

CHAPTER IV

Results and Discussion

4.1 Synthesis of Modifying Agent: 3-amino-2-hydroxyl-propyltrimethyl ammonium(3,5)-dichlorotriazine

The 3-amino-2-hydroxyl-propyltrimethylammonium(3,5)-dichlorotriazine which was used in this experiment has the following formula:

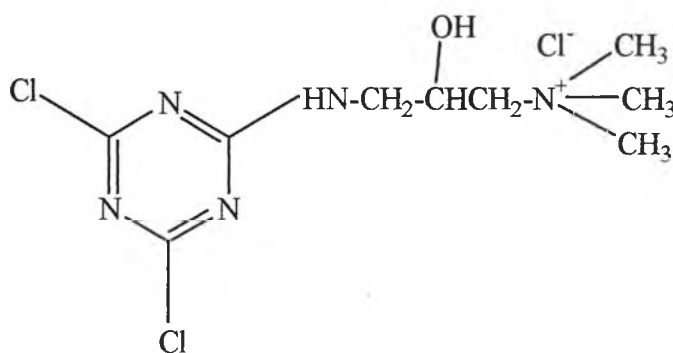


Figure 4.1 The structure of modifying agent, 3-amino-2-hydroxyl-propyltrimethylammonium(3,5)-dichlorotriazine

In this experiment, two approaches were adapted to prepare the modifying agent as described on section 3.3. The synthesizing results are discussed as follows:

4.1.1 Synthesis of the intermediate I: 3-amino-2-hydroxyl-propyltrimethylammonium chloride from (3-chloro-2-hydroxypropyl)trimethylammonium chloride

The intermediate I: 3-amino-2-hydroxyl-propyltrimethylammonium chloride was prepared by the reaction of (3-chloro-2-hydroxypropyl)trimethylammonium chloride with excess ammonia. Based on the scheme 3.1, the reaction between ammonia and (3-chloro-2-hydroxypropyl)trimethylammonium chloride was expected

to give 3-amino-2-hydroxyl-propyltrimethylammonium chloride, the primary amine containing quaternary ammonium moiety. The obtained intermediate was characterized by NMR. The quantitative analysis was carried out using pH-titration method.

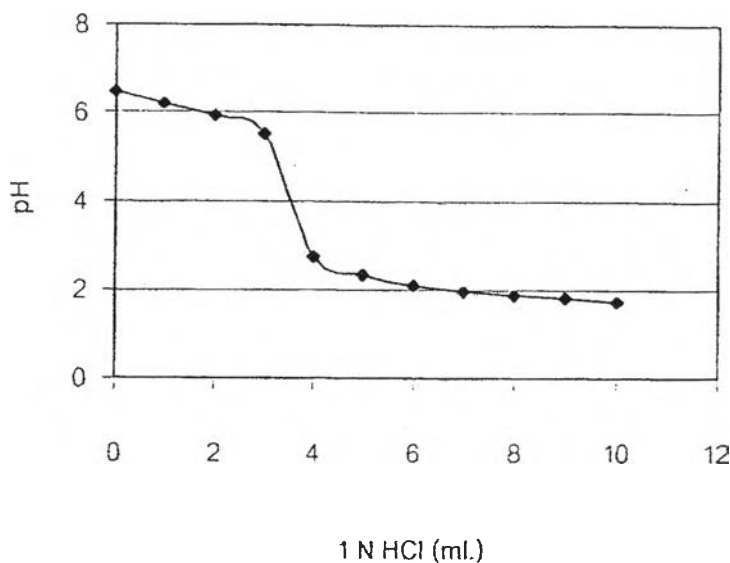


Figure 4.2 Titration curve of intermediate I and standard hydrochloric acid solution

From the titration curve in Figure 4.2, the amount of the primary amine was calculated from the volume of standard hydrochloric acid solution used at the inflection point. The percent of conversion of (3-chloro-2-hydroxypropyl)trimethyl ammonium chloride to 3-amino-2-hydroxylpropyl trimethyl ammonium chloride was determined. The obtained percent conversion is about 11% yield which is extremely low. This means that side reactions existed during the preparation of the intermediate. Since the primary amine produced behaved stronger nucleophile than the ammonia starting agent, it could easily undergo nucleophilic substitution reaction with unreacted (3-chloro-2-hydroxypropyl)trimethylammonium chloride to produce secondary amine. Likewise, the secondary amine which is more reactive reacted with unreacted (3-chloro-2-hydroxypropyl)trimethylammonium chloride. It was possible that the

quaternary ammonium compound could be present as a result of the reaction of tertiary amine with unreacted (3-chloro-2-hydroxypropyl) trimethylammonium chloride. Therefore it was very difficult to control the reaction of (3-chloro-2-hydroxypropyl) trimethylammonium chloride with ammonia. In this experiment, another approach to prepare the primary amine compound was proposed.

4.1.2 Synthesis of the intermediate II from glycidyltrimethyl ammonium chloride

It is a fact that glycidyltrimethyl ammonium chloride is more reactive than (3-chloro-2-hydroxypropyl)trimethylammonium chloride. The reaction between glycidyltrimethyl ammonium chloride with ammonia could occur at milder temperature and the reaction rate was presumably higher than those of (3-chloro-2-hydroxypropyl)trimethylammonium chloride-ammonia counterpart. The pH value of reaction mixture measured at about 9.4 preliminarily indicates that the presence of primary amine is markedly higher than that obtained from the previous reaction (section 4.1.1). The percent conversion of glycidyltrimethyl ammonium chloride into the primary amine is found to be 63% yield. Therefore the intermediate II was used throughout for the preparation of the modifying agent.

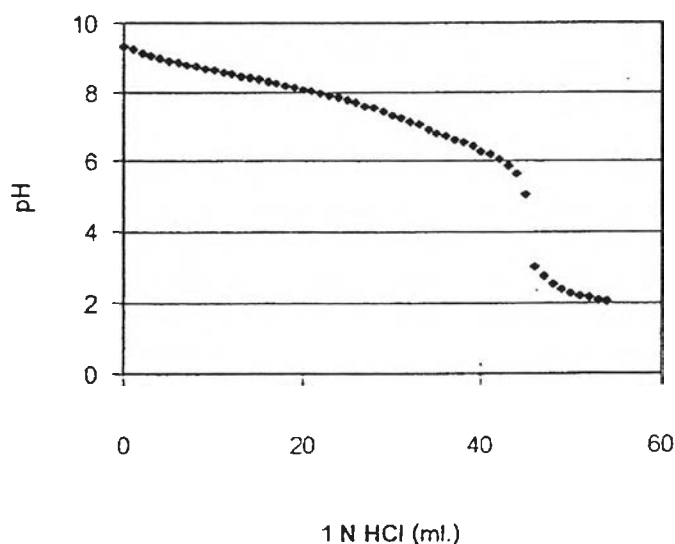


Figure 4.3 Titration curve of intermediate II and standard hydrochloric acid solution.

