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Process Optimization for Dyeing Polyester/Viscose Blended Fabric with Annato (*Bixa orellana*) Seeds: An Ecological Dyeing Process

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ABSTRACT: *The blend consisting polyester and viscose is widely used in the textile industry. This type of blend benefits the high strength of polyester fibre and from the natural qualities, brightness and comfortable wearing property of viscose fibre. The properties of the two fibres are different but complementary. In addition, when used together, polyester contributes durability, resiliency, shape retention and improved wet strength and viscose imparts absorbency and soft texture. But the coloration of such blend creates problems because of the differential dyeing affinity of both the fibres. However, some synthetic dyes can be used but the process is very complex and also not friendly to the environment. The global awareness of the adverse effects caused by the use of synthetic dyes on human being and environment has evoked people to practice and promote eco-friendly natural dyes in the world. These dyes are widely looked for due to their biodegradability and low toxicity and can be employed in the dyeing of natural as well as synthetic fibres. Hence, the present research has been made to assess the compatibility of natural dye obtained from Annato (Bixa orellana) seeds with polyester/viscose blend using high temperature high pressure dyeing technique.*

Keyword: *Natural dyes, synthetic dyes, Annato seeds, Polyester/viscose fabric, High-temperature-high-pressure dyeing.*

INTRODUCTION

Blends of polyester with natural and regenerated cellulose have become very popular in apparel usage for the obvious reason of techno-economic consideration including low cost, durability, comfort and aesthetic values of such blended fabrics. Textiles made from blends of polyester and cellulose fibres constitute about 10% of the total consumption of textile materials [1]. Various effects and combinations of properties are produced from these blends depending on the type and percentage of fibres used. The polyester/viscose blends are the most common blends available in this category and have a mass acceptance for various end uses. The properties of the two fibres are different but complementary. Both have the fibre qualities of uniformity, cleanliness, continuity of supply and low price as common to all manmade fibres. The selection of these two fibres ensured sufficient comfort resulting mainly from the use of viscose fibres, as well as suitable mechanical properties such as the tensile strength characteristics of polyester fibre. But the coloration of polyester-viscose blends is a very complex, labor intensive and time consuming process. The reason can be found in the very different dyeing behavior of both fibers. Direct/disperse dye combinations are often used and the dyeing is usually carried out by either in two step or in single step, pre-treating the fibres with solvents and other auxiliaries like dispersing agents, leveling agents, carrier, etc. which cause pollution in the manufacture as well as in their use. There is an increasing realization in the textile industry as well as among the textile consumers to develop and use eco-friendly methods of dyeing textiles. This concern for the environment has once again attracted the attention towards natural dyes, which are eco-friendly as well as safe for human skin and has gained momentum not only for safety but also for the beauty of colors and novelty. Hence, keeping in mind the exceeding popularity and benefits of natural dyes an effort has been made to assess the compatibility of Annato dye with polyester/viscose blend using HTHP dyeing mechanism. Annato is a tropical plant of great agro-industrial interest mainly because of its

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tinctorial value, availability and affordability. Its application for dyeing polyester/viscose blend will help in scaling its marketable value in textile sector too.

MATERIALS AND METHOD

Materials

Fabric

Pure white plain weave polyester/viscose (67/33) blended fabric with 92/66 fabric count and 0.23 mm thickness was used for dyeing experiments.

Natural dye material

The Annato seed powder was used as a dye. Annato seeds (Fig. 1 a) were procured from Hyderabad, India. The seeds were ground to coarse powder (Fig. 1 b) form using crushing bowl.

Figure 1 (a): Annato (Bixa orellana) seed pods

Figure 1 (b): Coarse powder

Method

Preparation of fabric for dyeing

The polyester/viscose (P/V) fabric was soaked in warm detergent solution containing 5 ml liquid non-ionic detergent in 1 litre of water for 1 hour. The fabric was rubbed, kneaded and squeezed in detergent solution from time to time then rinsed with excess tap water to remove traces of detergent completely and dried in shade.

(a) Sample size: Samples of 22 cm x 11 cm dimension were cut from the prepared P/V blended fabric for the dyeing experiments, each sample weighed 2.50g.

(b) Soaking: The fabric sample was soaked in water prior to dyeing for 30 minutes to remove air from it for rapid dye penetration.

