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DYEING OF POLYESTER FABRIC WITH NATURAL COLORANTS EXTRACTED FROM MAHOGANY (*Swietenia mahagoni*) SEED PODS

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ABSTRACT

Polyester fabric is usually dyed with disperse dyes which has severe limitations specially toxicity and environmental issues. The aim of the present research is to introduce an ecofriendly dyeing process for polyester fabric with natural dyes. The natural colorants were extracted from mahogany seed pods using the simple acid boiling method. The spectroscopic analysis of the crude extract was carried out by UV and IR spectra of the extracted dyes and illuminated the presence of natural tannins as coloring materials in the crude extract. 10g fabric was dyed in 200cc extracted solution at 130 ^{0}C for 60 minutes in exhaust dyeing method followed by neutralization and soaping. Finally, a light brown dyed fabric was obtained. The dyed fabric exhibited color strength in terms of k/s value of 0.63 (λ_{max} 360nm), lightness of 80.565 and chromaticity value of 12.002 CIE units. Different samples were dyed by fluctuating the dyeing period. The dyeing traits of the dyed materials were judged in terms of their color strength and fatness properties. All testes were carried out following the ISO standards. From the results, it is lucid that the dyed fabric showed acceptable color fastness properties in case of all fastness except color fastness to light. It is observed that dyeing time had profound influence on the color strength (k/s value) of the dyed material. The k/s value increases with the increase of dyeing period up to 120 minutes. The maximum color strength (0.76) was noted for the fabric. The shorter dyeing time produces lighter samples and the longer dyeing time produced colorful samples.

Keywords: *Natural colorants; polyester fabric; chromaticity; color strength; color fastness.*

1. INTRODUCTION

There is severe climate change for global warming, extreme pollution (Khan *et al*., 2011) from many sources, industrial development etc., destroying the ecosystems and the extinction of wildlife (Switi *et al.,* 2014). The global changes and human factors are surely altering the course of the earth's long-term sustainability including stream as well (Bhuiyan *et al.,* 2014; Anijiofor *et al.,* 2018). Textile industries, specially wet processing industries use huge synthetic dyes and chemicals, are destroying the aquatic environment by discharging the effluent directly into the water body. These industries are also responsible for air, noise and soil pollution. Traditionally, synthetic dyes have a wide range of hazardous effects: toxic or fatal, corrosive (destructive to living tissues), irritant (induces local inflammatory reaction in living tissues), contamination (representing a potential source of the spread of diseases to humans and animals), radioactive and so on (Hassaan *et al.,* 2017; Kant, 2012). But the natural dyes are non-carcinogenic, produce soothing and fashionable colors to the textiles, have better biodegradability and higher compatibility with the environment (Pereire *et al*., 2012; Mondan *et al.,* 2017; Bechtold *et al.,* 2003). So, environmental apprehensions about ecofriendly natural dyes are increasing than the synthetic ones (Kamel *et al.,* 2009; Chowdhury, 2018; Raa *et al*., 2016).

The plant kingdom has a vast source of natural dyes or colorants that can be extracted from many parts of plant such as leaves, fruits, wood, heartwood, roots, flowers, seeds and barks. Bangladesh has an abundance of plant species with dye yielding properties. The rural people extract dyes from leaves, fruits, wood, heartwood, roots, flowers, seeds and barks of some plant species generally by boiling, scraping, powdering and mixing with other materials to get the desired color. There are a good number of mahogany trees in Bangladesh which grow plenty of seed every year. These have some medicinal uses but the seed pods have no food or industrial uses in the growing areas and are, therefore, tons of seed pods are simply wasted. Oppositely, most of the textile industries use disperses dyes for polyester coloration which pollute the environment to great extent. So, this research was carried out for ensuring the commercial utilization of mahogany seed pods and introducing an eco-friendly dyeing process for polyester fabric.

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2. EXPERIMENTAL

2.1 Fabric

The fabric used includes commercially scoured-bleached 100% polyester woven fabric with the specification 110 gsm, plain woven, EPI=136, PPI=74, warp count=75 Denier, weft count=150 Denier, Fabric width= 56 inches

2.2 Dyes and Chemicals

Mahogany seed pods (MSP) were used as source of natural colorants. These were collected from Mawlana Bhashani Science and Technology University campus, Santosh, Tangail-1902.Laboratory grade hydrochloric acid was used for extraction of colorants. Laboratory grade soda ash was used to neutralize the fabric dyed in acidic dye solution. ISO standard soap without optical brightener was used to remove the unfixed dye from the dyed samples.

