

One-Bath Dyeing and Finishing by Using Exhaustion and Pad-Dry-Cure Methods on Cotton Fabrics Using Mangosteen Rind Dye and Glyoxal

Siriwan Kittinaovarat

Department of Materials Science, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.

ABSTRACT: The present study was taken up as an exploratory study to test the possibility of using one-bath dyeing and finishing (ODF) with Mangosteen Rind dye and glyoxal by the exhaustion and pad-dry-cure techniques. Both ODF techniques provided a darker shade on the dyed fabric than fabric dyed and finished using a two-bath conventional process or fabric dyed with Mangosteen Rind dye only. The ODF exhaustion method would not produce a good wrinkle recovery angles property on the dyed fabric. To improve this property of the dyed fabric in an ODF process the pad-dry-cure technique should be used. Wash fastness results of the dyed fabrics obtained from the ODF pad-dry-cure process were comparable with those of the fabric dyed with Mangosteen Rind dye only. Wash fastness results of the dyed fabrics obtained from the ODF exhaustion method were slightly worse than those of the fabric dyed with Mangosteen Rind dye only. In addition, wash fastness results of the dyed fabrics in both ODF processes were slightly better than those obtained from the conventional two-bath process. Light fastness results of the finished fabric in both ODF processes were slightly better than that of the fabric dyed with only Mangosteen Rind dye and were comparable with those obtained from the conventional two-bath process.

Key words: natural dyes, glyoxal, Mangosteen Rind, one-bath dyeing and finishing

INTRODUCTION

Normally, a fabric used for apparel needs to be dyed first and finished later. The concept of one-bath dyeing and finishing (ODF) is to combine the two steps of dyeing and finishing. The ODF process has been studied using cotton fabrics dyed with reactive and direct dyes.⁽¹⁻³⁾ The advantages of the ODF process are reduced energy and water consumption and time of operation. This study was to investigate the possibility of using the ODF process to dye with a natural dye from Mangosteen Rind and to finish with glyoxal as a crosslinking agent with aluminum sulfate as a catalyst on cotton fabric. This was the first time a study of the ODF technique with natural dye was conducted. Glyoxal⁽⁴⁾ is a nonformaldehyde reagent and readily available.

The crosslink formation in cotton by glyoxal is through hemiacetal or acetal formation. The chemical structure of Mangosteen Rind contains hydroxyl groups that can react with cotton or with glyoxal to form hydrogen bonding. Therefore, the hypothesis

of this study was that the ODF process could improve the depth of shade on cotton fabric dyed and finished with Mangosteen Rind dye and glyoxal. The fastness properties, depth of shade and wrinkle recovery angles of cotton fabrics dyed with the ODF processes of exhaustion and pad-dry-cure were tested in this study as well.

MATERIALS AND METHODS

Materials

Desized, scoured, and bleached plain weave cotton woven fabric was used for this study and was purchased from BekerTex Co., Ltd. The fabric count in the area of 2.5 cm² was 65x60, and the fabric weight was 4.04 oz/yd² as measured by the researcher. Mangosteen rind was dried and ground in a grinding mill and passed through a number 35 mesh. Glyoxal in a 40% aqueous solution and aluminum sulfate were purchased from A.C.S. Xenon Limited Partnership in Bangkok, Thailand. All chemicals were laboratory reagent grade.

Correspondence to: e-mail: ksiriwan@sc.chula.ac.th

Extract preparation of Mangosteen Rind dye

Aqueous extracts were prepared by adding 10 g of Mangosteen Rind powder to 1,000 ml tap water in a flask. This was stirred, heated and held at boil for 30 min then allowed to stand overnight at room temperature and finally filtered. This filtrate was used in the ODF processes throughout this study.