4.2 NMR study of the intermediate I, intermediate II and modifying agent

4.2.1 ^1H NMR study of (3-chloro-2-hydroxypropyl)trimethylammonium chloride and intermediate I

The ^1H NMR spectroscopy was employed to confirm the chemical structure of intermediate I and (3-chloro-2-hydroxypropyl)trimethylammonium chloride. The ^1H NMR spectra of (3-chloro-2-hydroxypropyl)trimethylammonium chloride is showed in Figure 4.4 and the ^1H NMR spectrum of intermediate I in D_2O solvent is show Figure 4.5 and the chemical shifts of all protons are summarized in Table 4.1

^1H NMR of (3-chloro-2-hydroxypropyl)trimethylammonium chloride (see Figure 4.4) shows the signals at 3.07(A), 2.80(B), 3.55(C) and 3.25(D), which is assigned to the presence of methylene(A) proton, methylene(B) proton, methylene(C) proton and methyl proton respectively. ^1H NMR in figure 4.5 confirms that the reaction between (3-chloro-2-hydroxypropyl)trimethylammonium chloride and ammonia completed because the signal of methylene(A) proton at 3.07 ppm. disappeared. However, the reaction product was not pure since the foreing signals are observed at 3.4 and 2.7 ppm. The results obtained indicate that the secondary amine, the tertiary amine and the quaternary ammonium salt were present in the product.

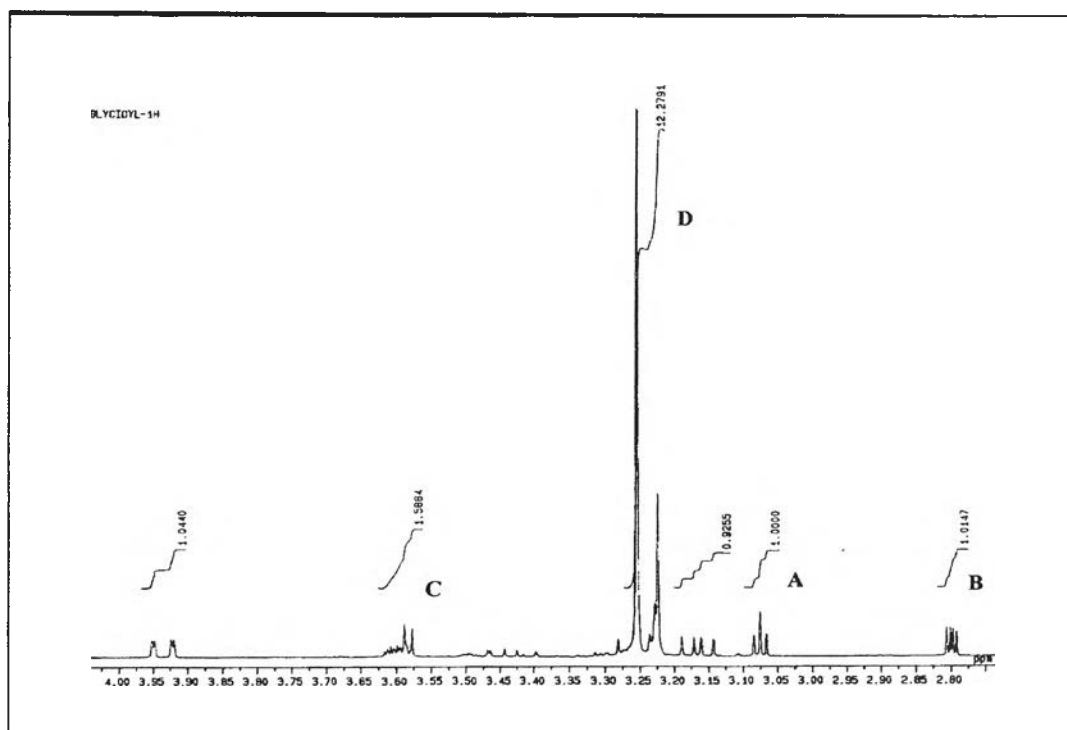


Figure 4.4 ^1H NMR spectrum of (3-chloro-2-hydroxypropyl)trimethylammonium chloride using D_2O as solvent.

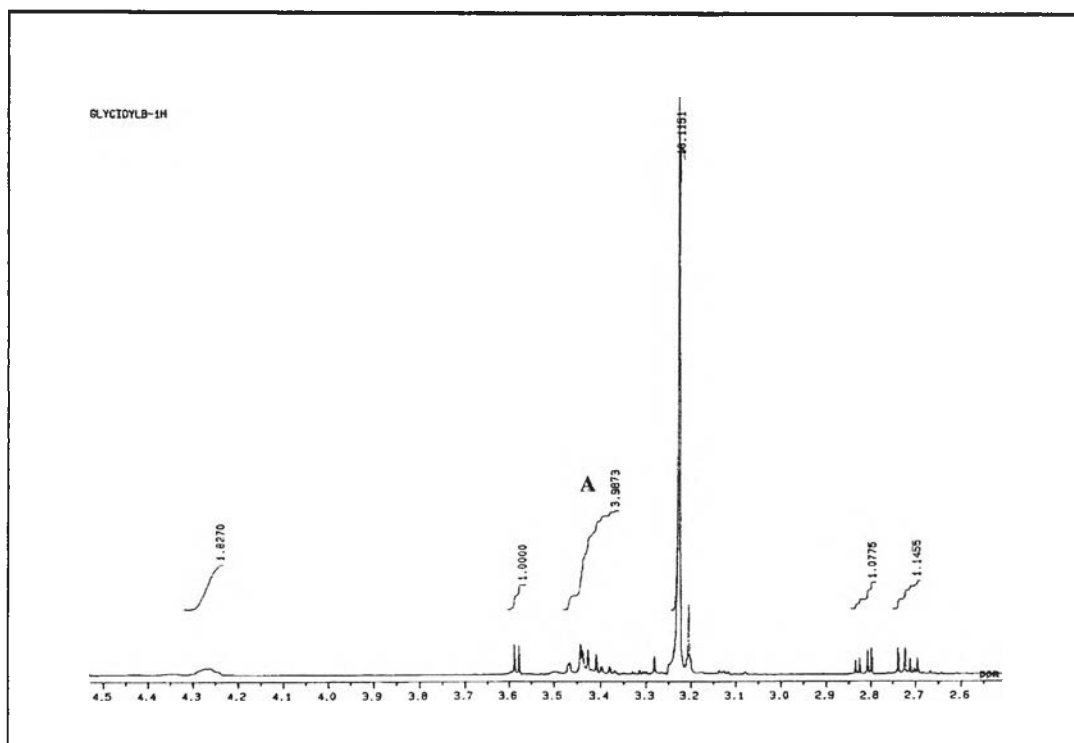


Figure 4.5 ^1H NMR spectrum of intermediate I using D_2O as solvent.

4.2.2 ^1H NMR study of glycidyltrimethyl ammonium chloride and intermediate II

The ^1H NMR spectroscopy was used to confirm the chemical structure of intermediate II. The ^1H NMR spectrum of glycidyltrimethyl ammonium chloride in D_2O solvent is shown Figure 4.6 and the ^1H NMR spectrum of intermediate II in D_2O solvent is shown Figure 4.7 and the chemical shifts of all protons are summarized in Table 4.2. The results indicated that glycidyltrimethyl ammonium chloride was completely converted to (3-amino-2-hydroxypropyl)trimethylammonium chloride, judged by the disappearance of epoxy proton signal at 3.1 ppm.

