010, Abdel-Halim & Al-Deyab, 2011a; Abdel-Halim, 2012c, 2012d; Abdel-Halim & Al-Deyab, 2013; Gonzalez & Zaror, 2000; Hashem, El-Bisi, Sharaf, & Refaie, 2010). The chemical nature of the bleaching agent may be oxidative or reducing and both can remove the naturally occurring coloring matter from the structure of the natural fibers. Due to the ecofriendly nature of hydrogen peroxide, it replaced completely all common bleaching agents (Abdel-Halim, Emam, & El-Rafie, 2008b; Abdel-Mohdy, Abdel-Halim, Abu-Ayana, & El-Sawy, 2009; Fahmy & Abdel-Halim, 2010; Hebeish, El-Rafie, Abdel-Mohdy, Abdel-Halim, & Emam, 2010.

Cellulosic fibers have very good performance properties, such as moisture regain, that is why fabrics made from cotton are comfortable, in addition to the ease of dying these fabrics due to their very good water absorbency. The composition of cotton fiber is about 94% cellulose, based on the weight of the fiber, in addition to about 6% of noncellulosic impurities like hemicelluloses, lignins and coloring matter. Cultivation conditions like maturity of the fibers, day length, temperature and so on govern the difference in cotton fiber composition (Abdel-Halim & Al-Deyab, 2011b; Ibrahim, Abdel Moneim, Abdel Halim, & Hosni, 2008; Renou, Téréta, & Togola, 2011; Shi, Sharma-Shivappa, & Chinn, 2009; Wolf & Hadas, 1984). The brown to yellow color, which cotton fiber acquires is due to the protein protoplasmic residues and also is due to the naturally occurring pigments in the structure of cotton flowers (Abidi, Cabrales, & Hequet, 2010; Ghule, Chen, Tzing, Lo, & Ling, 2004). Noncellulosics, like pectins, hemicelluloses in addition to impurities coming from contaminations like, greases and oils are removed by alkali treatment in the scouring stage, while naturally occurring coloring matters are removed through bleaching using the common oxidizing agents. Scouring process is carried out conventionally by boiling the fabrics in aqueous sodium hydroxide

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solution (Abdel-Halim, Fouda, Hamdy, Abdel-mohdy, & El-sawy, 2010; Abdel-Halim, El-Rafie, & Al-Deyab, 2011; Abdel-Halim & Al-Deyab, 2011c; Chung, Lee, & Choe, 2004; Degani, Gepstein, & Dosoretz, 2004). The most common bleaching agent used in textile industry is hydrogen peroxide due to its safety from environmental point of view. On the other hand, bleaching with hydrogen peroxide needs to be carried out in an alkaline medium which could be brought about using relatively large amount of sodium hydroxide, in addition to the need to hydrogen peroxide stabilizer, high bleaching bath temperatures and long bleaching duration (Abdel-Halim, Abdel-Mohdy, et al., 2011; Abdel-Halim & Al-Deyab, 2011d; Hebeish, Ramadan, Abdel-Halim, & Abo-Okeil, 2011; Khristova, Tomkinson, Valchev, Dimitrov, & Jones, 2002). Huge amounts of water are required to wash out and remove the unreacted hydrogen peroxide and the high alkalinity, before going to the dying process (Abou-Okeil, El-Shafie, & El Zawahry, 2010; Götz, Duschner, White, & Klukowska, 2007). Based on the aforementioned drawbacks in hydrogen peroxide bleaching process, research was directed to find bleaching systems which can operate well at lower temperatures and finish the bleaching process in relatively shorter reaction durations, in addition to the use of lower quantities of chemicals and auxiliaries, giving rise to acceptable whiteness index, together with acceptable decrease in the mechanical properties of the textile material.

One of the most efficient bleaching agents is sodium chlorite which when decompose, it gives chlorine dioxide, one of the most strong oxidizing gases. Sodium chlorite decomposition depends to great extent on the pH value and the bleaching bath temperature, that as the pH value goes down and the temperature of bleaching bath goes up, the rate of sodium chlorite decomposition increases (Hubbell & Ragauskas, 2010). The sodium chlorite concentration in its aqueous solution determines the rate of formation of chlorine dioxide, that the rate of chlorine dioxide formation is proportional to sodium chlorite concentration. Chlorine dioxide formation reaches its maximum value in the acid range pH 2–3.