Optimization of dyeing parameters

A series of experiments were conducted to determine the optimum values of six dyeing variables, namely pH of extraction liquor, dyeing temperature, dyeing time, amount of raw dye material, dye extraction time, dye extraction temperature. The dyeing operation was accomplished using HTHP beaker dyeing mechanism (Fig. 2). Colorfastness tests were used for the selection of optimum value of dyeing variables except for the selection of pH of extraction liquor which was done on the basis of visual evaluation by a panel of 30 judges. The dyed P/V blended samples were subjected to four colorfastness tests namely; fastness to washing, fastness to rubbing, fastness to perspiration and fastness to light. The experiments for optimization were conducted in the same sequence as given above. In each optimization experiment the value of the other parameter being optimized were varied keeping all other parameters constant. In every next optimization experiment, the optimized value from previous experiment was used.

(a) Selection of pH of extraction liquor: Extraction of color from dye source was carried out by heating 5 g of raw material in 100 ml of distilled water at acidic (pH 5), alkaline (pH 8) and neutral (pH 7) pH at 80°C for 60 minutes in separate beakers of dye bath. Polyester/viscose samples of 2.50 g each were dyed in the filtered dye solutions for 60 minutes at 80°C in HTHP beaker dyeing machine. These samples were then allowed to cool at room temperature, taken out of HTHP machine, rinsed thoroughly in water and drip dried in shade. After drying, visual evaluation of dyed samples was carried out by the panel of 30 judges. The extraction pH was selected on basis of

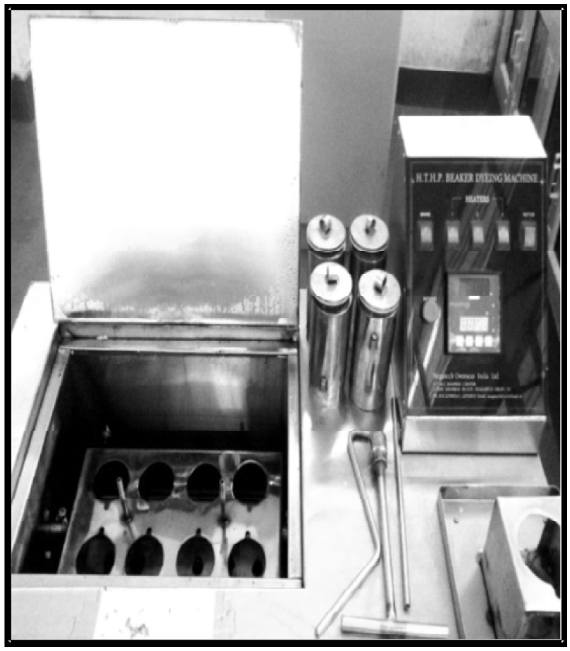

Figure 2: High Temperature High Pressure (HTHP) beaker dyeing machine

weighted mean score (WMS). Sample with highest WMS was selected and condition used for dyeing of that particular sample was taken as optimum for the further experiments.

(b) Optimization of dyeing temperature: Five gram raw material of dye was added in 100 ml of distilled water at selected pH and heated at 60°C in dye bath for 60 minutes. The solution was then filtered and the filtrate was used as dye solutions. Five dye solutions of selected dye prepared in this way were used for dyeing of polyester/viscose samples of 2.50 g each for 45 minutes at 100°C, 110°C, 120°C, 130°C and 140°C respectively in HTHP beaker dyeing machine. Colorfastness tests of the dyed samples were carried out and selection of the optimum dyeing temperature was done based on the colorfastness ratings of the dyed samples. Sample that got the maximum ratings in all the colorfastness tests was selected and conditions used for dyeing of that particular sample were taken as optimum. The diffusion rate of the dye into the polyester fibre increases at elevated temperature [2]. Hence the temperature range was selected between 100°C to 140°C.

(c) Optimization of dyeing time: Four dye solutions for optimization of dyeing time were prepared in the same manner as in case of dyeing temperature. The polyester/viscose samples of 2.50 g each were dyed in these solutions for 30 minutes, 45 minutes, 60 minutes and 75 minutes respectively at optimized temperature in HTHP beaker dyeing machine. Colorfastness tests of the dyed samples were carried out and selection of the optimum dyeing time was done in the same way as dyeing temperature.