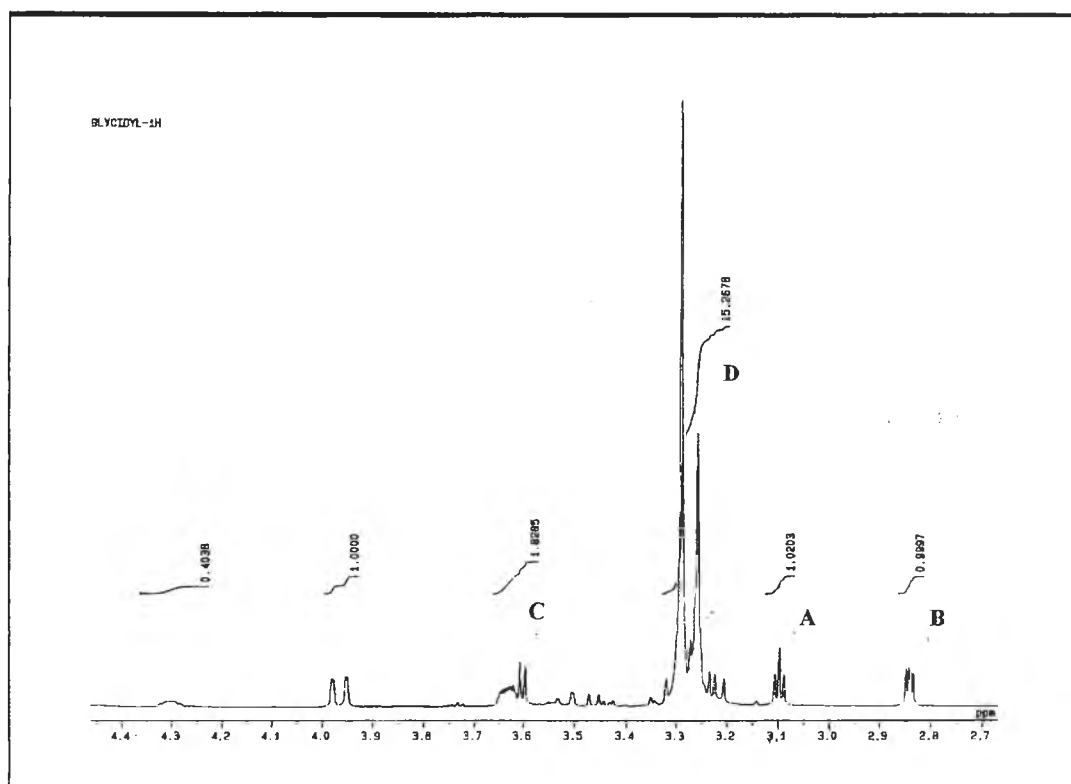


Figure 4.6 ^1H NMR spectrum of glycidyltrimethyl ammonium chloride using D_2O as solvent.

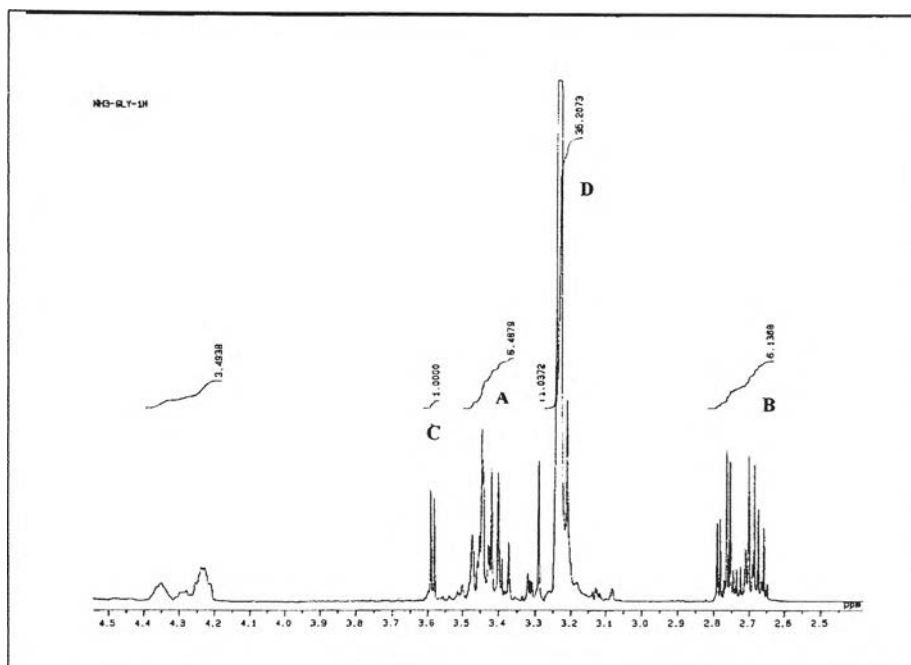
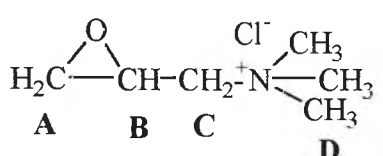
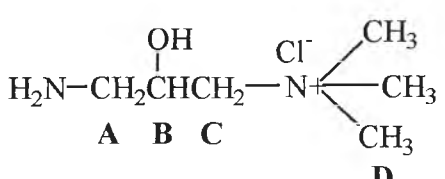


Figure 4.7 ^1H NMR spectrum of intermediate II using D_2O as solvent.

Table 4.2 Chemical shifts of glycidyltrimethyl ammonium chloride and intermediate II

| Compound | Chemical shift (δ) (ppm.) | Assignment |
|---|---------------------------------------|------------|
| glycidyltrimethyl ammonium chloride | | |
|  | 3.1 | A |
| | 2.8-2.9 | B |
| | 3.6 | C |
| | 3.2-3.3 | D |
| Intermediate II | | |
|  | 3.4-3.5 | A |
| | 2.7-2.8 | B |
| | 3.58 | C |
| | 3.23 | D |

4.2.3 ^1H NMR study of modifying agent: 3-amino-2-hydroxyl-propyltrimethyl ammonium(3,5)-dichlorotriazine

The ^1H NMR spectroscopy was used to confirm the chemical structure of modifying agent. The ^1H NMR spectrum of modifying agent in D_2O solvent is shown Figure 4.8 and the chemical shifts of all protons are summarized in Table 4.3