Sodium chlorite aqueous solutions are stable under alkaline conditions. In order to activate sodium chlorite and cause it to decompose, one has to turn the medium to the acid range. As mentioned above, when sodium chlorite is activated, it produces a toxic and corrosive gas which is chlorine dioxide. Accordingly, it is necessary to control the rate of chlorine dioxide libration in order to avoid its hazardous and corrosive effect (Hirota, Tamura, Saito, & Isogai, 2009). This can be achieved by optimizing the bleaching reaction temperature and controlling the bleaching bath pH through adding what is known as buffer to the bleaching bath.

This article discusses the possibility of bleaching cotton fabrics using sodium chlorite activated with different triethanolamine salts. The paper describes the optimum conditions for the bleaching process, taking in consideration the economic and ecological aspects of the bleaching process.

2. Experimental

2.1. Materials

The cotton fabric substrate was 100% cotton plain weave fabric and was kindly supplied by Misr Company for Spinning and Weaving, Mehalla El-Kobra, Egypt. The specifications of the fabric as given by the supplier were 150 g/m^2 for the fabric weight, 30 yarn/cm in the weft direction and 36 yarn/cm in the warp direction for the fabric construction. The warp threads were tested in our laboratory for the type of sizing agent and the test showed positive iodine test indicating the use of starch in the warp sizing process.

2.2. Chemicals

Sodium chlorite, triethanolamine, hydrochloric acid, sulphuric acid, phosphoric acid, formic acid, acetic acid, sodium hydroxide, potassium iodide, sodium carbonate, sodium thiosulphate, sodium bicarbonate and potassium permanganate were all laboratory grade reagent. Texazym T, a non-ionic wetting agent was purchased from Inotex Company.

2.3. Preparation of triethanolamine salts

Triethanolamine hydrochloride, triethanolamine sulphate, triethanolamine phosphate, triethanolamine acetate and triethanolamine formate were prepared by calculating the equivalent amounts of hydrochloric acid, sulphuric acid, phosphoric acid, acetic acid and formic acid, respectively and mixing with the equivalent amount of triethanolamine and the resulting triethanolamine salts were used as activators for sodium chlorite decomposition.

2.4. Bleaching process

Cotton fabric samples were bleached in one step using sodium chlorite/triethanolamine salt. This was done by impregnating the samples individually in different bleaching liquors, each of them containing 5 g/l $NaClO_2$. The triethanolamine salt concentration was varied in these solutions in the range of 0–20 mmol/l. The pH of all bleaching liquors was kept at an initial pH of 7 and to all bleaching liquors, 2 g/l Texazym T, non-ionic wetting agent was added and the material to liquor ratio was adjusted to be 1:20. The bleaching reactions were carried out at different temperatures ranging from 50 °C to 95 °C for different durations ranging up to 240 min. The decomposition of the bleaching agent sodium chlorite was followed up throughout the bleaching duration by withdrawing samples from the bleaching liquor and estimating the amount of residual sodium chlorite according to the method reported by Vogel (1961). After the desired bleaching duration is completed, the cotton fabric samples are washed thoroughly with hot water then cold water and air dried.

2.5. Tests and measurements

2.5.1. Loss in fabric weight

The loss in fabric weight due to the bleaching process was calculated on the basis of dry weight using the following equation:

$$\%\,\text{weight loss} = \frac{(W_1 - W_2) \times 100}{W_1}$$

where W_1 and W_2 represent the dry weight of the fiber before bleaching and after bleaching, respectively.

2.5.2. Carbonyl content and carboxyl content

The increase in the carbonyl content and in the carboxyl content of the cotton fabric samples due to bleaching were evaluated according to the methods reported by Mattisson and Nelson, respectively (Mattisson & Legendre, 1952; Nelson & Tripp, 1953).

2.5.3. Degree of whiteness

The whiteness degree of bleached cotton fabrics and gray cotton fabric was measured using the Hunterlab Reflectometer, Model D25 M/L-2. The whiteness index was calculated in terms of the reflectance components CIE Y (green) and (blue) using the following equation.

$$\text{W.I.} = \frac{4Z}{1.18} - 3Y$$

where *Y* and *Z* represent the readings of the hunterlab reflectometer.

