

Assessment of fastness properties of knitted cotton fabric dyed with natural dyes: a sustainable approach of textile coloration

Abstract

Now-a-days, the importance of natural sources is eminent because the increased awareness created due to most of the adverse effects of synthetic products. In recent years, it has been significantly important to use non-toxic & eco-friendly natural dyes to dye textile materials. Though a lot of research work was done on the application of natural dyes on textile materials, natural dyes was not been proved satisfactory. There is a main reason behind this which is the absence of a broad systematic study of the performance of these natural dyes. Extraction of natural dyes for the coloration of textile substrate is one of the most important research areas for the researchers. In this study, we tried to extract the natural dyes from Arjuna bark, myrobalan fruits, Bohera fruits and amla fruits. After extraction, cotton knitted fabric sample was dyed with extracted dyes by using mordant and without mordant. And then their colorfastness properties were evaluated.

Keywords: amla, arjuna, bohera, cotton fabrics, colorfastness, haritoky

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Mafzal Ahmed,¹ Tarikul Islam,² Md. Rezaul Karim,¹ Shahidul Kaiser,¹ Pallab Barua¹

¹Department of Textile Engineering, Port City International University, Bangladesh

²Department of Textile Engineering, Jashore University of Science and Technology, Bangladesh

Correspondence: Tarikul Islam, Lecturer, Department of Textile Engineering, Jashore University of Science and Technology, Jashore-7408, Bangladesh, Tel +8801722202322, Email matarikul.islam2014@gmail.com

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Introduction

Textile materials (natural and synthetic) used to be colored for value addition, for improving outlook and to attract the customers.¹ Anciently, this purpose of coloring textile was initiated using colors from natural source, until synthetic dyes were invented and commercialized. For ready availability of pure synthetic dyes of different classes and its low cost advantages, most of textile dyers/manufacturers shifted towards the use of synthetic colorant.^{2,3} Almost all the synthetic colorants being synthesized from petrochemical sources through hazardous chemical processes pose threat towards its eco-friendliness.⁴ There are two main ways to limit the environmental impact of textile processing. One is to construct sufficiently large and highly effective effluent treatment plants, and the other way is to make sure that the dyes and chemicals that are environment friendly.⁵ The rich biodiversity of our country has provided us plenty of raw materials, yet sustainable linkage must be developed between cultivation, collection and their use. Natural dyes can produce special aesthetic qualities, which, combined with the ethical significance of a product that is environmental friendly, gives value addition to textile production as craftwork and as an industry.⁶ Nature provides different coloring matters of vegetable, animal and mineral origin; used for dyeing since ancient times. The major advantage of natural dyes is that they are biodegradable, non-toxic, hygienic and colors soothing to human eyes.⁷ From different research work it was found that Arjun has a good scope for application on cotton fabrics with its eco-friendly nature.^{8,9} Haritaky contains considerable color strength for the application on cotton fabric as well as these dyes give very good anti-microbial characters on the cotton fabric and these are appreciably compatible with cotton fabric.^{10,11}

The present paper envisages the application of four natural dye sources:

(i) *Terminalia Arjuna*

(ii) *Terminalia chebula*

(iii) *Terminalia bellirica*

(iv) *Pyllanthus embelica*.

They were selected for dyeing through extraction of dyes from their barks and fruits. Dyes were extracted from Arjuna barks, Haritaky fruits, Bohera fruits, Amlaki fruits and cotton knit fabric was dyed with the help of mordant i.e. ferrous sulphate, potash alum and also without using any mordant. After dyeing, all the samples were tested by different testing instruments. The dyeing process was very unique and many outputs can be found from this project. And it can be used for further study and research work.

Materials and methods

Materials

Following materials are required for this research-

- Fabric
- Dye-stuffs
- Mordant

Selection of fabric

100% single jersey cotton knitted was collected from Super Knitting & Dyeing Mills Ltd., Chittagong, Bangladesh. Fabric GSM was 140.

Dye-stuffs

Arjuna dye: *Terminalia Arjuna* generally called as Arjuna is one which contains large amount of bio-actives in its bark. Arjuna tree is found in Bangladesh, Uttar Pradesh, Madhya Pradesh, West Bengal and central India. The bark of Arjuna contains large amount

of flavanoids & tannis. Extract of colorant from its bark powder has potential to act as natural dye having medicinal properties for textile substrate. Most natural dyes need a mordant to bond with fiber (metallic salt like alum) but Arjuna can dye fibers without mordant.