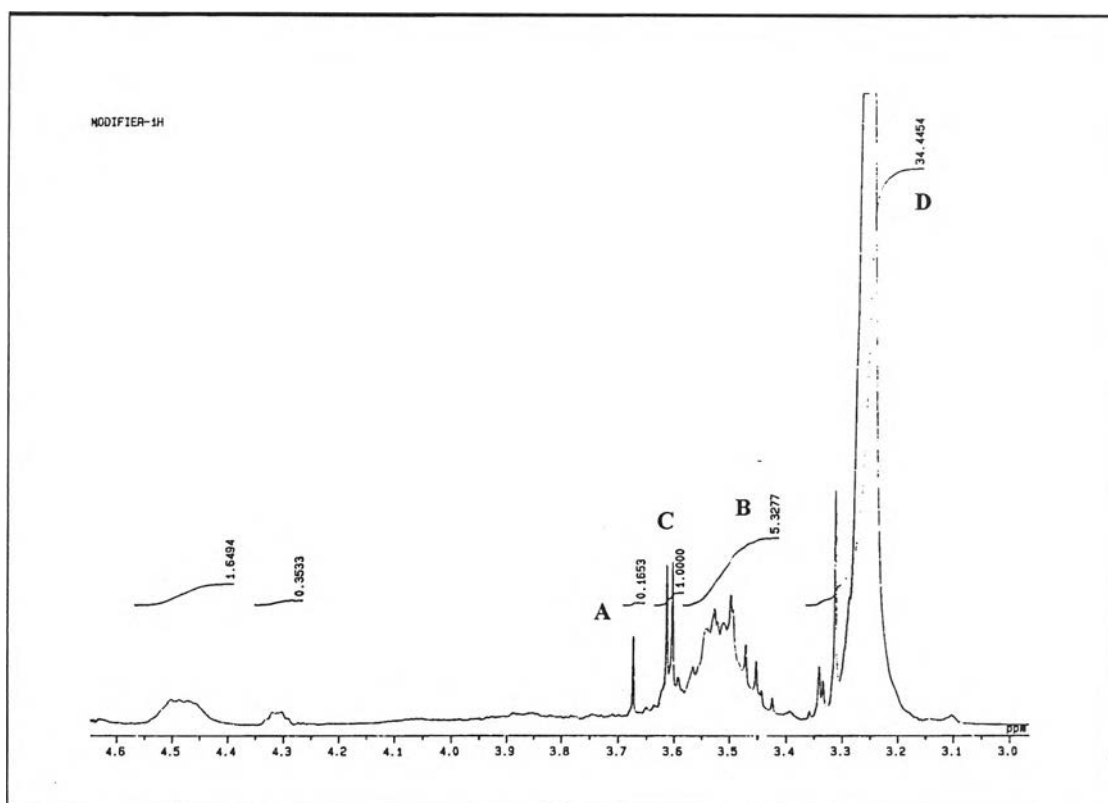


Figure 4.8 ^1H NMR spectrum of modifying agent: 3-amino-2-hydroxyl-propyltrimethylammonium(3,5)-dichlorotriazine using D_2O as solvent.

Table 4.3 Chemical shifts of modifying agent:3-amino-2-hydroxyl-propyltrimethyl ammonium(3,5)-dichlorotriazine

| Compound | Chemical shift (δ) (ppm.) | Assignments |
|----------|---------------------------------------|-------------|
| | 3.68 | A |
| | 3.45-3.55 | B |
| | 3.62 | C |
| | 3.2-3.3 | D |

4.3 Effect of the modifying agent concentration on whiteness property

Table 4.4 and Figure 4.9 show whiteness index which obtained from the modifying agent on bleaching single-bath treatment. The whiteness index of conventional bleached fabric was the highest value. In the presence of modifying agent, the white appearance of bleached fabrics kept to gradually decrease with an increase in concentration of modifying agent. Because the residual solution of modifying agent that presented pale yellowish color of modifying agent also consumed H_2O_2 during consequent bleaching, reducing the bleaching effect on whiteness, However, at the highest concentration of modifying agent applied (40 g/l), a slight decrease in whiteness index is observed, suggesting that the addition of modifying agent to bleaching process did not greatly affect the performance of bleaching agent.

Table 4.4 Whiteness index of modified bleached cotton fabric at various modifying concentrations

| Concentrations of Modifying agent | Whiteness index |
|-----------------------------------|-----------------|
| Scoured Fabric | 52.013 |
| Conventional Bleach | 78.443 |
| 10 g/l Modifier | 71.512 |
| 20 g/l Modifier | 67.368 |
| 30 g/l Modifier | 62.006 |
| 40 g/l Modifier | 58.678 |

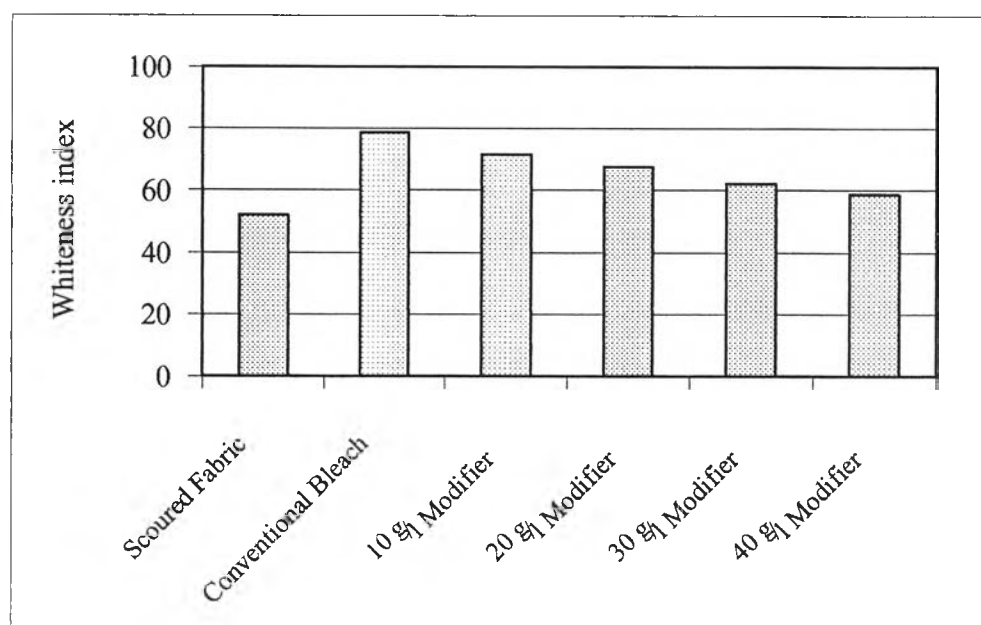


Figure 4.9 Whiteness index chart of modified bleached cotton fabric

4.4 Total nitrogen content determination

Total nitrogen content of modified cotton was measured in order to evaluate the extent of modifying agent fixation and the results are shown in table 4.5

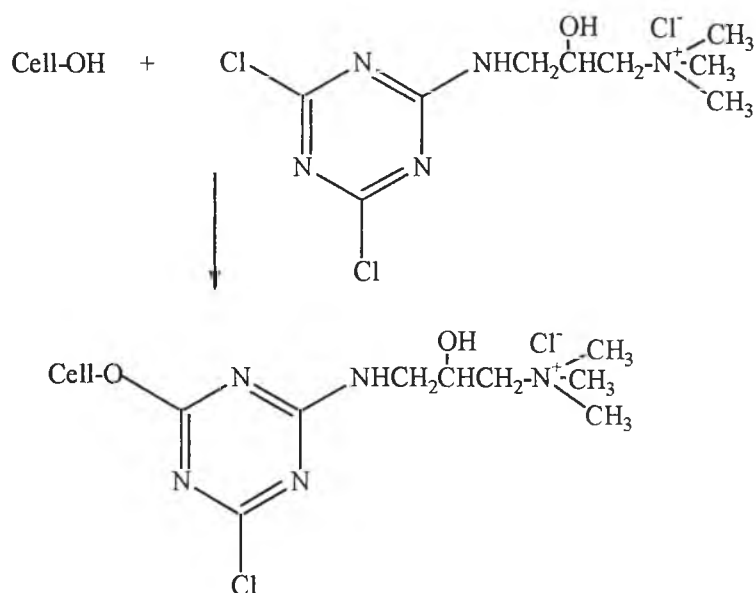
Table 4.5 Total nitrogen content of modifying agent on cotton fabric after H₂O₂/NaOH

| Concentration of modifying agent (g/l) | Total nitrogen content before adding H ₂ O ₂ /NaOH | Total nitrogen content after adding H ₂ O ₂ /NaOH |
|--|--|---|
| 10 | 0.149 | 0.117 |
| 20 | 0.155 | 0.127 |
| 30 | 0.169 | 0.142 |
| 40 | 0.196 | 0.168 |

The build-up of positive charges on fiber surface was likely to be the main influence causing no further absorption of the modifying agent. It was thought that once NaOH being added, absorption of cationic modifying agent should increase further due to the generation of cellulosate anions.