2.5.4. Fabric tensile properties

The tensile properties of bleached and gray cotton samples, expressed in terms of tensile strength was measured according to the ASTM strip test.

3. Results and discussion

3.1. Sodium chlorite/triethanolamine salt activated bleaching system

In this paper triethanolamine salt-activated sodium chlorite was used to bleach cotton fabric. Triethanolamine hydrochloride, as an example for the triethanolamine salt was applied for bleaching the cotton fabric in this schematic study and then the optimum conditions obtained were applied to other triethanolamine salts just for comparison. As stated above, sodium chlorite in acid media librates chlorine dioxide, and the rate of its libration affects to great extent the bleaching process efficiency and the properties of the bleached fabrics. The mechanism of the bleaching process involves two successive steps which are the decomposition of the weak triethanolamine salt to its two components triethanolamine and the acid. The second step is sodium chlorite decomposition in the created acid medium to give the bleaching species according to the following equations:

$$4ClO_2^- + 2H^+ \rightarrow 3ClO_2^- + Cl^- + 2OH^-$$

$$3ClO_2^- \rightarrow 2ClO_3^- + Cl^-$$

$$ClO_2^- \rightarrow Cl^- + 2O$$

3.2. Effect of triethanolamine hydrochloride concentration on the percent decomposed sodium chlorite

Several bleaching trials for cotton fabric samples have been carried out using constant concentration from sodium chlorite, at fixed pH value, fixed material to liquor ratio and fixed bleaching temperature, together with varying the concentration of the sodium chlorite decomposition activator, triethanolamine hydrochloride. This was done in order to show the effect of triethanolamine hydrochloride concentration as an activator for sodium chlorite, on the percent decomposed sodium chlorite and accordingly on the efficiency of the bleaching process as a whole. The reaction conditions were to use 5 g/l aqueous sodium chlorite solution, material to liquor ratio of 1:20, bleaching temperature of 95 °C at pH 7, for duration of 240 min and to vary the triethanolamine hydrochloride concentration from 0 mmol/l to 20 mmol/l.

Fig. 1 shows the extent of sodium chlorite decomposition at different time intervals during the bleaching of cotton fabric samples at 95 °C, upon incorporating different amounts of triethanolamine hydrochloride as sodium chlorite activator. The recorded sodium chlorite decomposition results show that as the concentration of triethanolamine hydrochloride incorporated in the bleaching medium increases, the percent decomposed sodium chlorite increases as well, this is at any given bleaching reaction duration. On the other hand, it was also noticed that at certain triethanolamine hydrochloride concentration, as the bleaching time is prolongated, the percent decomposed sodium chlorite increases. In another words, one can say that complete sodium chlorite decomposition is achieved either by using low concentration of triethanolamine hydrochloride together with prolonging the bleaching duration or by using high concentration of triethanolamine hydrochloride together with shortening the bleaching duration.

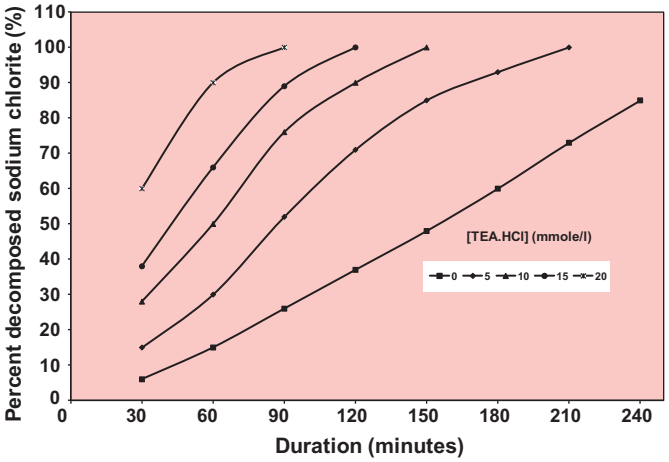

Fig. 1. Decomposition of sodium chlorite at different triethanolamine hydrochloride concentration. [$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; bleaching temperature, 95 °C; bleaching duration, 240 min.