Haritaky dye: *Terminalia chebula* commonly known as Haritaky is found in India, Bangladesh, Nepal, Sri Lanka. A number of glycosides have been isolated from Haritaky. Other constituents including chebulin, chebulic acid tannic acid terflavin B a type of tannin is found in the ripe fruits. Extract of colorant from its fruits powder has potential to act as natural dye having medicinal properties for textile substrate. Most natural dyes need a mordant to bond with fiber (metallic salt like alum) but Haritaky can dye fibers without mordant.

Bahera dye: *Terminalia bellirica* known as bahera is found in India, Bangladesh. It contains fatty acid methyl ester. It is used for not only dyeing of textile materials but also have potential to add additional properties like anti-microbial properties.

Amloki dye: *Pyllanthus emblica* known as Amloki is found in India, Bangladesh. It contains high amounts of ascorbic acid, polyphenols, flavonoids, ellagic acid and gallic acid. It is used for not only dyeing of textile materials but also have potential to add additional properties like anti-microbial properties. It is also used as mordant for dye fixing (Figure 1).



Figure 1 Different types of natural dye; (i) Arjuna Dyes (ii) Horitaky Dyes (iii) Bohera Dyes (iv) Amloki Dyes.

Mordant

There are evidences of dyeing textile materials with natural dyes since historic ages. But some key problems are yet to be solved for their wider uses. One of the difficulty is, these dyes are mostly non-substantive and need to be applied on textile materials with the help of mordants. Generally, metal salts of aluminum, iron, copper, chromium or tin are used for mordanting the fabric to help natural dye getting attached. Potash aluminum sulphate, ferrous sulphate or green vitriol, stannous chloride are well established mordant for the purpose.

In this project work ferrous sulphate and potash alum are used as mordant (Figure 2).



Figure 2 Mordant used in work.

Machinery

a) Light Fastness Tester (Xenon Arc Light Fastness Tester)

b) Washing Fastness Tester (Wascator)

c) Rubbing Fastness Tester (Crock Master)

Methods

Extraction of natural dyes: In our project work we used aqueous extraction method for dyes extraction where 100 gms of fine powder of dyes in 1 litre water was heated at boiling temperature for 2 hrs. And then the solution is filtered to get pure dye solution (Figure 3).

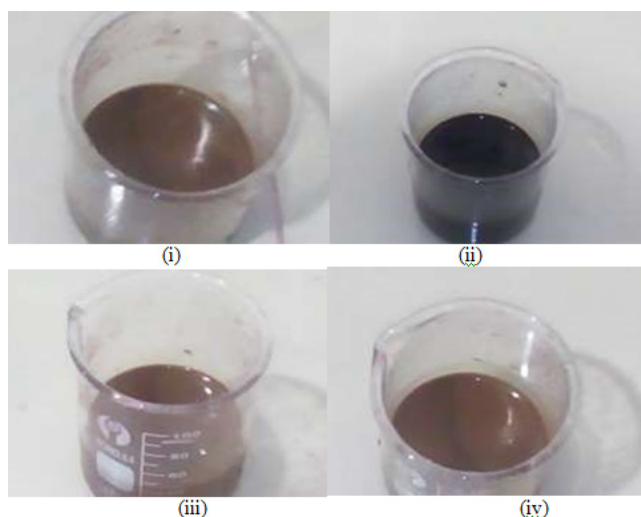


Figure 3 Extraction of natural dyes; (i) Arjuna (ii) Horitaky (iii) Bohera (iv) Amloki.

Mordanting

Sixteen cotton fabric samples were taken for mordanting. Eight samples are for mordanting with $FeSO_4$ and the others for mordanting with potash alum. 10gm / l $FeSO_4$ & potash alum were taken in dye pot separately and it was heated with the scoured & bleached cotton samples for 1hr at a temperature of $100^\circ C$. After 1hr the fabrics were let for conditioning for 24hrs. After washing these samples are dried (Figure 4).