2.3 Pictorial flow chart of colorants extraction and dyeing

The natural colorants were extracted from mahogany seed pods using the acid boiling method. Matured MSP were washed and sun dried. Then the MSP were cut into small pieces and crushed into powder. 50g MSP powder and 1cc hydrochloric acid were boiled in 1000cc water for 60 minutes. Thus, tannin based natural colors got extracted which was confirmed by UV and IR spectroscopy. The filtered solution was then used as the dye solution to dye 100% polyester bleached fabric. 10g fabric was dyed in 200cc extracted solution at 130^{0}C for 60 minutes.

Figure 1: Flow chart for the natural colorants' extraction and dyeing

2.4 Typical recipe for dyeing and after treatment

Polyester fabric was dyed and washed according to the following recipe

Dyeing recipe	Neutralization recipe	Soaping recipe
Fabric weight: 10g	Fabric weight: 10g	Fabric weight: 10g
M: L= 1:20	M: L= 1:20	M: L= 1:20
Dye solution: 200 cc	Soda ash: 2 g/L	Soaping agent: 2 g/L
Temperature: 130 ºC	Temperature: 50 ºC	Temperature: 95 ºC
Time: 60 Minutes	Time: 10 Minutes	Time: 15 Minutes

2.5 Polyester dyeing process

The dye bath was set with 200cc dye solution and 10g polyester fabric at 30 ^{0}C temperature. Then the temperature was raised at 130 ^{0}C following a gradient of 3 ºC per minute. The process was continued at the same temperature for further 60 minutes followed by cooling and draining of the effluent at 50 ^{0}C temperature.

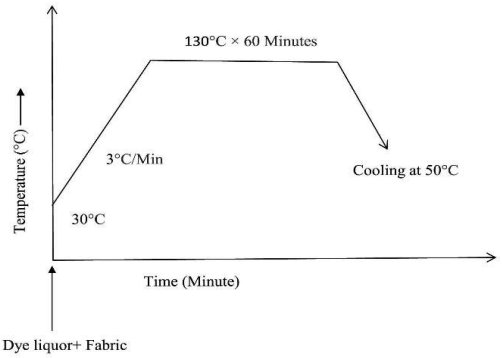

Figure 2: Process curve for the polyester dyeing with the natural colorants

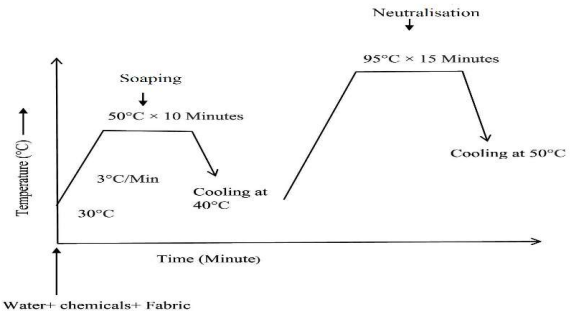

Figure 3: Process curve for neutralization and soaping

2.6 Neutralization and soaping

Neutralization bath was set with 180 cc water and 20 cc of 2% soda along with 10g dyed polyester fabric at 30 ^{0}C temperature. Temperature was raised at 50 ^{0}C following a gradient of 3 ºC per minute. The process was continued for further 10 minutes followed by cooling and draining of the effluent at 40 ^{0}C temperature. For soaping the bath was set with 180 cc water and 20 cc of 2% soaping agent along with 10g dyed polyester fabric at 30 ^{0}C temperature. Then the temperature was raised at 95 ^{0}C following a slope of 3 ºC per minute. The process was continued for further 15 minutes followed by cooling and draining of the effluent at 50 ^{0}C temperature.