ODF exhaustion process

The ODF exhaustion method was carried out in an AHIBA NUANCE dyeing machine. Five g of cotton fabric was dyed and finished at a liquor ratio of 20:1. The researcher studied six different scenarios of dyeing and finishing the cotton fabrics by the ODF exhaustion method in the preliminary study. These involved various combinations of holding times, temperatures and times of introduction of glyoxal. The results of the preliminary study found that the best depth of shade on dyed fabrics occurred when using the process as shown in Figure 1 below. The dye bath started with dye filtrate and aluminum sulfate as a catalyst at 40°C for 5 min. The temperature of the dye bath was raised to 100°C at the rate of 2°C/min and maintained at this temperature for 30 min. Then glyoxal as a crosslinking agent was added in the dye bath and left to stand for another 30 min. After that, the temperature of dye bath was reduced to 60°C. The dyed fabric was rinsed with tap water, and soaped at a liquor ratio of 30:1 with sodium carbonate 0.5 g/l at 60°C for 5 min. Finally, the dyed fabric was washed with tap water, squeezed and re-dried in the oven. The dyed fabric was kept in the standard condition of 21°C and 65% relative humidity for 24 hours for testing wrinkle recovery angles. The dyed fabric was kept in ambient conditions for 24 hours for testing depth of shade. The conventional dyeing method is to dye cotton fabric at 100°C for 60 min without adding any glyoxal and catalyst. The soaping process is done the same way as in the ODF process.

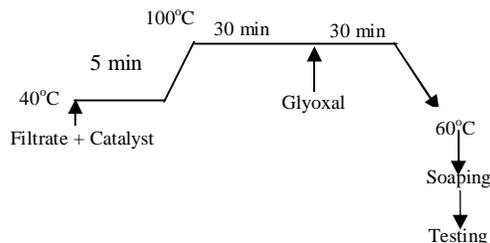


Figure 1. Diagram of ODF exhaustion process.

ODF pad-dry-cure process

The cotton fabric was impregnated in an aqueous bath containing 1,000 ml. of dye filtrate, glyoxal and aluminum sulfate catalyst. Glyoxal was used at 6 g/l constantly. Three different concentrations at 0.5, 1.0, 2.0 g/l of aluminum sulfate catalyst were

studied. The fabric was immersed in the aqueous solution for 10 min and padded to give a wet pick-up of 80-90%, mounted on a pin frame, and predried at 100°C for 5 min. The predried mounted fabric was removed from the oven, the temperature was raised to curing temperature of 150°C and the fabric was returned to the oven for curing for 3 min. After curing, the finished fabric was removed from the frame and rinsed in running tap water for 10 min, and soaped with sodium carbonate 0.5 g/l at 60°C for 5 min at a liquor ratio of 30:1. The washed fabric was remounted on the frame and redried in the oven at 100°C for 5 min. The finished fabrics were kept in ambient condition for 24 hours before conducting the evaluation tests.

Conventional two-bath process

Five g of cotton fabric was dyed with Mangosteen Rind dye only at a liquor ratio of 20:1. The dye bath contained dye filtrate only and the bath temperature was 40°C for 5 min. The temperature of dye bath was raised to 100°C at the rate of 2°C/min and maintained at this temperature for 60 min. After that, the temperature of dye bath was dropped to 60°C. The dyed fabric was rinsed with tap water and soaped at a liquor ratio of 30:1 with sodium carbonate 0.5 g/l at 60°C for 5 min. The dyed fabric was washed with tap water, squeezed and re-dried in the oven. After that the dyed fabric was taken to finish with glyoxal. The finishing formulations used in this step were 6 g/l of glyoxal and three different concentrations 0.5, 1.0, 2.0 g/l of aluminum sulfate catalyst. The fabric was immersed in the aqueous solution for 10 min and padded to give a wet pick-up of 80-90%, mounted on a pin frame, and predried at 100°C for 5 min. The predried mounted fabric was removed from the oven, the temperature was raised to the curing temperature of 150°C and the fabric was returned to the oven for curing for 3 min. After curing, the finished fabric was removed from the frame and rinsed in running tap water for 10 min and re-dried in the oven at 100°C for 5 min. The dyed and finished fabrics from the two-bath process were kept in ambient condition for 24 hours and ready for testing.

