Bleaching of Modal/AN-*g*-Casein Fiber Blend with H_2O_2/TAED Activating System

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ABSTRACT: The bleaching of modal/AN-*g*-casein fiber blend using hydrogen peroxide/tetraacetylethylenediamine (H_2O_2/TAED) activating system was investigated, and the influence of key factors on bleaching was determined. The whiteness index of bleached fabrics was greatly affected by sodium carbonate and H_2O_2/TAED dosages, and the dyeability of bleached fabrics with acid dyes was greatly dependent on H_2O_2/TAED dosages and bleaching temperature. Compared with the conventional H_2O_2 bleach under alkaline conditions, the activated bleach markedly decreased the loss of casein in AN-*g*-casein fiber due to its acidic conditions, and exhibited the advantages of energy saving and high efficiency. However, the fabrics bleached using the activated process had the poor acidic dyeing properties due to the oxidation of amino groups in AN-*g*-casein fiber. © 2012 Wiley Periodicals, Inc. J Appl Polym Sci 125: 1193–1200, 2012

Key words: blends; fibers; proteins; bleaching; peracetic acid

INTRODUCTION

Casein-acrylonitrile graft copolymer fiber (AN-*g*-Casein fiber), one of successfully developed chemical fibers containing proteins, enjoys extensive academic researches.[1–5] Modal fiber, one of new regenerated cellulose fibers, is processed by the dissolved beech pulp and has been widely used in textile industry because of its superior wettability, high strength, and good dyeability.[6] The modal/AN-*g*-Casein fiber blend is a faddish and novel fabric and aggregates the merits of two materials. During the wet processing, this blend is necessary to be scoured and bleached to achieve the white finished cloth and light-colored cloth. At present, most factories adopt alkaline H_2O_2 bleaching. However, AN-*g*-casein fiber has poor alkali resistance as observed in the earlier study.[5] The major casein component in AN-*g*-casein fiber is amorphous, and part of casein is not grafted with polyacrylonitrile.[1–4] These inherent structures readily give rise to the loss of casein during the wet processing under alkaline conditions. Besides, the nitrile groups in polyacrylonitrile can be hydrolyzed to form imine (—C=N—) conjugated system in the presence of high alkali (Scheme 1),[5,7,8] which produces a yellowing effect on this fiber. To avoid the issues of casein loss and fabric yellowing in alkaline medium, the proper bleaching approaches used for AN-*g*-casein fiber and its blend under nearly neutral conditions are necessary to be exploited and researched.

The hydrogen peroxide/tetraacetylethylenediamine (H_2O_2/TAED) activating system is one of widely investigated bleaching systems. Its bleaching mechanism could be described as follows (Scheme 2):[9–14] Perhydroxyl anion (HOO^-) is produced by the disassociation of H_2O_2 in alkali, peracetic acid is generated by the reaction between activator TAED and HOO^- ion, then peracetic acid exerts the bleaching action by the oxidation of double bonds present in unwanted colored compounds. Nowadays, the applications of this system are mainly focused on textile and pulp bleaching.[12,15–22] A lot of investigations on the bleaching of cellulosic fibers and their blends with this system have already been reported. Scarborough and Mathews carried out the bleaching of viscose/Lycra blend, viscose/cotton blend, Lyocell fabric and Lyocell/Lycra blend with H_2O_2/TAED activating system at 70°C under alkaline conditions, and found that the benefits of this system included increased whiteness, minimal loss of viscose strength, and reduced fibrillation of Lyocell fiber.[15] Cai reported the alkaline peroxide bleaching of cotton fabric and cotton/wool blend with the use of guanidine derivatives and TAED as activators, and noticed that the new process

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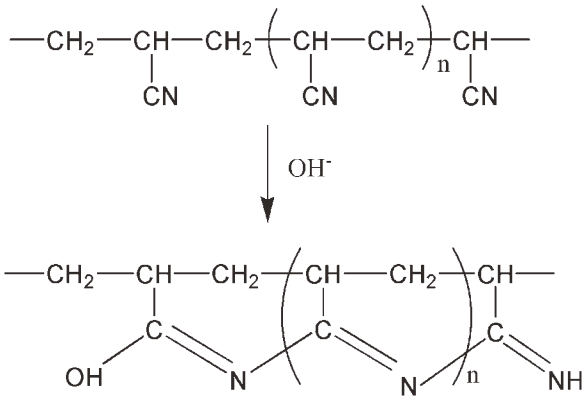