The total nitrogen content of H₂O₂/NaOH treated fabric increases with an increase in the concentration of modifying agent. Compared to the corresponding value obtained before H₂O₂/NaOH addition, however, the latter value was found to be lower. It was probable that some of absorbed modifying agent was subjected to alkaline hydrolysis during bleaching, leading to the reduction in the total nitrogen content. Hence, the presence of total nitrogen content indicated that the quaternary ammonium groups were incorporated. The increase in total nitrogen content implies the presence of higher amount of anionic dye sites that should mean higher capability of dye uptake.

The reaction of modifying agent, 3-amino-2-hydroxyl-propyltrimmonium-dichlorotriazine, onto cellulose may be represented as follows:



From these results, it may be said that bleaching performance obtained from this system such as whiteness, absorbency and removal of mote could meet the bleaching standard required. In addition, cationic groups were also concurrently incorporated into cellulose backbone during bleaching process.

4.5 Effect of increasing concentration of modifying agent on dye uptake and dye fixation

The dyeing of modified cotton fabric in the absence of salt was investigated. Cotton fabrics modified with various concentrations of modifying agent were dyed with 2% owf Procion Crimson CX-B at 80°C for 40 min in the presence of 20 g/L Na₂CO₃. The dye exhaustion and color yield values of resulting dyed fabrics are shown in Table 4.6 and Figure 4.10.

Table 4.6 Color yield, % dye exhaustion and % fixation of modified fabrics at various modifying concentrations

| Concentration of modifying agent (g/l) | K/S | | % Exhaustion | % Fixation |
|--|----------------|---------------|--------------|------------|
| | Before soaping | After soaping | | |
| Conventional bleach | 5.569 | 4.433 | 43.040 | 34.260 |
| 10 g/l Modifier | 7.757 | 6.571 | 56.120 | 47.540 |
| 20 g/l Modifier | 7.931 | 6.404 | 63.140 | 50.983 |
| 30 g/l Modifier | 7.742 | 6.760 | 60.760 | 53.053 |
| 40 g/l Modifier | 8.691 | 7.636 | 65.350 | 57.417 |

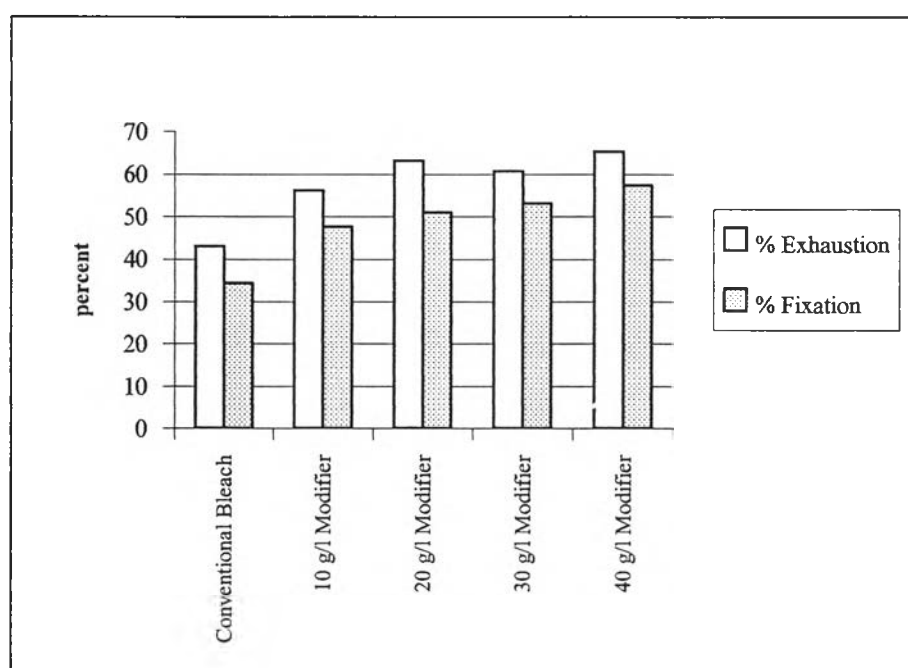


Figure 4.10 Chart of the exhaust dyeing of modified cotton

The result obtained from the control cotton fabric (conventional bleach) demonstrates that the percent dye exhaustion and color strength were quite low due to the repulsive interaction between anionic dye and negatively charged fiber surface. Hence, in order to achieve high dyeability without requirement of salt, it is essential to modify cotton fabric by incorporating cationic sites into cellulose backbone. After being modified, the dye exhaustion and color strength of dyed modified fabric show

marked increase with an increase in the concentration of modifying agent . An enhanced dyeability property of modified cotton fabrics was attributed to the presence of cationic groups that have a large electrostatic affinity with anionic dyes. As a result, the degree of dye exhaustion as well as color strength was closely dependent on the extent of modifying agent fixation. As can be seen, an increase in modifying agent concentration from 20 g/l to 40 g/l brings about little change in the cationic charges acted as charge barrier to prevent further absorption of modifying agent inside the fiber. In following experiments up to 40 g/l modifying agent was employed since, in practice, higher concentration is not preferable due to the cost of modifying agent itself and possible yellowing of bleached fabrics.

4.6 Effect of different dye types on dye uptake and color yield

Two types of dyes , low substantivity (Procion Red) and high substantivity (Modercion yellow HE4R) were chosen to study the effect of dye types. The results are presented in Table 4.7 Compared with Procion Red, Modercion yellow HE4R exhibited higher exhaustion on control and modified fabric due to its high substantive characteristic towards cotton fiber.

Table 4.7 Color yield, % dye exhaustion and % fixation of modified dyed fabrics at different dye types

| Concentration of modifying agent (g/l) | K/S | | % Exhaustion | | % Fixation | | | |
|---|----------------|---------------|--------------|-------|------------|--------|--------|--------|
| | Before soaping | After soaping | Yellow | Red | Yellow | Red | | |
| Conventional bleach | 4.914 | 5.569 | 3.844 | 4.433 | 49.170 | 43.040 | 38.463 | 34.260 |
| 10 g/l Modifier | 5.565 | 7.757 | 4.692 | 6.571 | 56.670 | 56.120 | 47.780 | 47.540 |
| 20 g/l Modifier | 7.153 | 7.931 | 5.476 | 6.404 | 63.330 | 63.140 | 56.393 | 50.983 |
| 30 g/l Modifier | 6.425 | 7.742 | 5.687 | 6.760 | 66.670 | 60.760 | 59.012 | 53.053 |
| 40 g/l Modifier | 6.727 | 8.691 | 6.045 | 7.636 | 70.830 | 65.350 | 63.649 | 57.417 |