3. RESULTS AND DISCUSSIONS

3.1 IR Spectra of the extracted colorants

Required amount of solution was air dried and converted into power form for IR spectroscopy analysis of colorants. IR spectra were generated in KBr pellet mode in IR affinity machine (Shimadzu, Japan). The wide peak in the region 3550–3100 cm^{-1} is characteristic of the -OH stretching vibration of benzene nucleus and methylol group of tannin (Ping *et al.,* 2012; Ooa *et al*., 2009; Jianzhong *et al*., 2009; Puica *et al.,* 2006; Kim and Joongkim, 2003; Ozacar *et al*. 2006). Mahogany seed pod (MSP) extract showed this characteristic peak at 3414 cm^{-1}. Small peak around 2900 cm^{-1} is for aromatic C-H stretching vibration of both methyl and methylene groups (Ping *et al.,* 2012; Kim and Joongkim, 2003; Ozacar *et al*., 2006). MSP extract exhibited this characteristic peak at 2954.95 cm^{-1}. The peaks pronounced at 1619-1450 cm^{-1} shows presence of aromatic rings (Ping *et al.,* 2012; Ooa *et al*., 2009; Puica *et al*., 2006; Kim and Joongkim, 2003; Laghi *et al*., 2010; Ozacar *et al*., 2006). MSP extract showed this peak at the range 1610.56 cm^{-1} -1436.97. The region of peaks 1500-950 cm^{-1} are called fingerprint for FTIR spectra of tannins. The peak at around 1285 cm^{-1} in the spectrum of pine tannin is a characteristic feature for the flavonoid based tannins (Edelmann *et al.,* 2002). MSP extract has this peak at 1265.30 cm^{-1}. The presence of natural tannins as coloring compound in MSP was confirmed by the above characteristic peaks.

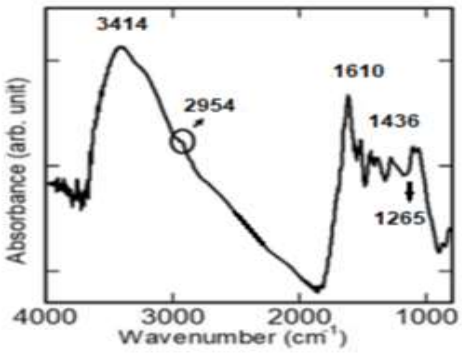

Figure 4: FTIR spectra of acidic MSP extract

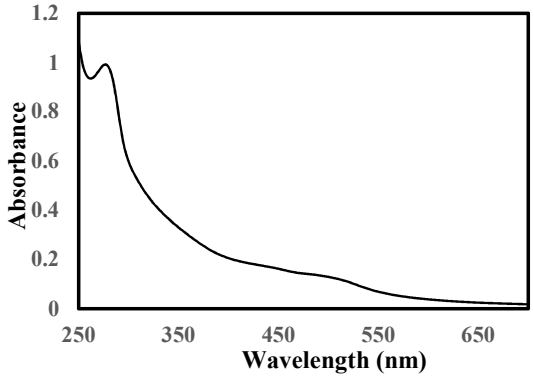

Figure 5: UV spectra of acidic MSP extract

3.2 UV spectra of extracted colorants

MSP extract was twenty times diluted for UV absorption spectra measurement. Presence of tannins in the extracted dye solution was confirmed by the characteristic UV absorption peak at 278 nm in UV-visible spectrophotometer (UV-1800, Japan)

3.3 Physical appearance of the dyed fabric

Figure 6 represents the physical appearance of the fabric dyed at 130 ºC for 60 minutes following 1:20 material-liquor ratio. Mahogany seed pod extract produced a light brown color on polyester fabric. The dyed fabric exhibited color strength in terms of k/s value of 0.63 (λ_{max} 360nm), lightness of 80.565 and chromaticity value of 12.002 CIE units.

3.4 Color fastness properties of the dyed material

The dyed fabric showed excellent resistance to color straining on multi fiber fabric with staining scale ratting 4-5 for every cases. The color fastness to dry rubbing, wet rubbing and alkaline perspiration of the dyed fabric are good with a grey scale ratting of 4. On the contrary color fastness to wash and acidic perspiration are moderate with 3-4 grey scale ratting. The dyed material showed poor color fastness to light having 2-3 blue wool ratting.

Table 1: Color fastness properties of dyed fabric

Color fastness to	Color-change ratting (Grey scale/blue wool)
Wash	3-4
Alkaline perspiration	4
Acidic perspiration	3-4
Dry rubbing	4
Wet rubbing	4
Light	2-3

Figure 6: Scanned image of polyester fabric dyed with mahogany seed pod extract

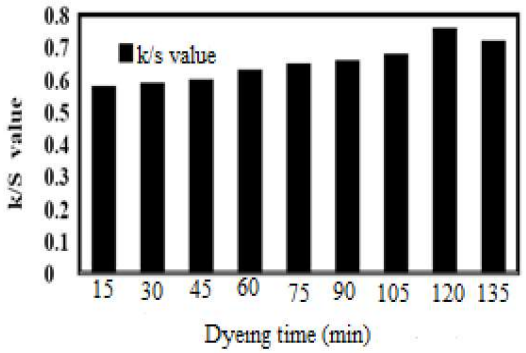

Figure 7: Bar diagram showing the effect of dyeing period on the color strength of dyed fabric