3.3. Effect of triethanolamine hydrochloride concentration on the physiochemical properties of the bleached cotton fabric

Table 1 shows the physiochemical properties of the gray and bleached cotton fabric samples, whiteness index, loss in cotton fabric weight, fabric tensile strength, carbonyl content and carboxyl content, when cotton fabrics are bleached using different triethanolamine hydrochloride as sodium chlorite decomposition activator. The results in Table 1 show that, triethanolamine hydrochloride concentration of 10 mmol/l is optimum concentration for activating sodium chlorite decomposition, based on the highest value of whiteness index. Back to Fig. 1, one can notice that utilization of 10 mmol triethanolamine hydrochloride for activating sodium chlorite decomposition leads to gradual decomposition of sodium chlorite within 150 min. This gradual decomposition leads to maximum benefit from the bleaching system which leads to maximum whiteness together with retaining good deal from the fabric tensile strength. Upon utilization of lower concentrations from the activator triethanolamine hydrochloride,

Table 1
Physiochemical properties of bleached cotton fabrics at different triethanolamine hydrochloride concentration.

Triethanolamine hydrochloride concentration	Whiteness index	Loss in fabric weight (%)	Tenacity (g/tex)	Carbonyl content (meq./100 g)	Carboxyl content (meq./100 g)
0	40.33	2.23	33.65	4.10	9.50
5	50.21	3.20	31.16	5.31	10.21
10	65.00	5.12	30.15	7.19	12.22
15	57.10	3.17	32.30	6.39	10.81
20	28.20	1.29	35.12	4.21	9.23
Gray cotton	20.12	–	38.50	4.11	8.60

[$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; bleaching temperature, 95 °C; bleaching duration, 24 min.

it will be necessary to prolong the bleaching duration more and more to get complete sodium chlorite decomposition, and even complete sodium chlorite decomposition is attained no great improvement neither in the degree of whiteness nor in the tensile strength is noticed. Again back to Fig. 1 and the physiochemical properties in Table 1, one can simply notice that when higher concentrations of the sodium chlorite decomposition activator triethanolamine hydrochloride are incorporated to the bleaching medium, sodium chlorite decomposition takes more shorter time and even it decomposes up to 90% within 60 min upon using 20 mmol/l triethanolamine hydrochloride. This fast 100% sodium chlorite decomposition seems to be useless, that it does not impart good degree of whiteness to the treated cotton fabric samples. Concerning the percent loss in the weight of the bleached fabrics, it is noticed that the higher the concentration of triethanolamine hydrochloride the more will be the percent loss in cotton fabric weight. This increment is not continuous, that after triethanolamine hydrochloride concentration higher than 10 mmol/l the reverse holds true. Concerning the tensile strength values, the data in Table 1 show that the tenacity of any bleached cotton fabric is in general lower than the tenacity of the gray cotton fabric. Also it is noticed that the tenacity decreases gradually by increasing the concentration of triethanolamine hydrochloride up to 10 mmol/l and upon increasing its concentration above this limit, it leads to cotton samples having higher tensile strength values. As it is understood, the tensile strength is strongly related to the percent loss in fabric weight, that the loss in fabric weight means removal of the cementing materials binding the fiber bundles together. The decrease in the values of carboxyl content and carbonyl content when concentrations from triethanolamine hydrochloride above 10 mmol/l are used for sodium chlorite activation is explained in terms of fast decomposition of sodium chlorite without imparting any bleaching effect to the cotton fabric samples.

3.4. Effect of triethanolamine hydrochloride concentration on the pH value of the bleaching liquor

Initial triethanolamine hydrochloride concentration was changed from 0 mmol/l to 20 mmol/l and its effect on the pH of the bleaching bath was monitored by withdrawing samples from the bleaching liquor to estimate the percent decomposed sodium chlorite and at the same time measuring the pH at this time. The results in Fig. 2 show follow up of the bleaching bath pH with time by varying the initial concentration of triethanolamine hydrochloride. Different initial concentrations from triethanolamine hydrochloride were used and the bleaching bath temperature was kept at 95 °C. It is clear from the date in Fig. 2 that for certain initial concentration from triethanolamine hydrochloride, there is continuous decrease in the pH value as the bleaching time increases. Also there was remarkable decrease in the pH value with the increase in the initial concentration of triethanolamine hydrochloride. As noticed from the data in Fig. 2, for the initial triethanolamine hydrochloride concentration 10 mmol/l there is gradual decrease in the pH until it reaches the value 4 after 150 min and there the percent decomposed sodium chlorite is corresponding to 100%. This means again that this initial concentration from triethanolamine hydrochloride is optimum for activating sodium chlorite decomposition, that it gives, when decompose suitable amount from the acid which cause controllable change in the acidity of the bleaching medium which is responsible for the decomposition of sodium chlorite to the bleaching species. On the other hand, when higher concentrations from triethanolamine hydrochloride are used initially for activating sodium chlorite decomposition, the acidity of the bleaching bath increases suddenly giving rise to very fast decomposition of sodium chlorite very early which does not cause bleaching effect to the cotton fabric. Also the alkaline triethanolamine resulting from the decomposition of the triethanolamine salt acts as buffer which prevent sudden drop in the bleaching bath pH, giving rise to gradual decomposition of sodium chlorite to give the desired bleaching effect. Absence of such alkaline buffer would lead to very low pH value which in turn leads to very fast sodium chlorite decomposition without imparting real bleaching effect to the treated cotton fabrics.