Scheme 1 Reaction of the nitrile groups in polyacrylonitrile during hydrolysis.[5,7,8]

allowed effective bleaching of cotton fabric to be achieved under relatively mild conditions, but TAED gave little improvement in the bleaching of cotton/wool blend with hydrogen peroxide.[16] Shao studied the cold pad-batch bleaching of cotton fabrics with H_2O_2/TAED activating system, and her results showed that the optimized activated bleaching process could achieve excellent bleaching effects under mild alkali conditions with reduced alkali consumption, batch time, and fabric damage.[17] Hebeish and Ismal undertook the investigations of one-step process for the bio-scouring and bleaching of woven and knitted cotton fabrics using alkaline pectinase enzymes and H_2O_2/TAED, respectively; the combined bioscouring and bleaching resulted in higher whiteness, and water and energy savings.[18,19] In addition, Shafie found that sodium perborate/TAED could act as an oxidation desizing agent in the one-step process for the desizing, bio-scouring and bleaching of woven cotton fabric.[20] According to the above-mentioned reports, the fabrics bleached using the activated process showed an excellent whiteness index under mild conditions with reduced fiber damage. However, there have been few reports investigating the behaviors of H_2O_2/TAED activated bleach on AN-*g*-casein fiber and its blends.

In this study, the bleaching of modal/AN-*g*-casein fiber blend with H_2O_2/TAED activating system was studied. The effects of key processing factors on the activated bleach were investigated in detail; the weight loss, whiteness index, and dyeability of bleached fabric were measured. In addition, the comparisons of H_2O_2/TAED bleaching with conventional H_2O_2 bleaching were carried out.

EXPERIMENTAL

Materials

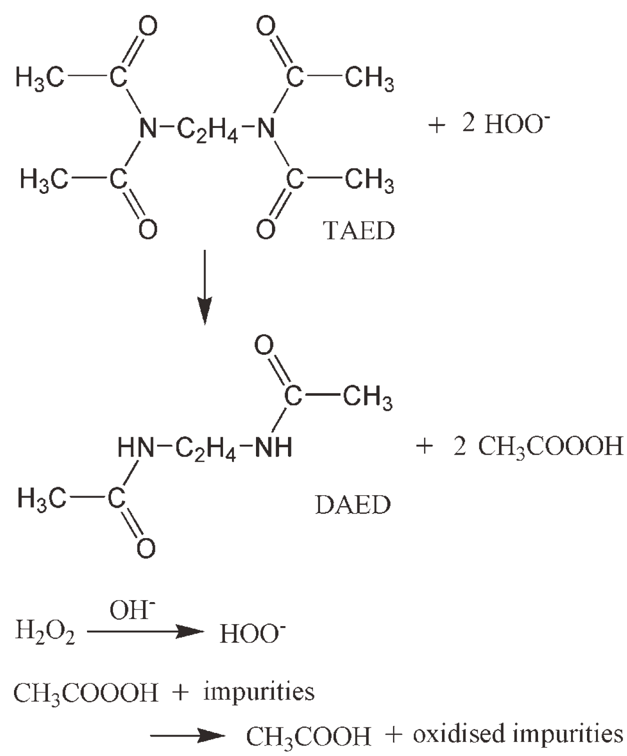
The modal/AN-*g*-casein fiber knit was kindly supplied by Ningbo Guangyuan Textile, China. The blending ratio of modal to AN-*g*-casein fiber and the count of yarn were 70/30 and 14.6 tex, respectively. The control sample was obtained by washing the fabric in the solution of 1 g/dm^3 Invadine DA at 70°C for 60 min, then rinsing completely and drying in the oven at 60°C for 2 h; the weight loss of this sample during washing was 0.39%, this being caused by the loss of a finish oil added during the spinning.

The oxidation bleaching activator TAED (content 99%) was generously provided by Zhejiang Jinke Chemicals, China. 30% (w/w) Hydrogen peroxide, sodium carbonate, sodium silicate, sodium acetate, and acetic acid were of analytical reagent grade. Invadine DA (Huntsman Textile Chemical & Dyes) and Leveler O (a nonionic polyoxyethylene ether surfactant) were commercial products. Everacid Blue A-2G and Yellow A-4R were from Everlight Chemical Industrial, Taiwan.

Oxidation bleaching

All bleaching experiments were carried out in sealed and conical flasks immersed in a universal dyeing machine. The ratio of the solution to the fabric was 50 : 1.