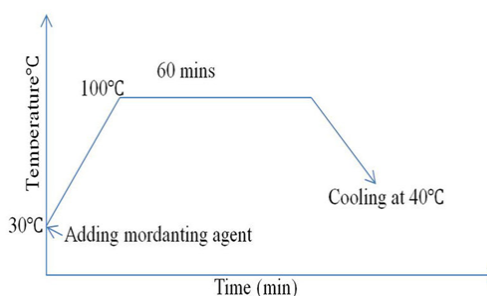


Figure 4 Fabric mordanting process curve.

Recipe:

- i. Sample weight-10gm
- ii. Mordant-10gm/l
- iii. Time-60min

- iv. Temp-100°C
- v. M: L -1:30

Dyeing

Dyeing the cotton fabric without mordant: Dyeing was carried out by exhaust method in sample dyeing machine 10 gm/l Arjuna dyes, Haritaky dyes, Bohera dyes, Amloki dyes were used for dyeing (Table 1) (Figure 5).

Table 1 Dyeing the cotton fabric without mordant

Dyeing recipe	After treatment recipe
Sample weight - 10gm	Sample weight - 10gm
Leveling agent - 1.5g/l	Soaping agent - 1.5g/l
Dyes - 10gm/l	Temp - 60°C
Time - 60min	Time - 10min
Temp - 80°C	
Soaping agent - 0.5g/l	
M: L - 1: 30	

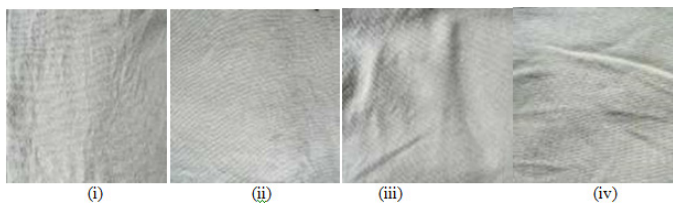


Figure 5 Dyed fabric without mordant; (i) Amloki (ii) Bohera (iii) Arjun (iv) Horitaky.

Procedures

- a. The liquor ratio is 1:30 at 80°C for 60 minutes in presence of 1.5gm/l leveling agent.
- b. Then the dye bath was cooled at 40°C. Sample was washed at room temp. And samples was squeezed and dried in oven dryer machine.
- c. Then sample was washed with 1.5gm/l soaping agent where material and liquor ratio was 1:30 at 60°C for 10 minutes.

Dyeing the cotton fabric mordanted with FeSO₄

Dyeing was carried out by exhaust method in sample dyeing machine 10gm/l Arjuna dyes, Haritaky dyes, Bohera dyes, Amloki dyes were used for 10gm mordanted sample fabric (Table 2) (Figure 6).

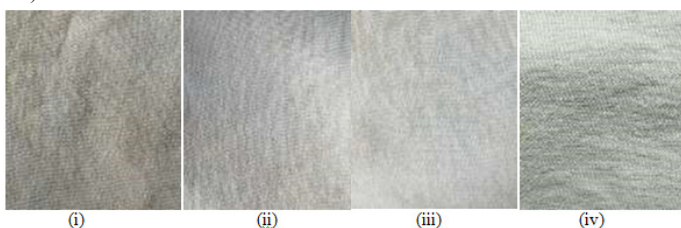


Figure 6 Dyed fabric mordanted with FeSO₄; (i) Amloki (ii) Bohera (iii) Arjun (iv) Horitaky.

Table 2 Dyeing the cotton fabric mordanted with FeSO₄

Dyeing recipe	After treatment recipe
Sample weight - 10gm	Sample weight - 10gm
Leveling agent - 1.5g/l	Soaping agent - 1.5g/l
Dyes - 10gm/l	Temp - 60°C
Time - 60min	Time - 10min
Temp - 80°C	
Soaping agent - 0.5g/l	
M: L - 1: 30	

Procedures

- a. The liquor ratio is 1:30 at 80°C for 60 minutes in presence of 1.5gm/l leveling agent.
- b. Then the dye bath was cooled at 40°C. Sample was washed at room temp. And samples was squeezed and dried in oven dryer machine.
- c. Then sample was washed with 1.5gm/l soaping agent where material and liquor ratio was 1:30 at 60°C for 10 minutes.