3.5. Effect of bleaching temperature on sodium chlorite decomposition

The bleaching reaction was carried out in this section of the study at constant concentrations from sodium chlorite and the activator triethanolamine hydrochloride and the bleaching bath temperature was varied from 50 °C to 95 °C, to show the effect of the bleaching bath temperature on the percent decomposed sodium chlorite. The data presented in Fig. 3 show proportional relationship between the bleaching bath temperature and the percent decomposed sodium chlorite, in general at any of the presented reaction duration, but the increment in the percent decomposed sodium chlorite, at the duration of 60 min due to raising the bleaching temperature from 50 °C to 70 °C is very small compared with the corresponding increment on raising the bleaching temperature from 70 °C to 95 °C. This reflects the high activation energy required

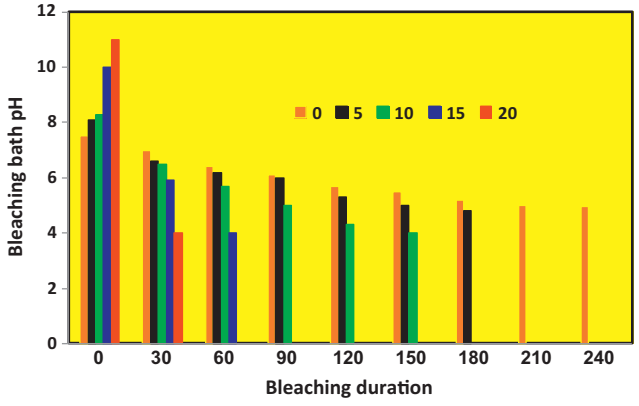

Fig. 2. Change in the pH of the bleaching bath at different triethanolamine hydrochloride concentration. [$NaClO_2$, 5 g/l]; M/L ratio, 1:20; bleaching temperature, 95 °C; bleaching duration, 240 min.

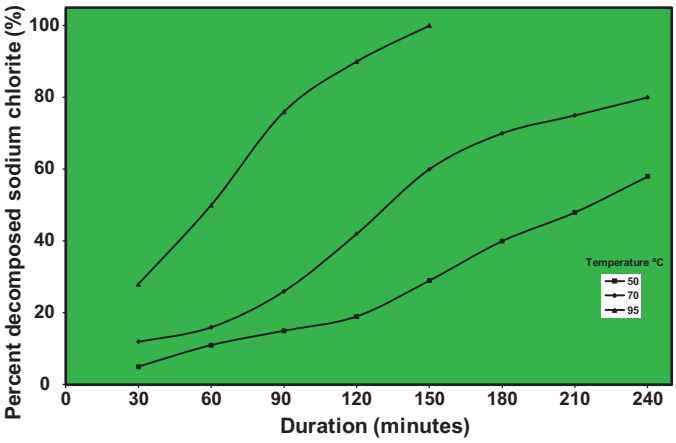

Fig. 3. Decomposition of sodium chlorite at different bleaching temperatures. [$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; [TEA·HCl], 10 mmol/l; bleaching duration, 240 min.

Table 2
Physiochemical properties of bleached cotton fabrics at different bleaching temperatures.