(d) Optimization of amount of raw dye material: Five dye solutions were prepared by boiling 1.00 g, 3.00 g, 5.00 g, 7.00 g and 9.00 g of raw dye material in 100 ml of distilled water with selected pH at 80°C for 60 minutes in separate beakers of dye bath. The solutions were cooled and filtered and the filtrate was used as dye solutions. The polyester/viscose samples weighing 2.50 g each were dyed with these solutions in separate beakers of HTHP beaker dyeing machine for optimized dyeing time at optimized dyeing temperature. Colorfastness tests of the dyed samples were carried out and selection of the optimum amount of raw dye material was done in the same way as dyeing temperature.

(e) Optimization of extraction time of dye material: Five dye solutions were prepared by adding optimized amount of raw dye material in 100 ml of distilled water at selected pH and heated for 30 minutes, 45mintes, 60 minutes, 75 minutes and 90 minutes respectively at 80°C. The dye extract obtained in this way were cooled and filtered. The polyester/viscose samples of 2.50 g each were dyed in these solutions for optimized dyeing time at optimized dyeing temperature in HTHP beaker dyeing machine. Colorfastness tests of the dyed samples were carried out and selection of the optimum extraction time was done in the same way as dyeing temperature.

(f) Optimization of extraction temperature of dye material: Four dye solutions were prepared by adding optimized amount of raw dye material in 100 ml of distilled water at selected pH and dye was extracted at 60°C, 70°C, 80°C and 90°C respectively for optimized period of extraction time. The polyester/viscose samples of 2.50 g were dyed in these solutions for optimized dyeing time at optimized dyeing temperature in HTHP beaker dyeing machine. Colorfastness tests of the dyed samples were carried out and selection of the optimum extraction temperature was done in the same way as dyeing temperature.

RESULTS AND DISCUSSION

Details of weighted mean score for selection of extraction pH and the colorfastness ratings for the optimization of each variable namely, dyeing temperature, dyeing time, amount of raw dye material, dye extraction time, dye extraction temperature have been presented in Table 1 and Table 2 respectively.

Selection of pH of extraction liquor

It can be seen from Table 1 that the Annato dyed P/V blended sample obtained highest weighted mean score when the dye was extracted at alkaline pH (8). The extraction of color component from Annato raw dye source was the best in alkaline medium [3].

Table 1
Weighted mean scores (WMS) for visually evaluated P/V samples dyed with Annato dye at different extraction pH

Dye source	*Extraction pH*	*WMS*
Annato dye	Acidic (pH 5)	8.37
	Alkaline (pH 8)*	14.10
	Neutral (pH 7)	8.5

*Selected dye extraction pH

Optimum dyeing temperature

On the basis of overall fastness ratings it was found that the samples dyed with Annato dye at 130°C got the maximum fastness ratings and hence selected as optimum dyeing temperature for further research work. It was observed visually that the depth of shade in the dyed samples was low at both minimum (100°C) and maximum (140°C) temperatures. It has been reported that in a successful process of dyeing polyester fabric with indigo dye, the solubility of indigo dye in the aqueous solution and the amorphous regions of the polyester fabrics increased at a high temperature [4].

Table 2
Optimization of dyeing temperature, dyeing time, amount of raw dye material, dye extraction time, dye extraction temperature of Annato dye on polyester/viscose blended fabric on the basis of colorfastness ratings