(a) Bleaching with H_2O_2/TAED: The bleaching solution contained 1–15 g/dm^3 hydrogen peroxide, 1.02–15.24 g/dm^3 TAED, 0.5–3 g/dm^3



Scheme 2 Bleaching mechanism of H_2O_2/TAED activating system.

sodium carbonate, 0.5 g/dm^3 sodium silicate (stabilizer), and 1 g/dm^3 Invadine DA (detergent). The molar ratio of H_2O_2 to TAED was 2 : 1. The fabrics were immersed into a series of bleaching solutions at 45°C for 10 min, then the solutions were heated to a required temperature at a rate of 2°C/min and the bleaching continued for a required time. After bleaching, the fabrics were rinsed thoroughly with tap water, dried in the open air, and finally dried in the oven at 60°C for 120 min.

(b) Bleaching with H_2O_2: The fabrics were immersed into the aqueous solutions containing 1–15 g/dm^3 hydrogen peroxide, 0.5 g/dm^3 sodium silicate, 0.5 g/dm^3 sodium carbonate, and 1 g/dm^3 Invadine DA at 30°C, then the temperature was raised to 85°C at a rate of 2°C/min and held for 60 min. After bleaching, the fabrics were treated as mentioned earlier.

Dyeing with acid dyes

The dyebath was composed of 1% omf dye and 0.4 g/dm^3 Leveler O, and its pH was adjusted to 4.0 with sodium acetate/acetic acid buffer. The fabrics were immersed into the dyebath at 30°C, then the temperature was heated to 85°C at a rate of 2°C/min and kept for 80 min. At the end of dyeing, the dyed samples were removed, rinsed in tap water, and allowed to dry in the open air.

Color characteristic evaluation

The color space coordinates (lightness [*L*], redness-greenness [*a*], blueness-yellowness [*b*], and chroma [*C*]), tristimulus value (*X*, *Y*, and *Z*) and the apparent color depth (*K/S* value) were measured with an UltraScan PRO reflectance spectrophotometer (Hunter Associates Laboratory) using illuminant D65 and 10° standard observer. Each sample was folded twice, which gives a thickness of four layers of fabric, an average of four readings was calculated for each sample. The Hunter whiteness index (*WI*) and yellowness index (*YI*) were calculated using eqs. (1) and (2):

$$\mathrm{WI} = 100 - [(100 - L)^2 + a^2 + b^2]^{0.5} \quad (1)$$

$$\mathrm{YI} = 100 \times (1 - 0.847Z/Y) \quad (2)$$

Weight loss estimation

The fabrics before and after bleaching were dried in the oven at 60°C for 2 h, and then weighed quickly. The weight loss (*WL*) of bleached fabrics was calculated using eq. (3):

$$\%\mathrm{WL} = 100 \times (W_0 - W_1)/W_0, \quad (3)$$

where W_0 and W_1 are the weights of the dried fabrics before and after bleaching, respectively.

Exhaustion determination

The exhaustion was determined according to the residue colorimetry. The absorbance of dyebath was measured using a Shimadzu UV-1800 UV-Vis spectrophotometer (Shimadzu, Japan). The exhaustion was calculated using eq. (4):

$$\%\mathrm{Exhaustion} = 100 \times (A_0 - A_1)/A_0, \quad (4)$$

where A_0 and A_1 are the absorbance of the dyebath at the maximum wavelength before and after dyeing, respectively.

RESULTS AND DISCUSSION

Effect of sodium carbonate dosage on the weight loss, whiteness, and dyeability of fabrics

Sodium carbonate is vital to the activated bleaching process. Its dosage affects the extent of H_2O_2/TAED activation and the chemical behaviors of AN-*g*-casein fiber as described in Introduction section. Thus, the effect of sodium carbonate dosage on bleaching was first investigated.

