

Research Article

Investigation of Dyeing Synthetic Fabrics by Using Bacterial Colorants for More Sustainable Textile Production

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Abstract

Polyester and polyamide fibers are the most commonly used textile fibre globally. For this reason, studies conducted on the production and dyeing of synthetic fabrics, especially polyester fabrics, have a significant environmental impact. In this study, it was aimed to put forward a more sustainable way to dye synthetic fabrics. Even if plant dyes are a good alternative for sustainable dyeing in the absence of synthetic dyestuff, the usage amount of plant dyestuffs is high and consistency is low. Bacterial dyeing can be a good alternative for more sustainable synthetic fabric dyeings due to consistent production and free of petroleum-based dyestuffs.

Within the scope of this study, 100% polyester and %100 polyamide woven fabric were dyed using 3 different receipts with 3 different bio-colors, the most suitable dyeing methods were determined for both polyester and polyamide fabric. Quality control parameters were checked regarding color depth, washing and rubbing fastness. The finding reveal that polyamide fabrics have higher K/S values compared with polyester fabrics while dyeing with the same receipt and the process. pH adjustment and adding salt are necessary to get better result for dyeing pink and brown polyester. Only adding dyestuff to the dyeing bath is enough to dye polyester in the blue color. On polyamide fabrics, the most suitable dye bath includes salt and pH is 4 to dye pink and brown. But for blue color, adding salt and adjusting pH to 4 gives better results in polyamide fabric.

Keywords: Bacterial dyeing, Sustainable dyeing, Microbial dyeing

1. Introduction

The sustainable concept in the textile industry becomes even more important every passing day [1]. According to Textile Exchange Preferred Fiber & Materials Market Report published in 2022, synthetic fiber category made up approximately 64% of the global fiber production in 2021 [2]. Polyester fiber alone accounts for approximately 54% of the global fiber production market share with approximately 60.5 million tonnes of polyester production [2]. These numbers show the importance of developments on sustainable polyester production and dyeing methods.

Sustainable polyester production can be supported by recycling and developing new production methods which cause less pollution [3-4]. However, due to the negative effects of synthetic dyestuffs on the environment and human health, environmentally friendly natural dyestuffs become more important in recent years, especially in the textile sector. Besides plant-based dyestuffs have some disadvantages such as higher costs due to higher usage and low stability when compared with synthetic colorants [5]. But microorganisms produce a wide variety of stable pigments such as carotenoids, flavonoids, quinones and rubramines, and fermentation allows to produce deeper colorants compared to pigments derived from plants and animals [6-7]. *Chromobacterium violaceum*, *Chryseobacterium* sp., *Hahella chejuensis*, *Serratia marcescens*, *Streptomyces*, *Vibrio psychroerythrus* and *Vibrio* spp. can be good examples for bio-color sources [8-9]. There are different studies at the literature related to dyeing textile fabrics with bacterial colorants obtained from fermentation. These studies were carried out at 80-85°C at different pH values [8] [10-11]. Promising results were obtained from the studies.

In this paper, the dyeings of polyester and polyamide fabrics were carried out with different receipts by using three different bacterial-based bio-color. K/S values of dyeings were compared to find the most suitable dyeing technique and fastness values were checked.

2. Materials and Methods

2.1. Materials

100% polyester woven fabric with a weight of 257 g/m² and %100 polyamid woven fabric with a weight of 125 g/m² was used in the study. Three powder and water-soluble bio-colors (blue, pink and brown) were used for dyeing fabrics. Bio-colors were produced by using bacterial fermentation process. Trade names were not disclosed for commercial concerns. But blue bio-color belongs to the indole family group, pink bio-color belongs to the pyrrole family and brown bio-color belongs to the alcoholic carotenoid pigment

family. The bio-colors were free from the bacteria. All microorganisms worked with have Biosafety Level 1. Sodium chloride (NaCl) was used as salt and acetic acid was used for pH adjustment.

2.2. Methods

The fabrics were dyed with bacterial dyestuffs in a TERMAL branded 30-litre capacity water bath. The bath ratio was maintained at 1:20. The dyeing process was carried out for 45 minutes at 85°C. Subsequently, the dyed fabrics rinsed with 20°C cold-water, followed by washing at 60°C for 30 minutes with 0.5 g/l washing soap. Table 1 shows the dyeing receipts.