Bleaching bath temperature (°C)	Whiteness index	Loss in fabric weight (%)	Tenacity (g/tex)	Carbonyl content (meq./100 g)	Carboxyl content (meq./100 g)
50	33.15	3.1	35.97	5.1	9.1
70	42.11	3.9	32.70	6.3	10.3
95	65.00	5.12	30.15	7.19	12.22

[$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; [TEA·HCl], 10 mmol/l; bleaching duration, 24 min.

for sodium chlorite to decompose and to give its oxidizing species and also shows the favorable effect of the high temperature in increasing the kinetic energy of the reactant molecules. Also it was found that when the bleaching reaction was carried out at 95 °C, full decomposition of sodium chlorite was attained in 150 min, while on the other hand, when the bleaching reaction was carried out at temperatures lower than 95 °C, no complete decomposition of sodium chlorite was obtained within the duration range studied.

3.6. Effect of bleaching temperature on the physicochemical properties of the bleached cotton fabric

Different bleaching trials at different bleaching bath temperatures were conducted to show the effect of varying the bleaching bath temperature on the values of the physicochemical properties of the bleached cotton fabric. Sodium chlorite concentration was fixed in all trials at 5 g/l and also triethanolamine hydrochloride concentration was fixed at 10 mmol/l. The physiochemical properties presented in Table 2 show that the bleaching bath temperature has great effect on the physiochemical properties of the bleached cotton fabrics, that as the bleaching bath temperature is raised, the degree of whiteness expressed in terms of whiteness index for the bleached cotton fabric increases as well. The improvement in the whiteness index at high temperature is interpreted in terms of the favorable effect of high temperature on the percent decomposed sodium chlorite, that as the bleaching medium temperature increases, more triethanolamine hydrochloride is decomposed to give triethanolamine and hydrochloric acid. Hydrochloric acid in turn activates sodium chlorite decomposition to give more active bleaching species.

The recorded data for the percent loss in cotton fabric weight also demonstrates remarkable increment in the percent weight loss when the bleaching temperature was raised from 50 °C to 95 °C and the gradual increase in the fabric weight loss is accompanied by proportional enhancement in the degree of whiteness. The yellowish to brown color characterizing the gray fabric is a direct result of the presence of noncellulosic materials, like pectin, lignin, hemicellulose and some coloring matter in the structure of these gray cotton fabrics. Although these noncellulosic materials are causing some performance drawbacks to the cotton fabric, like this undesirable coloration and poor water absorbency, but their presence on the other hand, gives the fabrics very good tensile strength. As the bleaching bath temperature increases, the efficiency of the bleaching reaction will be generally higher and this will lead to better removal of this noncellulosic matter which is the cause for the coloration. This implies to better degree of whiteness, but on the other hand, higher losses in the fabric weight, which will be reflected as loss in bleached fabric tensile strength. As a final conclusion in this point, one can say that part of these noncellulosic materials should be removed in order to improve the bleached cotton fabric properties, like degree of whiteness and absorbance of water, which is very important factor which determines the ease of dyeability of cotton fabrics.

Table 2 presents also the values of carbonyl contents and carboxyl content at different bleaching bath temperatures. From these data one can easily notice that there is increment in both carboxyl and carbonyl contents when the bleaching bath temperature was raised from 50 °C to 95 °C, which of course due to increase in the generation of active oxidizing species responsible for formation of more carboxyl and carbonyl groups, upon raising the bleaching bath temperature.

3.7. Effect of using different triethanolamine salt on the percent decomposed sodium chlorite

As concluded from the previous discussion 10 mmol/l was found to be the optimum concentration of the triethanolamine salt required for activating the decomposition of sodium chlorite to give the active species responsible for bleaching. Based on this conclusion, different mineral and organic acids were used to prepare varying triethanolamine salts to be tried as activators for sodium chlorite decomposition. These salts were prepared by neutralizing triethanolamine directly with hydrochloric acid, sulphuric acid, phosphoric acid, formic acid and acetic acid to get the corresponding triethanolamine salts, triethanolamine hydrochloride, triethanolamine sulphate, triethanolamine phosphate, triethanolamine formate and triethanolamine acetate, respectively. Five bleaching bathes were prepared using definite concentration from sodium chlorite (5 g/l) and equal concentrations from the five prepared triethanolamine salts were incorporated, individually in the bleaching bath. The initial bleaching bath pH was fixed at 7 before adding the triethanolamine salt and material to liquor ratio of 1:20 was used in each bleaching bath and the bleaching reaction was carried out at 95 °C with following up the percent decomposed sodium chlorite each 30 min.