Dyeing the cotton fabric mordanted with potash alum

Dyeing was carried out by exhaust method in sample dyeing machine 10gm/l Arjuna dyes, Haritaky dyes, Bohera dyes, Amloki dyes were used for 10gm mordanted sample fabric (Table 3) (Figure 7).

Table 3 Dyeing the cotton fabric mordanted with potash alum

Dyeing recipe	After treatment recipe
Sample weight - 10gm	Sample weight - 10gm
Leveling agent - 1.5g/l	Soaping agent - 1.5g/l
Dyes - 10gm/l	Temp - 60°C
Time - 60min	Time - 10min
Temp - 80°C	
Soaping agent - 0.5g/l	
M: L - 1: 30	

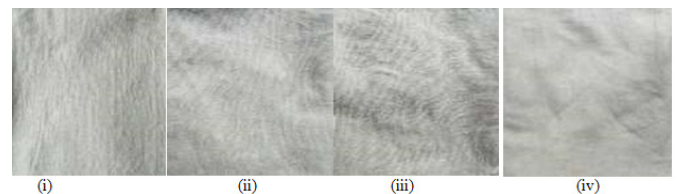


Figure 7 Dyed fabric mordanted with potash alum; (i) Amloki (ii) Bohera (iii) Arjun (iv) Horitaky.

Procedures

- a. The liquor ratio is 1:30 at 80°C for 60minutes in presence of 1.5gm/l leveling agent.
- b. Then the dye bath was cooled at 40°C. Sample was washed at room temp. And samples was squeezed and dried in oven dryer machine.
- c. Then sample was washed with 1.5gm/l soaping agent where material and liquor ratio was 1:30 at 60°C for 10 minutes

Testing

- i. Color Fastness to Rubbing-ISO 105 X 12
- ii. Color Fastness to Light- ISO 105 E03
- iii. Color Fastness to Wash- ISO 105 C06
- iv. CMC Test

Results & discussion

Color fastness to rubbing: From Table 4, it is noticed that all dyes show better result without mordant & with potash alum and it's about 4. FeSO₄ doesn't show good result, hence it is not compatible with these dyes as a mordant.

Table 4 Rubbing fastness properties of dyed fabric

Dyes source	Mordanting agent	Dry rubbing	Wet rubbing
Amloki	CONTROL	4	3-4
	Ferrous Sulphate	3-4	2-3
	Potash Alum	4	3-4
Bohera	CONTROL	4	3-4
	Ferrous Sulphate	4	3-4
	Potash Alum	4	3-4
Arjun	CONTROL	4-5	4
	Ferrous Sulphate	3-4	3
	Potash Alum	4	3-4
Horitaky	CONTROL	4-5	3-4
	Ferrous Sulphate	3-4	3
	Potash Alum	3-4	3-4

Table 6 Wash fastness properties of dyed fabric

Dyes source	Mordanting agent	Change in color	Color staining					
			Diacetate	Cotton	Polyamide	Polyester	Polyacrylic	Wool
Amloki	CONTROL	2	4-5	4	4-5	4-5	4-5	4-5
	Ferrous Sulphate	2	4-5	4	4-5	4	4	4-5
	Potash Alum	1-2	4-5	4	4-5	4-5	4-5	4-5
Bohera	CONTROL	3	4-5	4	4-5	4	4-5	4-5
	Ferrous Sulphate	2	4-5	4	4-5	4-5	4-5	4-5
	Potash Alum	2	4-5	4	4-5	4-5	4-5	4-5
Arjun	CONTROL	1-2	4-5	4	4	4	4-5	4-5
	Ferrous Sulphate	1-2	4-5	4	4-5	4-5	4-5	4-5
	Potash Alum	1-2	4-5	4	4-5	4-5	4-5	4-5
Horitaky	CONTROL	2	4-5	4	4-5	4	4	4-5
	Ferrous Sulphate	2	4-5	4	4-5	4-5	4-5	4-5
	Potash Alum	2	4-5	4	4-5	4-5	4-5	4-5

Color fastness to light: From Table 5, In case of color fastness to light all dyes are fair to moderate. Amloki, Bohera, Haritaky shows better result for both mordanted and without mordanted sample. But Arjuna dyes don't show good result.