Variable	*Washing fastness*			*Rubbing fastness*				*Perspiration fastness*						
Dyeing temp.(°C)	*CC*	*CS*		*Dry*		*Wet*		*Acidic*			*Alkaline*			
		C	*P/V*	*CC*	*CS*	*CC*	*CS*	*CC*	*CS*		*CC*	*CS*		*Light fastness*
									C	*P/V*		*C*	*P/V*	
100	2	2	3	4	3-4	3	3-4	3	1-2	3	4	1-2	3	2-3
110	2	2	3-4	4	3-4	3-4	3-4	3-4	1-2	3	4	1-2	3	2-3
120	2-3	2-3	3-4	4	3-4	4	3-4	3-4	1-2	3	4	1-2	3	2-3
130*	3	3	4	4-5	4	4-5	4	4	1-2	3	4	1-2	3	2-3
140	2	3	4	4-5	4	4	4	3	1-2	3	4	1-2	3	2-3
Dyeing time (minutes)														
30*	4	2-3	3	5	5	5	4	3	2	3	4	2	3	2-3
45	3	2-3	3	4	5	5	3-4	3	2	3	3	2	3	2-3
60	3	2-3	3	3-4	5	4-5	3-4	3	2	3	3	2	3	2-3
75	3	2-3	3	3	5	4	3-4	3	2	3	3	2	3	2-3
Amount of raw dye material (g/100ml)														
1	3	3	3-4	5	5	4	3-4	4	2-3	3	3-4	2-3	3	2-3
3	3	3	3-4	5	5	4	3-4	4	2-3	3	3-4	2-3	3	2-3
5*	3	3	3-4	5	5	5	4	4-5	2-3	3	4	2-3	3	2-3
7	3	3	3-4	5	4	4-5	3-4	4	2-3	3	3-4	2-3	3	2-3
9	3	3	3-4	5	3-4	4	3	4-5	2-3	3	4	2-3	3	2-3
Extraction time (minutes)														
30	2-3	3	4	5	5	4	4	3	2-3	3	3	2-3	3	2-3
45	3	3	4	5	5	4	3-4	3	2-3	3	3	2-3	3	2-3
60	3	3	4	5	4	4	4	4	2-3	3	3-4	3	3	2-3
75*	3-4	3	4	5	5	4-5	4	4	2-3	3	4	2-3	3	2-3
90	2-3	3	4	5	4	4	3	4	2-3	3	4	2-3	3	2-3
Extraction temperature (°C)														
60	3	3	4	4-5	5	4-5	3	3	2	3	3	3	3	2-3
70	3	3	4	4-5	4-5	4-5	3	3-4	2-3	3	3	3	3	2-3
80*	3	3	5	5	5	5	3-4	4	3	3	4	3	3	2-3
90	3	3	4	5	5	5	3-4	3	2	2	4	3	3	2-3

* Selected dyeing variable
CC- Change in color, CS- Color staining, C- Cotton fabric, P/V- Polyester/viscose fabric

Optimum dyeing time

It can be seen from the Table 2 that the samples dyed with Annato dye for 30 minutes, got the maximum overall fastness ratings and hence selected as optimum dyeing time for further research work. Beyond 30 minutes dyeing time the washing, rubbing and alkaline perspiration fastness ratings were slightly decreased however the acidic perspiration and light fastness ratings remained unchanged.

Optimum amount of raw dye material

On the basis of overall good results of fastness for sample dyed with 5 g amount of Annato dye (Table 2), it was selected as optimum for further work. It can be seen from Table 2 that beyond this amount the rubbing fastness ratings were slightly decreased however the other fastness rating remained unchanged with increase in amount of dye material.

Optimum extraction time

On the basis of overall fastness ratings it was found that Annato dyed sample showed better results when dye was extracted for 75 minutes. Hence, 75 minutes extraction time was selected as optimum dye extraction period for further research work. It was observed that beyond this extraction temperature the washing and rubbing fastness ratings were slightly decreased however the perspiration and light fastness ratings remained unchanged.

Optimum extraction temperature

On the basis of overall fastness ratings it was found that the samples dyed with Annato dye extracted at 80°C got the maximum fastness ratings and hence selected as optimum extraction temperatures for further research work. It was found that higher extraction temperatures gave better results and this may be attributed to the reason that at higher temperature more color could be extracted from the dye source.

Table 3
Optimized conditions of dyeing P/V fabric with Annato dye

S.No.	*Dyeing variables*	*Optimized conditions*
1	pH of extraction	Alkaline (pH 8)
2	Dyeing temperature (°C)	130
3	Dyeing time (minutes)	30
4	Amount of dye raw material (g/100ml)	5
5	Extraction time (minutes)	75
6	Extraction temperature (°C)	80

CONCLUSION

It can be concluded that polyester/viscose blended fabric can be effectively dyed with Annato dye using HTHP dyeing technique with moderate fastness properties. Subtle shade of orange color was produced on P/V blended fabric when dyed with Annatto dye. However, it is believed that after mordant treatment different color shades with improved fastness properties can be obtained. Annato is a commercial food coloring agent and its application for coloration of polyester/viscose blended fabric will further enhance its marketable value even in textile industry. The technical and economic advantages of HTHP dyeing system may be seen in shorter dyeing time, improved dye uniformity and partly also in improved dye utilization and in saved carrier cost.

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