The fabrics were treated in the bleaching solutions containing 5 g/dm^3 30% H_2O_2 and 5.08 g/dm^3 TAED along with sodium carbonate in the concentration range of 0–3 g/dm^3 at 70°C for 60 min. Figure 1 shows that the weight loss increased gradually with increasing sodium carbonate dosage, and the maximum value only reached to 1.94%. Considering the low content of added finish oil in the fiber

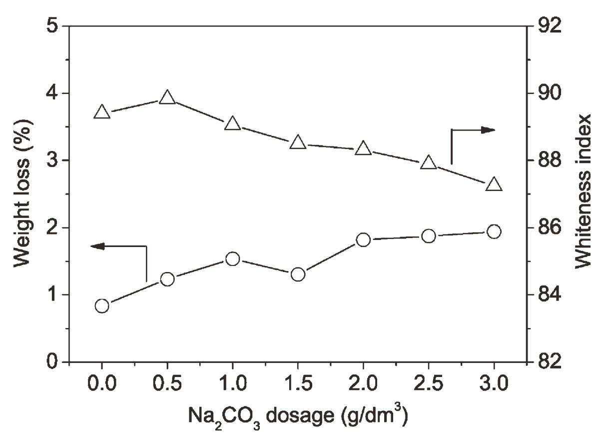


Figure 1 Effect of sodium carbonate dosage on the weight loss and whiteness index of bleached fabrics.

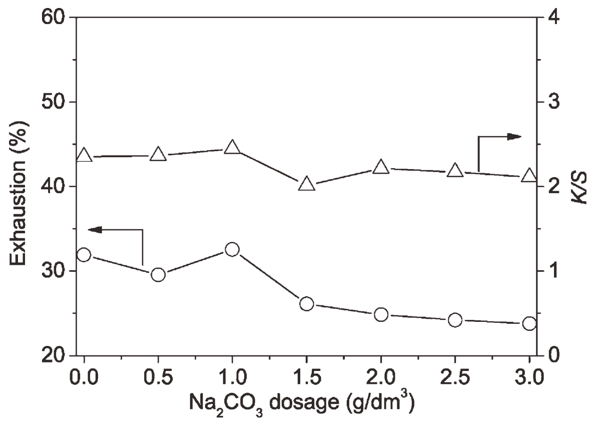


Figure 2 Effect of sodium carbonate dosage on the dyeability of bleached fabrics with Everacid Blue A-2G.

as mentioned in Materials section, this small quantity of weight loss is primarily a consequence of dissolution of casein fraction in AN-*g*-casein fiber.[5] This finding suggests that the H_2O_2/TAED activating system can reduce the loss of casein effectively.

Figure 1 also reveals that the whiteness index increased slightly when the sodium carbonate dosage was changed between 0 and 0.5 g/dm^3, and the highest value (89.83) was reached at this point of 0.5 g/dm^3 sodium carbonate. As the dosage increased further, the whiteness index decreased obviously. These observations indicate that the sodium carbonate dosage has great influence on the whiteness index and this could be explained by Schemes 1 and 2. A small quantity of sodium carbonate is beneficial to the formation of peracetic acid (Scheme 2), which leads to the improvement of whiteness index.[9,13,14] When its dosage exceeds a reasonable amount, the formation of imine (—C=N—) conjugated system produces a yellowing effect on AN-*g*-casein fiber (Scheme 1).[5,7,8]

As 0.5 g/dm^3 sodium carbonate had been found to provide the highest whiteness index, this dosage was used to study the influence of H_2O_2/TAED dosages, bleaching temperature and duration, as described below.

To compare the influence of different sodium carbonate concentrations on the dyeability of bleached fabrics, the fabrics were subsequently dyed with an anthraquinone dye, namely Everacid Blue A-2G. The anionic sulfonate groups in Everacid Blue A-2G are primarily attracted to the protonated amino groups in AN-*g*-casein fiber by electrostatic interaction under acidic conditions, and the dye hardly stains on modal fiber owing to its low molecule weight, so the exhaustion is mainly dependent on the quantity of amino groups in casein under the same dyeing condition.

Figure 2 shows that the exhaustion decreased gradually with increasing sodium carbonate dosage, and accordingly the *K*/*S* value decreased slightly. It is worthwhile to note that the uptake of this dye by bleached fabrics only reached to the level of 24–33%, whereas the exhaustion for the control sample reached to 72% under the same dyeing condition. As the loss of casein was low as shown in Figure 1, it is believed that the poor dyeability of bleached fabrics with acid dyes is caused by the oxidation of amino groups by peracetic acid which is a stronger oxidant when compared with hydrogen peroxide.

Effect of H_2O_2/TAED dosages on the weight loss, whiteness, and dyeability of fabrics

The fabrics were treated in the bleaching solutions containing 0–15 g/dm^3 30%H_2O_2, 0–15.24 g/dm^3 TAED, and 0.5 g/dm^3 sodium carbonate at 70°C for 60 min. Figure 3 reveals that the weight loss of bleached fabrics was still low at different H_2O_2/TAED dosages. This finding is nearly consistent with the result of low weight loss shown in Figure 1, further verifying the low loss of casein component during the activated bleaching process.