Fig. 4 shows the percent decomposed sodium chlorite upon using different kinds of triethanolamine salts for activating sodium chlorite decomposition. It is clear from Fig. 4 that the type of triethanolamine salt used for activating the sodium chlorite decomposition has noticeable effect on the percent decomposed sodium chlorite, that at a certain bleaching time, like 120 min for example, the percent decomposed sodium chlorite increases

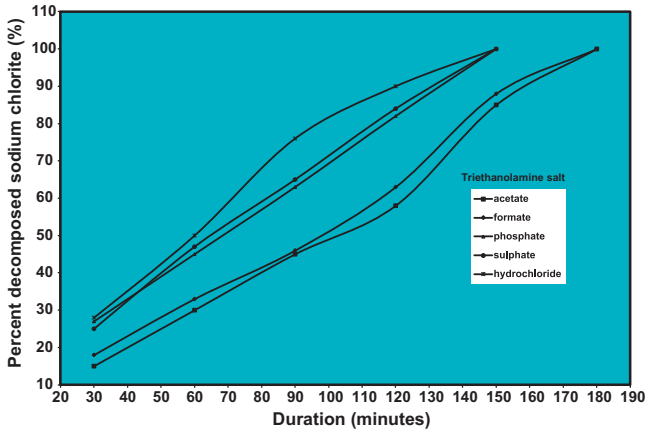

Fig. 4. Decomposition of sodium chlorite at different triethanolamine salts. [$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; [TEA·salt], 10 mmol/l; bleaching temperature 95 °C; bleaching duration, 180 min.

Table 3
Physiochemical properties of bleached cotton fabric using different triethanolamine salts.

Triethanolamine salts	Whiteness index	Loss in fabric weight (%)	Tenacity (g/tex)	Carbonyl content (meq./100 g)	Carboxyl content (meq./100 g)
Acetate	50.15	2.84	35.17	4.81	8.00
Formate	51.12	2.96	35.22	4.94	8.24
Phosphate	63.8	5.06	31.12	7.21	11.98
Sulphate	63.5	5.13	30.56	7.2	12.11
Hydrochloride	65.00	5.12	30.15	7.19	12.22

[$NaClO_2$, 5 g/l]; M/L ratio, 1:20; pH 7; [TEA·salt], 10 mmol/l; bleaching temperature 95 °C; bleaching duration, 180 min.

upon using varying triethanolamine salts and the increase follows the order triethanolamine acetate < triethanolamine formate < triethanolamine phosphate < triethanolamine sulphate < triethanolamine hydrochloride. This means that in general the organic salts of triethanolamine activate sodium chlorite decomposition less than do the inorganic salts of triethanolamine. Even among the inorganic salts, the hydrochloride salt was found to be more efficient than the sulphate salt and the sulphate salt more efficient than the phosphate salt. This efficiency of activating sodium chlorite decomposition reflects the strength of the acids coming from the decomposition of the triethanolamine salts and its power to reduce the bleaching bath pH and accordingly enhance sodium chlorite decomposition in the highly acidic medium. Due to the weakness of the acids coming from the decomposition of triethanolamine acetate and triethanolamine formate, the bleaching reactions carried out using these salts for activating sodium chlorite decomposition showed completeness of the sodium chlorite decomposition after three hours.

3.8. Effect of using different triethanolamine salt on the physiochemical properties of the bleached cotton fabrics

Physiochemical properties of cotton fabrics bleached with sodium chlorite activated with different triethanolamine salts are given in Table 3. As stated above, the fabrics were bleached in a bleaching bath containing 5 g/l sodium chlorite, 10 mmol/l triethanolamine salt. The initial pH of the bleaching bath was adjusted at 7 and the bleaching reaction was allowed to run for 180 min at 95 °C. It is clear from the values of physiochemical properties given in Table 3 that the use of mineral acids in preparing the triethanolamine salt leads to improvement in the physiochemical properties of the bleached fabrics, compared with the corresponding physiochemical properties when the triethanolamine salt was prepared using organic acids. This again reflects the strength of the acids coming from the decomposition of the hydrochloride, sulphate and phosphate salts and their ability to reduce the bleaching medium pH, thus enhancing sodium chlorite decomposition to the oxidizing species which lead to better whiteness, but keeping also reasonable tensile strength.

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