Fabric evaluation

Wrinkle recovery angle evaluation

Dry wrinkle recovery angle (DWRA) of the finished cotton fabric was evaluated by using the Standard method AATCC 66-1990 Wrinkle recovery of woven fabrics: recovery angle.

Color measurement

Color values were evaluated by means of K/S and CIE L*, a*, b* color difference values (illuminant D₆₅/10° observer) on Macbeth Color-eye 7000 Spectrophotometer.

Fastness determination

Wash fastness tests were carried out according to the ISO105-CO2:1998 (E) in an AHIBA NUANCE dyeing machine. The changes in color of the tested samples were determined. The changes were related to the standard grey scale (marks 1-5, 1=poor, 5=excellent). Light fastness tests were carried out according to the AATCC Method 16-1998 in M237 light fastness testing. The color change of the samples was assessed against the blue wool reference for light fastness (marks 1-8, 1=poor, 8=excellent).

RESULTS AND DISCUSSION

Depth of shade and wrinkle recovery angles of cotton fabrics dyed and finished with Mangosteen Rind dye and glyoxal by using ODF exhaustion process

A total of 12 formulations were studied: four different glyoxal concentrations of 6, 9, 12 and 15 g/l and three different concentrations of aluminum sulfate catalyst of 0.5, 1 and 2 g/l. The results of depth of shade of dyed fabrics by ODF exhaustion method are shown in the Figure 2.

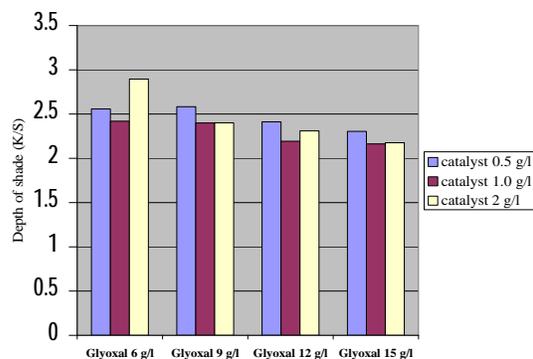


Figure 2. Depth of shade of dyed fabrics by ODF exhaustion process.

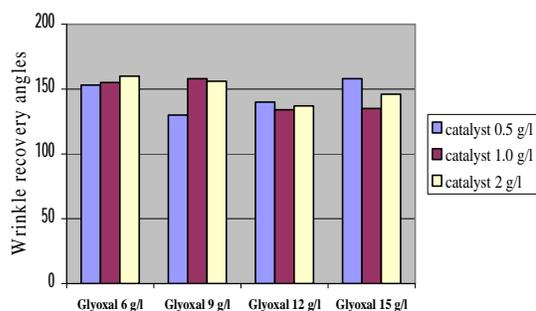


Figure 3. Wrinkle recovery angles of dyed fabrics by ODF exhaustion process.

The results shown in Figure 2 illustrate that increasing glyoxal tended to decrease the depth of shade on dyed fabrics, and the aluminum sulfate catalyst tended to decrease depth of shade except at the concentration of glyoxal 6 g/l. The K/S values of the dyed fabrics obtained from the conditions containing glyoxal and catalyst were higher than the K/S value of the fabric (K/S = 1.016) dyed by conventional process with Mangosteen Rind dye only.

The results of wrinkle recovery angles of dyed fabrics with Mangosteen Rind dye and glyoxal by ODF exhaustion method are shown in Figure 3. The results show that adding glyoxal and aluminum sulfate catalyst did not improve the wrinkle recovery angles on the dyed fabrics. This may be because the temperature of the dyeing bath was not high enough to cause the reaction of crosslinking to occur; therefore, the wrinkle recovery angles of the dyed fabrics were not affected.