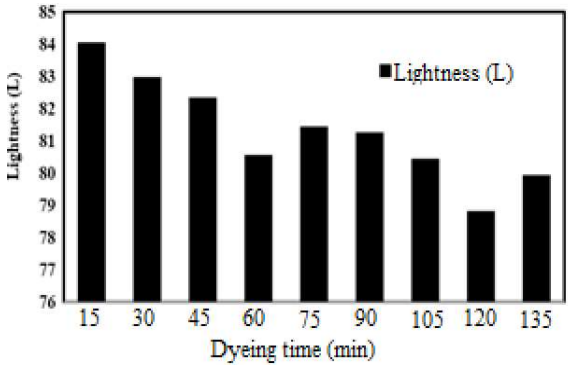

Figure 8: Bar diagram showing the effect of dyeing period on the lightness of dyed fabric

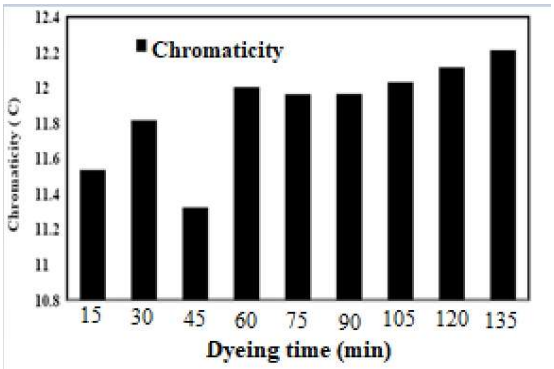

Figure 9: Bar diagram showing the effect of dyeing period on chromaticity

3.5 Effect of dyeing time on the color strength (k/s value)

Color strength (k/s value) represents a relative measure of the amount of dyes in the dyed fabric. It is the measure of the ratio of amount of light absorbed and scattered by the dyed material. Hence higher k/s values denote more amount of dyes in the material. It is observed that dyeing time had profound influence on the color strength (k/s value) of the dyed material. Amount of dyes adsorbed by the polyester increased with the increase of dyeing time until the fabric got saturated with dyes. So, the k/s values of the dyed polyester increased with the increase of dyeing period up to 120 minutes. The maximum color strength (0.76) was noted for the fabric

3.6 Effect of dyeing time on lightness of the dyed fabric

The value of L in the CIELAB system, recommended by CIE in 1976 gives a measure of the lightness of the color. L varies between 0 (perfect black) and 100 (perfect white) (Broadbent, 2001). Higher value of L denotes lighter hue and lower values refers to darker hue of a dyed material. It was noticed that dyeing time had remarkable encouragement on the lightness of the dyed material. The lightness values followed a decreasing trend in most of the cases. The reason behind this phenomenon is the increase in the amount of dyes in the fabric with the increases of dyeing time. The maximum lightness (84.056) was noted for the fabric dyed for lowest dyeing time 15 min.

3.7 Effect of dyeing period on chromaticity of the dyed material

Chroma is the attribute of color used to indicate the degree of departure of the color from the grey of the same lightness (Choudhury, 2014). It can be termed as the colorfulness of an object. Higher chroma indicates more colorfulness on an object. Dyeing parameters change the chromaticity of the dyed samples differently. It was observed that dyeing time had notable stimulus on the chromaticity of the dyed material. The chromaticity followed an increasing trend in most of the cases due to the increase in the amount of dyes in the fabric. The maximum chromaticity value (12.212) was recorded for the fabric dyed for 135 minutes.

4. CONCLUSION

Dyeing of polyester fabric with natural dyes extracted from mahogany seed pods is a new approach in textile coloration. Natural tannins got extracted from MSP due to boiling in acidic solution. The presence of tannins in the crude extract was illuminated by UV and IR spectra of the crude extract. Colorfastness to wash, rubbing and perspiration were moderate to good demonstrating the competitiveness with commercial synthetic dyes for polyester though the color fastness to light was poor with comparison with the other fastness properties. Polyester fabric dyed with MSP extract may be used in different purposes where there is little chance of light exposure. In future, studies of some chemical treatments may be carried out for the enhancement of the light fastness properties of dyed fabric.

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