Figure 3 also shows that the whiteness index increased gradually with increasing H_2O_2/TAED dosages until at a 10 g/dm^3 dosage of 30% H_2O_2, a maximum whiteness level was reached. Then the whiteness index declined obviously when the 30% H_2O_2 dosage exceeded 10 g/dm^3. This observation indicates the significant influence of H_2O_2/TAED dosages on the whiteness of bleached fabrics. An increase in H_2O_2/TAED dosages is accompanied with an increase in the quantity of their reaction product, i.e., peracetic acid, which results in an improved whiteness index. However, excessive peracetic acid is likely to cause the intense oxidation of casein, and correspondingly the formation of unexpectedly yellow substance, which may explain the

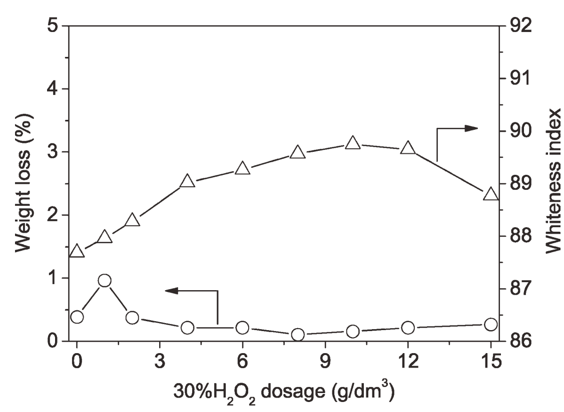


Figure 3 Effect of H_2O_2/TAED dosages on the weight loss and whiteness index of bleached fabrics (TAED dosage calculated according to the 2:1 molar ratio of H_2O_2 to TAED).

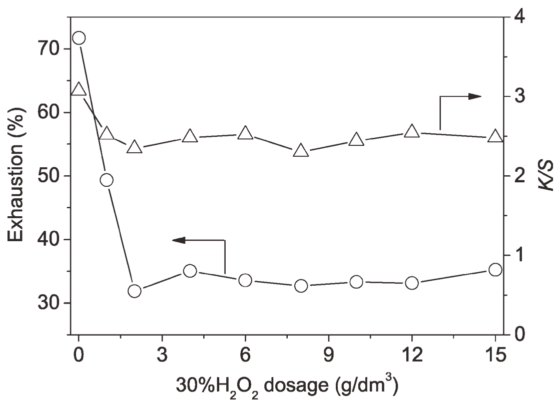


Figure 4 Effect of H_2O_2/TAED dosages on the dyeability of bleached fabrics with Everacid Blue A-2G.

reduced whiteness index as the H_2O_2/TAED dosages exceed an adequate amount.

As the dosages of 8 g/dm^3 30% H_2O_2 and 8.13 g/dm^3 TAED had been found to provide a high whiteness index, they were used to study the influence of bleaching temperature and duration, as described below.

The dyeability of fabrics bleached at various H_2O_2/TAED dosages is shown in Figure 4. The exhaustion decreased sharply when the 30% H_2O_2 dosage varied in the range of 0–2 g/dm^3, but remained almost constant when the dosage changed between 4 and 15 g/dm^3. These observations suggest that H_2O_2/TAED dosages are the major factor influencing the dyeability of bleached fibers. The sharp reduction in the dyeability of bleached fabrics at low H_2O_2/TAED dosages might be explained by two reasons. One reason is that peracetic acid exerts a strong oxidation action on the amino groups in AN-*g*-casein fiber and causes a decrease in the dyeability of this fiber with acid dyes. Another reason is that the major casein component in AN-*g*-casein fiber is amorphous, and part of casein is not grafted with polyacrylonitrile,[1–4] and consequently amorphous casein is prone to be oxidized by peracetic acid.

Effect of temperature on the weight loss, whiteness, and dyeability of fabrics

The fabrics were treated in the bleaching solutions containing 8 g/dm^3 30%H_2O_2, 8.13 g/dm^3 TAED, and 0.5 g/dm^3 sodium carbonate at different temperatures for 60 min. As can be shown in Figure 5, all the weight loss of the fabrics bleached at various temperatures was low. The whiteness index increased slightly with increasing temperature, and the maximum value (90.08) was reached at 70°C. As the temperature continued to be elevated, the whiteness index decreased instead. On the whole, the influence of temperature on the whiteness is not distinct. It seems reasonable to presume that the slight decline of whiteness index at high temperature is related to the excessive oxidation of casein in the AN-*g*-casein fiber.