Comparison of ODF exhaustion, ODF pad-dry-cure and conventional two-bath processes

The results of the tested properties of wrinkle recovery angles, depth of shade (K/S), and wash and light fastness on the fabrics dyed and finished in ODF process are reported in Table 1. The results in Table 1 were observed in the fabrics dyed and finished by ODF processes in the conditions of glyoxal at 6 g/l and three different concentrations at 0.5, 1.0, 2.0 g/l of aluminum sulfate catalyst. Both ODF exhaustion and ODF pad-dry-cure processes provided better K/S on cotton fabrics than that of fabric dyed with Mangosteen Rind dye only. This was because glyoxal provided more dye-sites for attaching the Mangosteen Rind dye so that the adsorption of dye increased on the fabric obtained from the ODF processes. ODF pad-dry-cure process provided better wrinkle recovery angles than those of ODF exhaustion process. This result indicates that glyoxal would crosslink with cotton more efficiently under the ODF pad-dry-cure method than the other. This may be because the condition of ODF exhaustion process did not provide temperatures high enough to drive the crosslinking reaction of glyoxal and cotton to occur, but only produced more dye-sites to attach more dye to the cotton fabric. The wash fastness results on fabrics obtained from ODF exhaustion process were slightly worse than that of fabric dyed with Mangosteen Rind dye only. But the wash fastness results on fabrics obtained from ODF pad-dry-cure process were comparable with that of fabric dyed with Mangosteen Rind dye only. The light fastness improved one unit on the standard blue wool scale on cotton fabrics dyed and finished by using the ODF exhaustion process, and one and a half units by using the ODF pad-dry-cure process. This may be due to the complex forming ability of glyoxal and Mangosteen Rind dye occurring differently under different methods.

Table 1. Tested properties of cotton fabrics.

Aluminum sulfate catalyst (g/l)	Wrinkle recovery angles (°)	Depth of shade (K/S) at 360 nm	Wash fastness	Light fastness
ODF Exhaustion Process				
0.5	153	2.558	4	3
1	155	2.229	3-4	3
2	160	2.896	3-4	3
ODF Pad-Dry-Cure Process				
0.5	167	1.587	4	3-4
1	171	1.627	4	3-4
2	176	1.588	4-5	3-4
Cotton fabric dyed with Mangosteen Rind dye only				
none	153	1.016	4	2

In the ODF pad-dry-cure process, the cotton fabrics cured at the highest temperature of 150°C still had better K/S values than that of fabric dyed with Mangosteen Rind dye only. Therefore, glyoxal and the catalyst used in the ODF method could be used as an auxiliary to improve dye uptake for natural dye from Mangosteen Rind.

In addition, the tested properties of cotton fabrics dyed and finished with Mangosteen Rind dye and glyoxal by the conventional two-bath process were studied for comparing with the results of tested properties on the cotton fabrics dyed and finished with Mangosteen rind dye and glyoxal by the ODF method. The results of the tested properties of cotton fabrics dyed and finished by the conventional process of two baths are reported in Table 2.

Table 2. Tested Properties of cotton fabrics dyed and finished by conventional process in two-steps.

Aluminum sulfate catalyst (g/l)	Wrinkle recovery angles (°)	Depth of shade (K/S) at 360 nm	Wash fastness	Light fastness
Two-bath process : Cotton fabrics were dyed with Mangosteen Rind dye by exhaustion method and finished with glyoxal by pad-dry-cure method				
0.5	197	0.826	3	3
1	208	0.824	3	3
2	200	0.793	3	3
Cotton fabric dyed with Mangosteen Rind dye only				
none	153	1.016	4	2

The conventional two-bath process provided much better wrinkle recovery angles than that of the ODF processes. This may be due to the glyoxal in the conventional two-bath process performing the function of a crosslinking agent only for the cotton fabric, while the glyoxal in the ODF processes had two functions-increasing dye-sites and acting as a crosslinking agent for the cotton fabric. The results of K/S on fabrics obtained from the conventional two-bath process were lower than that of fabric dyed with only Mangosteen Rind dye. This may be due to the curing temperature of 150°C used in the conventional two-bath process fading the shade of dye on the cotton fabric.