Table 1. Dyeing receipts of the trials

Receipt no	Substrate	Bio-color	Dye Concentration	pH	Salt
1B-PES	%100 PES Woven Fabric	Blue	10%	-	-
2B-PES				4	-
3B-PES				4	25
1P-PES		Pink	5%	-	-
2P-PES				4	-
3P-PES				4	25
1Br-PES		Brown	5%	-	-
2Br-PES				4	-
3Br-PES				4	25
1B-PA	%100 PA Woven Fabric	Blue	10%	-	-
2B-PA				4	-
3B-PA				4	25
1P-PA		Pink	5%	-	-
2P-PA				4	-
3P-PA				4	25
1Br-PA		Brown	5%	-	-
2Br-PA				4	-
3-Br-PA				4	25

K/S values of dyed fabrics were measured by using Datacolor 1050 model spectrophotometer. Washing fastness and rubbing fastness values were checked according to ISO 105-C06:2012 A2@40°C and ISO 105X12:2006 respectively [12-13].

3. Results

Upon examination of the study results in Table 2, it became apparent that 3P-PES and 3Br-PES receipts (contained 25g/l salt and pH 4), gave the highest K/S values for Pink and Brown bio-color in polyester, while 1B-PES is the most effective receipt for blue bio-color in polyester fabric dyeing.

Table 2. Colorimetric measurement results of the dyeings

Receipt no	L	a	b	c	K/S
1B-PES	81,47	2,04	-6,26	6,58	0,1512
2B-PES	84,43	1,33	-4,37	4,57	0,1227
3B-PES	86,32	1,07	-1,72	1,29	0,1478
1P-PES	88,68	12,15	2,19	12,34	0,1129
2P-PES	88,5	10,55	2,91	10,95	0,1034
3P-PES	86,49	6,52	2,72	7,06	0,1427
1Br-PES	93,57	-0,25	6,08	6,09	0,0988
2Br-PES	87,43	2,17	9,51	9,75	0,2186
3Br-PES	86,61	2,16	9,21	9,46	0,2304
1B-PA	82,49	-0,64	-6,14	6,17	0,1315
2B-PA	78,44	-0,56	-5,3	5,33	0,2664
3B-PA	72,24	-0,11	-11,36	11,36	0,3257
1P-PA	73,91	32,86	-10,21	34,41	0,2025
2P-PA	74,3	28,27	-8,74	29,59	0,2256
3P-PA	75,65	32,19	-7,72	33,1	0,1726
1Br-PA	83,83	3,26	15,94	16,27	0,4986
2Br-PA	66,34	8,83	28,03	29,39	3,2783
3-Br-PA	72,49	7,52	26,47	27,52	1,9984

When polyamide fabric dyeings were examined, 2P-PA and 2Br-PA receipts gave the best results in terms of K/S values to dye pink and brown color respectively. While pH 4 help to obtain darker color, salt reduces dyeing effect. Differently from this, 3B-PA receipt, which includes salt and acid to adjust pH, is recommended to dye polyamide with blue bio-color.

Figure 1 and Figure 2 show the colors of the dyed fabrics. It is clear that polyamide fabrics have deeper color when compared with polyester.



Figure 1. Pictures of the bacterial-dyed polyester fabrics



Figure 2. Pictures of the bacterial-dyed polyamide fabrics

When the fastness values of the fabrics that have highest color depth for each color were checked, color fastness for washing and rubbing fastness values are perfect, except PA staining on washing fastness of 1B-PES receipt (Table 3). Also, color change value of this dyeing is good but the lowest one. It is thought that dyestuff doesn't fix to the fabric surface properly.

Table 3. Fastness values of the dyeing which has the highest color depth

Receipt no	Color Fastness for Washing							Rubbing Fastness	
	Color Change	ISO 105-C06:2010 A2@40°C						ISO 105X12:2006	
		AC	CO	PA	PES	CA	WO	DRY	WET
1B-PES	4	4/5	4	2	4/5	4/5	4/5	4/5	4/5
3P-PES	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
3Br-PES	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
3B-PA	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
2P-PA	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5
2Br-PA	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	3/4

4. Discussion and Conclusion

There are lots of study in the literature that shows plant dyes have acceptable results for both dyeing cellulosic and synthetic materials [14-16]. But since there are limited amount of plant waste, there are not enough source to scale up these studies for large productions [17]. The findings reveal that bacterial colorant can be used for dyeing synthetic fabrics in a sustainable way. Because bacterial colorants are suitable to produce large amounts in bioreactors without using any natural source. Besides bacterial colorants also have successful applications on cellulosic materials [18]. In this way one type of dyestuff can dye most fabrics. For the future studies, it can be study to dye different fabric compositions such as polycotton, modal/pes etc. by using bacterial colorant.

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