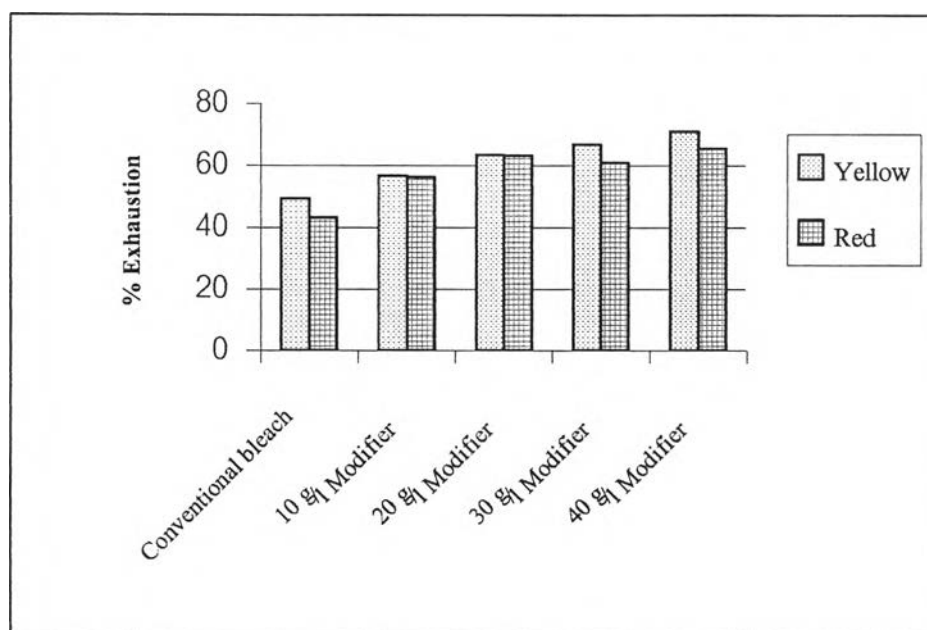


Figure 4.11 Chart of the exhaust dyeing of modified cotton at 2% owf dye concentration at different dye types.

4.7 Effect of increasing dye concentration on dye uptake and color strength

Cotton fabrics modified with various concentrations of modifying agent in bleaching process were dyed with 1, 2, 3 and 4% owf Procion Crimson CX-B and Modercion yellow HE4R at 80°C for 40 min in the presence of 20 g/l Na₂CO₃. The dye exhaustion values and color strength of resulting dyed fabrics are shown in Table 4.8. The degree of dye fixation (%F) and total dye fixation (%T) are shown in Table 4.9.

Table 4.8 Effect of increasing dye concentration on dyeing properties of modified fabric

| Concentrations of modifying agent (g/l) | | Dye concentrations | | | | | | | |
|---|--------|--------------------|--------|--------|--------|--------|--------|--------|--------|
| | | 1% owf | | 2% owf | | 3% owf | | 4% owf | |
| | | K/S | %E | K/S | %E | K/S | %E | K/S | %E |
| Control | Yellow | 2.332 | 55.560 | 3.844 | 49.170 | 4.585 | 51.340 | 5.997 | 49.580 |
| | Red | 2.890 | 59.650 | 4.433 | 43.040 | 6.754 | 35.290 | 6.424 | 35.730 |
| 10 | Yellow | 2.781 | 65.080 | 4.692 | 56.670 | 5.842 | 53.480 | 6.614 | 50.000 |
| | Red | 3.515 | 58.250 | 6.571 | 56.120 | 7.665 | 52.520 | 7.504 | 44.290 |
| 20 | Yellow | 3.173 | 76.190 | 5.479 | 63.330 | 6.648 | 62.030 | 7.919 | 55.930 |
| | Red | 3.888 | 62.140 | 6.404 | 63.140 | 8.774 | 52.810 | 8.253 | 48.720 |
| 30 | Yellow | 3.552 | 76.190 | 5.687 | 66.670 | 7.074 | 62.030 | 8.077 | 57.630 |
| | Red | 3.998 | 67.960 | 6.760 | 60.760 | 9.081 | 55.490 | 8.727 | 48.720 |
| 40 | Yellow | 3.713 | 79.370 | 6.045 | 70.830 | 7.334 | 62.030 | 8.873 | 58.900 |
| | Red | 4.438 | 67.960 | 7.636 | 65.350 | 9.487 | 56.970 | 10.098 | 48.950 |

Table 4.9 Effect of increasing dye concentration on degree of dye fixation(%F) and total dye fixation(%T) of modified fabric

| Concentrations of modifying agent (g/l) | | Dye concentrations | | | | | | | |
|---|--------|--------------------|--------|--------|--------|--------|--------|--------|--------|
| | | 1% owf | | 2% owf | | 3% owf | | 4% owf | |
| | | %F | %T | %F | %T | %F | %T | %F | %T |
| Control | Yellow | 81.481 | 45.271 | 78.225 | 38.463 | 76.826 | 39.443 | 81.536 | 40.426 |
| | Red | 84.627 | 50.480 | 79.601 | 34.260 | 86.170 | 30.409 | 88.084 | 31.473 |
| 10 | Yellow | 85.517 | 55.654 | 84.313 | 47.780 | 84.826 | 45.365 | 85.221 | 42.610 |
| | Red | 86.110 | 50.159 | 84.711 | 47.540 | 85.499 | 44.904 | 84.695 | 37.512 |
| 20 | Yellow | 91.152 | 69.449 | 89.046 | 56.393 | 86.789 | 53.835 | 86.860 | 48.581 |
| | Red | 89.730 | 55.758 | 80.746 | 50.983 | 87.417 | 46.165 | 84.664 | 41.248 |
| 30 | Yellow | 93.696 | 71.387 | 88.514 | 59.012 | 87.420 | 54.226 | 90.397 | 52.096 |
| | Red | 89.441 | 60.784 | 87.316 | 53.053 | 87.858 | 48.752 | 85.794 | 41.799 |
| 40 | Yellow | 95.108 | 75.487 | 89.862 | 63.649 | 88.266 | 54.751 | 90.800 | 53.481 |
| | Red | 91.354 | 62.084 | 87.861 | 57.417 | 92.701 | 52.812 | 88.285 | 43.215 |

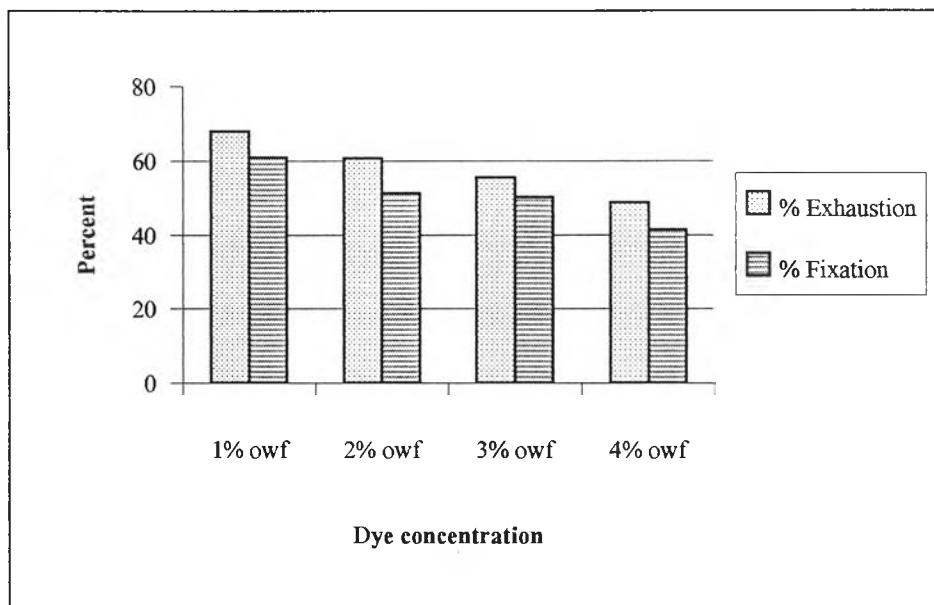


Figure 4.12 Percent exhaustion and percent fixation of dyed modified fabric (30 g/l modifying agent) at using Procion Crimson CX-B

From the results of dye exhaustion and the degree of dye fixation, it can be seen that the trend of dye uptake onto the fiber as well as the degree of dye fixation gradually decreases when the dye concentration increases. These results reflect the buildup of fixed dye onto cellulose retards the further absorption of dye molecule from dyebath due to the effect of negative repulsion.