As the bleaching at 70°C had been found to provide the highest whiteness index, this temperature was used to study the effect of bleaching duration, as described below.

Figure 6 shows that the exhaustion of acid dyes decreased markedly with an increase in bleaching temperature, implying that the dyeability of AN-*g*-casein fiber was evidently affected by bleaching temperature. The reason for the obvious reduction in exhaustion is the enhanced oxidation of casein by peracetic acid with increasing bleaching temperature.

Effect of time on the weight loss, whiteness, and dyeability of fabrics

The fabrics were treated in the bleaching solutions containing 8 g/dm^3 30% H_2O_2, 8.13 g/dm^3 TAED, and 0.5 g/dm^3 sodium carbonate at 70°C for different times. Figure 7 shows that the varieties in the weight loss and whiteness index of bleached fabrics were negligible in the range of time used. Even if the fabric was bleached for 5 min, the whiteness index could reach to 89.48. This finding could be explained in

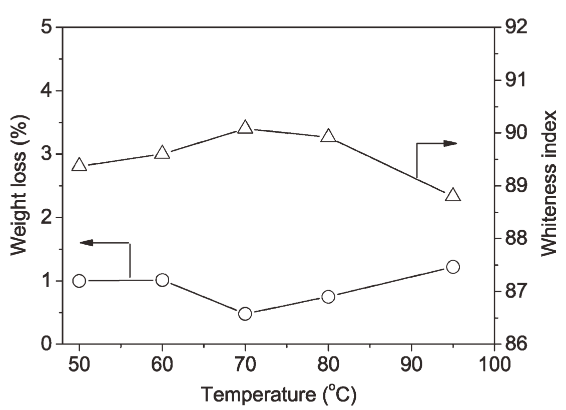


Figure 5 Effect of bleaching temperature on the weight loss and whiteness index of bleached fabrics.

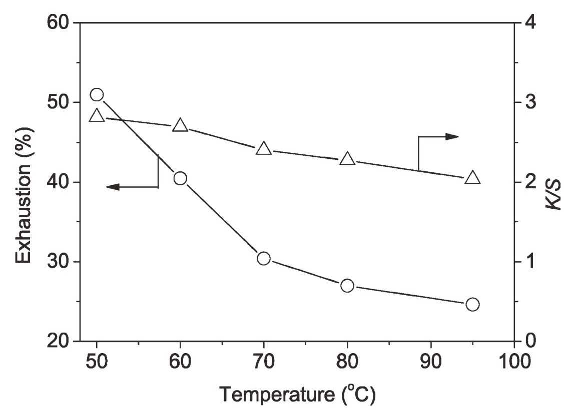


Figure 6 Effect of bleaching temperature on the dyeability of bleached fabrics with Everacid Blue A-2G.

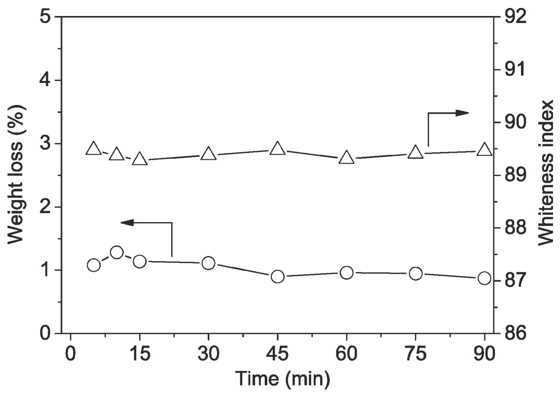


Figure 7 Effect of bleaching time on the weight loss and whiteness index of bleached fabrics.

terms of the high rate of the reaction of H_2O_2 with TAED shown in Scheme 2,[23] and the strong oxidation ability and high bleaching efficacy of peracetic acid in a short time.[13] Therefore, it can be concluded that the H_2O_2/TAED system enjoys the advantages of high bleaching efficiency and time saving.

Figure 8 reveals that the extent of the uptake of acid dyes by bleached fabrics decreased clearly with an increase in bleaching time, indicating the obvious impact of bleaching time on the dyeability of AN-*g*-casein fiber. This phenomenon is believed to be attributed to the increasing extent of oxidation of casein in AN-*g*-casein fiber that accompanied an increase in duration of bleaching. Despite all this, the bleaching time is still suggested to be prolonged to 30 min or so to achieve the thoroughly bleached yarns.