The light fastness results of fabrics obtained from conventional two-bath process were similar to those of fabrics obtained from ODF processes, but had one unit better on the standard blue wool scale than that of fabric dyed with Mangosteen Rind dye only. The wash fastness of fabric obtained from conventional two-bath process had one unit lower than that of fabric dyed with Mangosteen Rind dye only. This may be because the dyed fabric, after finishing with glyoxal, was not neutralized and this may cause a little bit of shade change under alkali soaping condition.

CONCLUSIONS

This study examined the possibility of dyeing and finishing cotton fabrics using Mangosteen Rind dye and glyoxal in one-bath process using both exhaustion and pad-dry-cure methods. The expectation was that the fabric dyed and finished in the one-bath process of both techniques would have a darker shade than that of a fabric dyed with the Mangosteen Rind dye only and that of a fabric dyed and finished with a conventional two-bath process. In addition, the dyed fabric would have durable press property at the same time. The results found that it was possible to use one-bath containing Mangosteen Rind dye and glyoxal to dye the cotton fabric to obtain a darker shade than that of the conventional method. Both ODF methods provided the darker shade on the dyed fabric than that of the fabric dyed and finished with two-bath conventional process or that of the fabric dyed with only Mangosteen Rind dye. ODF exhaustion method did not affect wrinkle recovery angles of the dyed fabrics. The results of wrinkle recovery angles of the tested fabrics from ODF exhaustion method were similar to those of the fabric dyed with only Mangosteen Rind dye. To improve the wrinkle recovery angles property the ODF pad-dry-cure method should be used. Wash fastness results of the dyed fabrics obtained from the ODF pad-dry-cure process compared well with that of the fabric dyed with Mangosteen Rind dye. Wash fastness results of the dyed fabrics obtained from the ODF pad-dry-cure process were similar to that of the fabric dyed with Mangosteen Rind dye. Wash fastness results of the dyed fabrics obtained from the ODF exhaustion methods were slightly worse than that of the dyed fabric dyed with Mangosteen Rind dye only. In addition, wash fastness results of the dyed fabrics in both the ODF processes were slightly better than those obtained from a conventional two-bath process. Light

fastness results of the finished fabric in both the ODF processes were slightly better than that of the fabric dyed with only Mangosteen Rind dye and were comparable with those obtained from conventional two-bath process.

ACKNOWLEDGMENT

The author wishes to thank the National Metal and Materials Technology Center of Thailand (MT-S-47-POL-09-263-G) for financial support of this work. We also thank the Textile Industry Division Bureau of Industrial Sectors Development for providing all equipment used in this study and Ms. Angkhana Amornsri for helping by conducting the dyeing process throughout this study.

REFERENCES

1. Choi, H. M., (2002) "One-Bath Dyeing and Norformaldehyde Durable Press Finishing of Cotton Using Dialdehyde and a Monochlorotriazinyl Reactive Dye" *Textile Research Journal*, **72**(6), 469-476.
2. Dong, Y., Wang, J. and Liu, P., (2001) "Dyeing and Finishing of Cotton Fabric in a Single Bath with Reactive Dyes and Citric Acid" *Coloration Technology*, **117**, 262-265.
3. Raheel, M. and Guo, C., (1998) "Single-Step Dyeing and Formaldehyde-Free Durable Press Finishing of Cotton Fabric" *Textile Research Journal*, **68**(8), 571-577.
4. Welch, C. M. and Danna, G. F., (1982) "Glyoxal as a Non-Nitrogenous Formaldehyde-Free Durable-Press Reagent for Cotton" *Textile Research Journal*, **52**, 149-157.

Received: May 15, 2006

Accepted: July 28, 2006