In all cases of modifying agent concentrations, trends of percent dye exhaustion is gradually reduced as the concentration of dye increases. Differently, color strength increases with an increase in dye concentration and reached the optimum value, and then further increase in dye concentration resulted in little change in color strength. It is believed that dye exhaustion was controlled by ionic-ionic interaction, hence the amount of absorbed dye was closely dependent on the amount of cationic sites inside the fiber. Once the cationic sites were fully occupied no further dye exhaustion took place. This type of dye absorption was suited well with Langmuir absorption isotherm. These results obtained were found to contradict those obtained

from conventional reactive dyeing where increased dye concentration always results in a gradual increase in color strength. Therefore, dyeing of cationic cotton may offer an advantage in terms of reproducibility when compared to conventional dyeing since depth of color shade is not so sensitive to a small variation of changes in dyebath concentration. The build-up of positive charge on fiber surface was likely to be the main influence causing no further absorption of the modifying agent above the concentration of 30g/l. This phenomenon was found similarly with the dyeing of cellulose with cationic reactive dye.

4.8 Evaluation of color fastness to light

This study was to investigate the influence of the presence of cationic groups on the light fastness property of dyed cationic fabric. The dye fabrics were tested for the resistance of the color to the action of daylight, according to NO. ISO method by using Xenon Weather Meter (as seen in Figure 3.8) Model X75 (Suga Test Instruments Co., LTD, Japan). The degree of dye fading was assessed using standard blue wool scales. The results are shown in Table 4.10

Table 4.10 Light fastness of dyed cotton fabrics modified with various concentrations of modifying agent

| Concentrations of modifying agents | Light Fastness | | | | | | | |
|--|----------------|--------|--------|--------|--------|--------|--------|--------|
| | 1% owf | | 2% owf | | 3% owf | | 4% owf | |
| | Red | Yellow | Red | Yellow | Red | Yellow | Red | Yellow |
| 0 | 2 | 6 | 2 | 6 | 2 | 6 | 2 | 6 |
| 10 | 2-3 | 5 | 2-3 | 5 | 3-4 | 6 | 3-4 | 6 |
| 20 | 2-3 | 5 | 2-3 | 5 | 3-4 | 6 | 3-4 | 6 |
| 30 | 2-3 | 5 | 2-3 | 5 | 3-4 | 6 | 3-4 | 6 |
| 40 | 2-3 | 5 | 3 | 5 | 3-4 | 6 | 3-4 | 6 |

Table 4.10 shows that, light fastness rating of dyed fabrics with Procion Crimson CX-B decreased with an increase in the amount of the modifying agent applied. This indicated that the presence of cationic groups caused the reduction in fastness to light. Partly, the cationic group is known as photocatalyst that might accelerate the rate of dye decomposition. Another possibility was that the cationic modifying agent tended to locate on the yarn surface, resulting in consequent surface dyeing. Therefore, the surface dye was prone to photo-degradation when compared to conventional dyeing as for Modercion yellow, the light fastness rating property is not decreased with an increase in the concentration of modifying agent. Probably, this dye may contain the nitro group which is known as photodeactivating group, hence preventing the dye chromophore from photodegradation. It is recommended that the cationic groups should be removed at the end of dyeing process in order to improve fastness to light.

4.9 Microscopic analysis of cross-section of dyed yarn

Microscopic analysis of the cross-section of modifying agent treated yarns dyed with 2% owf Procion Crimson CX-B and Modercion yellow HE4R are shown in figure 4.13 and 4.14, respectively. The distribution of dye on treated yarn indicated the distribution of modifying agent across the treated yarn which the distribution of modifying agent across the treated yarn is desirable in order to obtain good dyeing properties including even dyeing and light fastness.

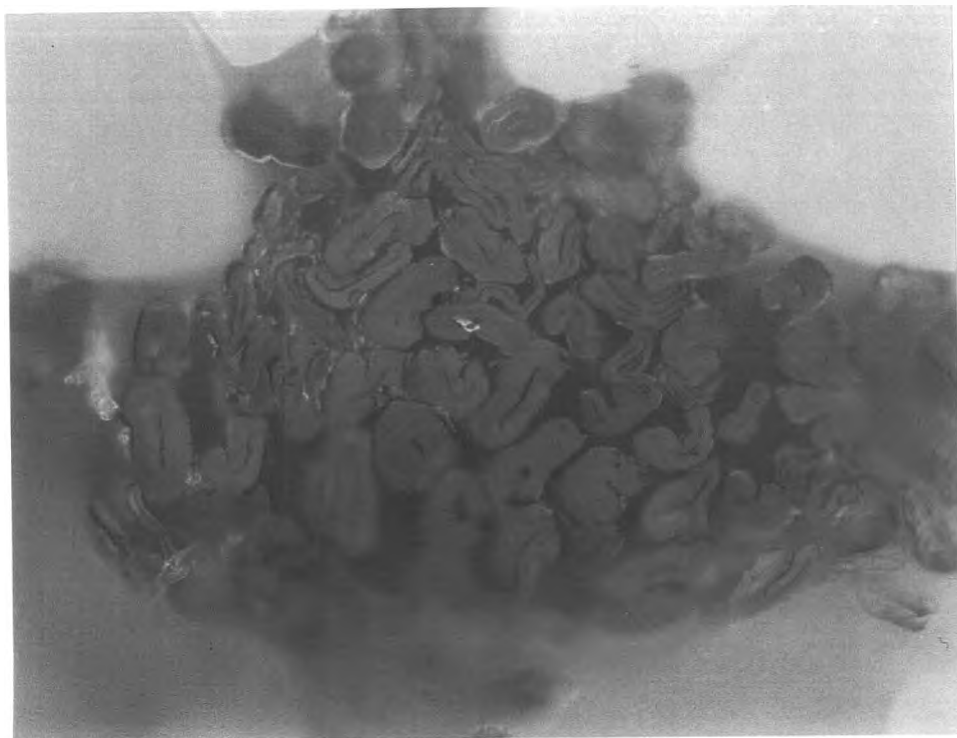


Figure 4.13 Optical micrograph of modifying agent treated yarn dyed with 2% owf
Procion Crimson CX-B