Changes in pH values during the activated and conventional bleach

To compare the conditions of the activated and conventional bleach processes, and discuss the reason of yellowish appearance of the fabrics bleached using different methods, the pH values at different bleaching times and temperatures during two bleaching processes were measured for the same initial dosages of sodium carbonate and sodium silicate. In Figure 9, the activated bleach solution included 8 g/dm^3 30% H_2O_2 and 8.13 g/dm^3 TAED, and the conventional bleach solution contained 8 g/dm^3 30% H_2O_2; other chemicals were added as described in Experimental section. As shown in Figure 9, the pH value of solution decreased markedly during the activated bleach; it descended below 7 in short times, and further decreased to 3.6–3.2 at the temperature holding stage. This low pH is a consequence of the formation of peracetic acid. Thus, the activated bleach can provide the mild bleaching condition for the fibers inherently sensitive to alkali. By contrast, the pH values during the conventional bleach process almost stayed in the range of 9–10.2. Obviously, such an alkaline condition is likely behind the weight loss and yellowing of AN-*g*-casein fiber as reported earlier.[5]

Comparison of the color characteristic values of fabrics between the activated and conventional bleach

The conventional bleach was carried out under the conditions described in Experimental section. The H_2O_2/TAED activated bleach was implemented at 70°C for 60 min using 0.5g/L sodium carbonate. The color characteristic values are summarized in Table I. The multiple parameters were used to assess the bleaching effects comprehensively. Among these parameters, the higher *WI* and *L* as well as the lower *YI*, *a*, *b*, and *C* indicated a better bleaching effect.

From Table I it can be observed that the *YI*, *b* and *C* of the fabrics bleached using the conventional method were much higher than those of the control sample; moreover, these samples exhibited a visible yellowish appearance. Thus, the conventional method resulted in a yellowish effect instead of achieving the aim of bleaching. This fact is attributed

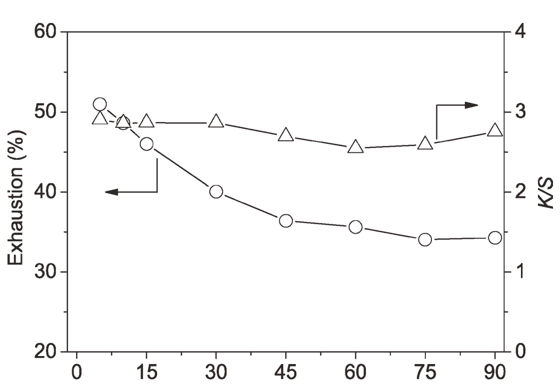


Figure 8 Effect of bleaching time on the dyeability of bleached fabrics with Everacid Blue A-2G.

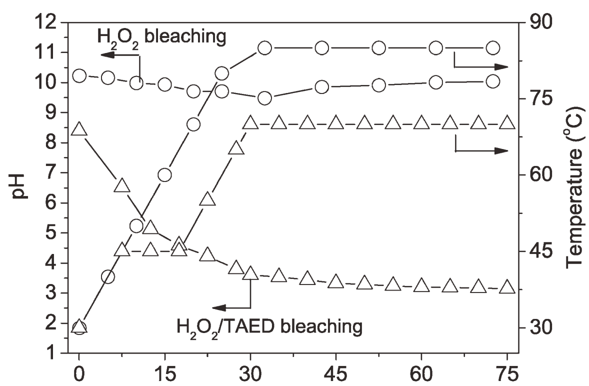


Figure 9 Changes in pH values during the activated and conventional bleach.

TABLE I
Comparison of the Color Characteristic Values of Fabrics Between the Activated and Conventional Bleach

30%H_2O_2/TAED (g/dm^3)/(g/dm^3)	*WI*	*YI*	*L*	*a*	*b*	*C*
Control sample	87.69	22.25	91.45	−0.67	8.83	8.85
H_2O_2/TAED bleaching						
1/1.02	87.96	21.72	91.48	−0.89	8.47	8.52
2/2.03	88.28	21.47	91.74	−0.23	8.32	8.32
4/4.06	89.02	20.21	91.99	−0.35	7.50	7.51
8/8.13	89.57	18.85	91.91	−0.10	6.58	6.58
15/15.24	88.77	19.93	91.44	−0.13	7.26	7.26
H_2O_2 bleaching						
1/0	80.58	34.11	89.80	−1.18	16.48	16.52
2/0	81.52	32.90	90.55	−1.48	15.81	15.88
4/0	82.30	31.58	90.66	−1.55	14.95	15.03
8/0	83.51	29.84	91.29	−1.77	13.89	14.00
15/0	86.99	24.68	92.67	−1.85	10.59	10.75

to the formation of imine (—C=N—) conjugated system by the hydrolysis of nitrile groups in AN-*g*-casein fiber under the alkaline condition.[5,7,8] So the conventional bleach is not suitable for AN-*g*-casein fiber and its blends.