Table 5 Light fastness properties of dyed fabric

Dyes source	Mordanting agent	Grading
Amloki	CONTROL	3-4
	Ferrous Sulphate	4
	Potash Alum	3-4
Bohera	CONTROL	3-4
	Ferrous Sulphate	4
	Potash Alum	4
Arjun	CONTROL	2-3
	Ferrous Sulphate	4
	Potash Alum	2-3
Horitaky	CONTROL	3-4
	Ferrous Sulphate	4
	Potash Alum	4

Color fastness to wash: From Table 6, it shows that wash fastness of these dyes for change in color isn't good. But color staining is excellent. So, it is recommended to use these dyes for dyeing of fabric which need less wash like wound bandage.

CMC test: From Table 7, it shows that the higher the difference, the more the shade changes. In reference to sample without mordant, the mordanted sample gives darker & red shade for both Amloki and Arjun. Bohera and horitaky gives darker and red shade for FeSO₄ whereas darker and green for potash alum.

Table 7 CMC value of dyed fabric

Standard	Sample Batches	Illuminant/ Observer	DL*	Da*	Db*	DC*	DH*	DE	Remarks
Almoki (Without mordant)	with Ferrous Sulphate	D65/10 Deg	-17.42	2.68	0.95	1.45	-2.45	17.65	Darker + Red
	with Potash Alum		-5.86	0.95	3.66	3.74	-0.53	6.97	Darker + Red
Bohera (Without mordant)	with Ferrous Sulphate		-14.82	2.56	0.19	0.55	-2.5	15.04	Darker + Red
	with Potash Alum		-6.86	-0.29	4.72	4.71	0.44	8.33	Darker + Green
Arjun (Without mordant)	with Ferrous Sulphate		-7.74	6.12	8.64	9.51	-4.65	13.11	Darker + Red
	with Potash Alum		-0.43	0.2	1.31	1.32	-0.2	1.4	Darker + Red
Horitaky (Without mordant)	with Ferrous Sulphate		-13.3	3.11	3.16	3.66	-2.5	14.02	Darker + Red
	with Potash Alum		-7.53	-0.46	5.19	5.15	0.79	9.15	Darker + Green

From the overall testing data it has been concluded that without the aid of mordanting agents the applied natural dyes show better results in fastness properties. It may happen due to the presence of tannic acid in those dyes which is act as mordanting agent itself. But from CMC test it has been claimed that the shade variety is profound after using different mordanting agents.

Conclusion

In the present scenario, the growing concerns among the communities globally against the use of azo and benzidine synthetic dyes due to their carcinogenic, non-biodegradable nature and hazardous effects on environment and human health. With increasing in awareness for eco-friendly materials from sustainable resources, natural dyes attracted researchers in traditional and diversified applications to develop effective eco-friendly and cleaner process technologies. Natural dyeing is gradually making its way in the global market and the production of naturally dyed eco-friendly textiles itself is a boon to save the environment from hazardous synthetic dyes. Furthermore, the fast moving inexpensive synthetic dyes stand as a big question before natural dyers. But, the non-toxic, non-carcinogenic, biodegradable and eco-friendly characteristics of naturally derived colorants made its own way to reach the hearts of conscious consumers for healthy lifestyle, and can be achieved on a higher cost. Hence, the applications of bio-colorants to textile substrates will be helpful to entrepreneurs to take up this venture which have good potential and bright future in a number of applied sectors: leather, textiles and clothings, cosmetics, food, pharmaceutical, and paint industries etc.

In this research it is shown that studied dyes are compatible with cotton fabric but the wash fastness is so poor. With further research it may be possible to apply different metal salts to enhance the wash fastness properties. Moreover, this research is based on lab scale but for the use of industrial purpose the dye extraction process should be in efficient manner. We used here aqueous extraction methods which may be replaced by solvent extraction method for getting more dyes and liquid dyes may convert into solid form which will be very much helpful for industrial purpose.

Author contributions

M.A. and M.R.K. planned and supervised the work. Moreover, S.K. and M.R.K. have done the specimen fabrication, characterization, testing, data analysis, and presentation part with the help of T.I. All authors read and finally approved the manuscript.

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None.

Conflicts of interest

The authors declare that they have no competing interests.

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