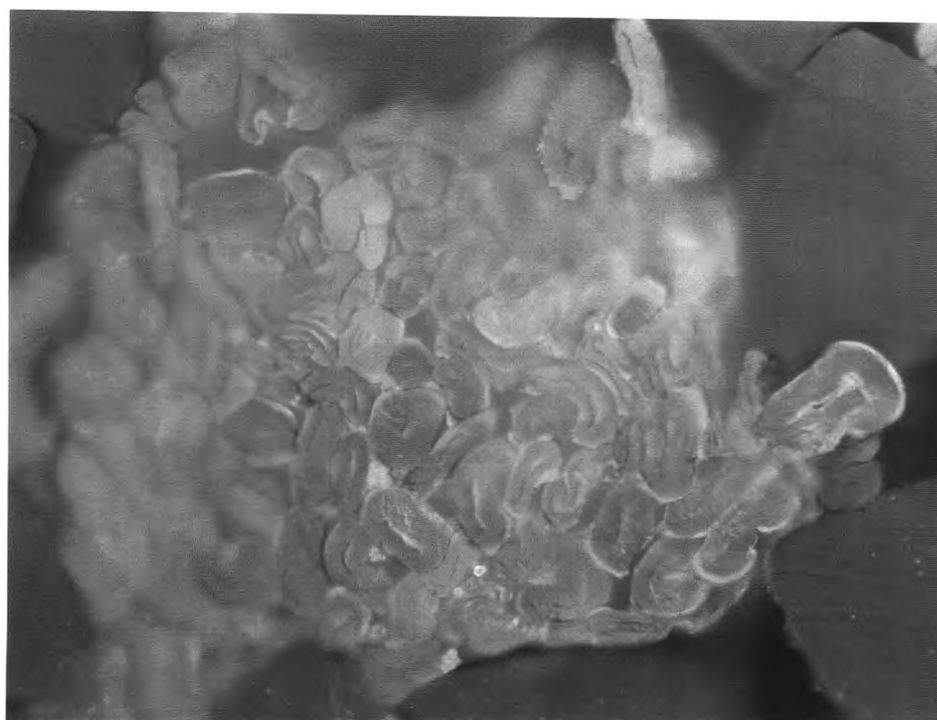


Figure 4.14 Optical micrograph of modifying agent treated yarn dyed with 2% owf
Modercion yellow HE4R

From the figure, individual fibers on the yarn surface and in the inner of yarn exhibited even distribution of dyes, indicating the good migration property of modifying agent that was cationic reactive compounds. Since this compound carries a cationic group, the substantivity towards cotton fiber should be high enough to force the modifying agent to diffuse into the inner of the fiber.

4.10 Dyeing of unmodified cotton fabric

Dyeings of unmodified cotton fabrics using different concentrations of commercial Procion Crimson CX-B and Modercion yellow HE4R (1%, 2%, 3%, and 4% owf) were conducted in similar manner to the dyeing of modified fabrics except various amount of electrolyte (NaCl 0, 10, 20, 30, 40 g/l) were added into the dye solution at the temperature of 50°C for 10 min. Dyeing properties of resulting fabrics are shown in Table 4.11, Table 4.12, and Table 4.13, respectively.

Table 4.11 Color yield, and % dye exhaustion of unmodified fabrics dyed with various concentrations of electrolyte

| Concentrations of electrolyte (g/l) | Dye concentrations | | | | | | | | |
|---|--------------------|-------|--------|--------|--------|--------|--------|--------|--------|
| | 1% owf | | 2% owf | | 3% owf | | 4% owf | | |
| | K/S | %E | K/S | %E | K/S | %E | K/S | %E | |
| 0 | Yellow | 2.646 | 60.320 | 4.231 | 46.430 | 5.459 | 51.720 | 6.309 | 38.790 |
| | Red | 3.888 | 54.620 | 5.797 | 50.630 | 6.759 | 42.450 | 8.147 | 34.700 |
| 10 | Yellow | 3.286 | 76.190 | 5.671 | 63.390 | 6.695 | 65.520 | 8.092 | 54.310 |
| | Red | 5.143 | 66.920 | 8.202 | 64.140 | 9.240 | 55.030 | 11.757 | 50.910 |
| 20 | Yellow | 3.729 | 77.770 | 6.321 | 75.000 | 8.242 | 73.560 | 9.633 | 64.220 |
| | Red | 5.964 | 76.920 | 9.211 | 74.260 | 11.298 | 65.720 | 14.086 | 60.050 |
| 30 | Yellow | 3.887 | 82.540 | 6.828 | 83.040 | 9.230 | 80.460 | 10.723 | 70.690 |
| | Red | 6.637 | 80.770 | 10.166 | 81.010 | 12.338 | 73.580 | 15.712 | 67.350 |
| 40 | Yellow | 4.138 | 84.130 | 7.400 | 86.610 | 10.362 | 81.610 | 11.641 | 75.430 |
| | Red | 6.717 | 83.850 | 10.462 | 84.390 | 13.176 | 77.040 | 16.460 | 73.970 |

Table 4.12 The degree of dye fixation(%F) and total dye fixation(%T) of unmodified fabrics dyed with various concentrations of electrolyte

| Concentrations of electrolyte (g/l) | | Dye concentrations | | | | | | | |
|---|--------|--------------------|--------|--------|--------|--------|--------|--------|--------|
| | | 1% owf | | 2% owf | | 3% owf | | 4% owf | |
| | | %F | %T | %F | %T | %F | %T | %F | %T |
| 0 | Yellow | 81.215 | 48.989 | 85.544 | 39.718 | 77.886 | 40.282 | 86.036 | 33.373 |
| | Red | 86.573 | 47.286 | 81.763 | 41.397 | 83.900 | 35.616 | 88.161 | 30.592 |
| 10 | Yellow | 80.264 | 61.153 | 90.548 | 57.398 | 80.945 | 53.035 | 87.434 | 47.485 |
| | Red | 86.919 | 58.166 | 87.098 | 55.865 | 87.733 | 48.279 | 89.680 | 45.656 |
| 20 | Yellow | 85.040 | 66.136 | 90.897 | 68.173 | 86.959 | 63.967 | 88.669 | 56.943 |
| | Red | 90.749 | 69.804 | 87.682 | 65.113 | 89.888 | 59.074 | 96.275 | 57.813 |
| 30 | Yellow | 83.358 | 68.804 | 90.222 | 74.920 | 89.577 | 72.074 | 90.489 | 63.967 |
| | Red | 91.874 | 74.207 | 90.284 | 73.139 | 90.968 | 66.934 | 96.057 | 64.694 |
| 40 | Yellow | 91.125 | 76.664 | 94.028 | 81.438 | 87.332 | 71.272 | 91.907 | 69.326 |
| | Red | 91.177 | 76.452 | 93.228 | 78.675 | 93.387 | 71.945 | 96.145 | 71.118 |

Table 4.13 Light fastness of unmodified cotton fabrics dyed with various concentrations of dyes and electrolyte

| Concentrations of electrolyte | | Light Fastness | | | | | | | |
|----------------------------------|--|----------------|--------|--------|--------|--------|--------|--------|--------|
| | | 1% owf | | 2% owf | | 3% owf | | 4% owf | |
| | | Red | Yellow | Red | Yellow | Red | Yellow | Red | Yellow |
| 0 | | 2 | 6 | 2 | 5-6 | 2 | 5-6 | 2 | 5-6 |
| 10 | | 3-4 | 6 | 3-4 | 6 | 4 | 6 | 4 | 6 |
| 20 | | 3-4 | 6 | 4 | 6 | 4 | 6 | 4 | 6 |
| 30 | | 4 | 6 | 4 | 6 | 5 | 6 | 5 | 6 |
| 40 | | 4 | 6 | 4 | 6 | 5 | 6 | 5 | 6 |

As can be seen from Table 4.13, light fastness of dyed unmodified cotton fabrics increases with an increase in concentration of salt. Yellow dye exhibits the higher light fastness values than the red dye. It can be concluded that the presence of salt promotes the deeper penetration of dye molecules to the inner of fiber yarn, hence avoiding the direct exposure to light. As a result, red dye's light fastness of conventional dyeing is still greater compared to cationic cotton fiber but yellow dye's light fastness is not change when compared to cationic cotton fiber.