Table I also shows that the whiteness index of the fabrics bleached using the activated process was higher than that of the control sample; in addition, the *YI*, *b*, and *C* decreased obviously. This suggests that the activated process can be used to bleach the AN-*g*-casein fiber and its blends effectively.

Comparison of the weight loss and dyeability of bleached fabrics between the activated and conventional bleach

From Table II, it can be seen that the weight loss of the conventionally bleached fabrics was much higher than that of the fabrics bleached using the activated process. This higher weight loss is induced by the dissolution and hydrolysis of casein in AN-*g*-casein fiber under the alkaline condition.[5] Compared with the conventional bleach, the activated bleach almost took effect under the acidic condition as described earlier, and consequently prevented the hydrolysis and loss of casein in AN-*g*-casein fiber.

To further compare the influence of two bleaching processes on the dyeability of bleached fabrics, the samples in Table I were dyed with Everacid Blue A-2G and Yellow A-4R. As shown in Table II, all the bleached fabrics displayed the markedly decreased dyeability of acid dyes compared with the control sample. In addition, the fabrics bleached using the conventional method showed poorer dyeability, especially when a high H_2O_2 dosage was used. As the exhaustion of these two acid dyes are primarily dependent on the quantity of amino groups in AN-*g*-casein fiber under weakly acidic condition, the oxidation of amino groups and the loss of casein during bleaching would affect the dyeability of bleached fabrics. The decreased dyeability of the fabrics bleached using the activated process is believed to be a consequence of the intense oxidation of amino groups in AN-*g*-casein fiber by peracetic acid, whereas that of the fabrics treated using the conventional bleach results from the oxidation of amino groups and the loss of casein under the alkaline condition. To solve the problem of the poor acidic dyeing properties of the bleached fabrics, it is suggested that reactive dyes should be studied for the simultaneous coloration of AN-*g*-casein and modal fibers.

CONCLUSIONS

The H_2O_2/TAED activated bleach system improved the whiteness of modal/AN-*g*-casein fiber blends. Sodium carbonate and H_2O_2/TAED dosages had great

TABLE II
Comparison of the Weight Loss and Dyeability of Bleached Fabrics Between the Activated and Conventional Bleach

30%H_2O_2/TAED (g/dm^3)/(g/dm^3)	Weight loss (%)	Exhaustion (%) Blue A-2G	Yellow A-4R
Control sample	0.39	71.73	78.99
H_2O_2/TAED bleaching			
1/1.02	0.96	49.37	50.91
2/2.03	0.37	31.86	38.99
4/4.06	0.21	35.02	37.78
8/8.13	0.11	32.70	38.79
15/15.24	0.27	35.23	35.46
H_2O_2 bleaching			
1/0	4.00	46.41	40.65
2/0	4.12	39.69	35.37
4/0	4.06	37.00	29.88
8/0	4.10	31.84	25.41
15/0	4.14	28.48	22.76

influence on the whiteness index of fabrics. A high whiteness index was reached at low sodium carbonate dosage. The whiteness index increased obviously with increasing H_2O_2/TAED dosages, but decreased with further increasing dosages. Compared with the conventional H_2O_2 bleach, the activated bleach markedly decreased the loss of casein in AN-*g*-casein fiber due to its acidic bleaching condition, reduced bleaching temperature and time, and hence exhibited the advantages of energy saving and high efficiency.

Both the activated and conventional bleaching caused the poor dyeability of bleached fabrics with acid dyes. For the activated bleach, the H_2O_2/TAED dosages and temperature had great influence on the dyeability of fabrics, a low dosage led to a noticeable decrease in dyeability due to the strong oxidation of amino groups in AN-*g*-casein fiber by small quantities of peraectic acid. To solve this problem, it is suggested that some suitable reactive dyes could be selected to dye AN-*g*-casein and modal fibers simultaneously.

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