

Effect of henna natural dye on antibacterial properties of dyed nylon fabric with various mordants

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Received: August 2014; Revised: September 2014; Accepted: October 2014

Abstract: In this study, the effect of different mordants on dyeing of nylon fabric with Henna natural dye was studied. Nylon fabrics were treated with different mordants and the dyeing process was carried out on the fabrics in the state simultaneously-mordanting. The antibacterial properties were determined by reduction growth of a Gram-negative bacterium *E. coli* and a Gram-positive bacterium *Staphylococcus aureus*. The relationship between antibacterial ability and Henna concentration was investigated. Durability of antibacterial activity to laundering is also discussed. Result indicate that the nylon dyed with Henna displayed excellent antibacterial activity in the presence of ferric sulfate, cupric sulfate and potassium aluminum sulfate, and exhibited good and durable fastness properties.

Keywords: Henna, Antibacterial, Mordant, Nylon, *S. aureus*, *E. coli*.

Introduction

Since the last decade, the application of natural dyes on textile materials is gaining popularity all over the world, possibly because of increasing awareness of environment, ecology, and pollution control. Human health has been seriously threatened by environmental pollution, especially indoor microbiological contamination (SARS, Influenza, etc.). The statistical figures reveal that the total number of deaths caused by bacterial infection exceeds 17 million, about 1/3rd of world-wide deaths [1]. Textiles can thus enhance cross-contamination by pathogenic microorganisms in environments such as home and hospitals. Textile materials provide an excellent environment for microorganisms to grow, because of their large surface area and ability to retain moisture. Microbial activity can be detrimental to textiles. It can cause unpleasant

odor, lead to weakening of the substrate, discoloration, and even contribute to the spread of disease. For this reason, antimicrobials have been investigated as a finish for textiles [2, 3].

Antibacterial finishes are applied to textiles for three major reasons: (a) to contain the spread of disease and avoid the danger of injury-induced infection, (b) to contain the development of odor from aspiration, stains and soil on textile materials, and (c) to contain the deterioration of textiles caused by mildew, particularly fabrics made of natural fibres [4]. Various methods, depending on the active agent and the fibre types, have been developed or are under development to confer antimicrobial activity to textiles. Many methods have been reported, such as fluorocarbon repellent finish, chemical binding of heterocyclic N halamine functional group to polyamide, using plasma to graft polymerize an antibacterial polymer, or immobilisation

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of antimicrobial metallic nanoparticles on textiles (TiO_2 , Ag, Cu, ZnO, etc.) [5-14].

Natural dyes are believed to be safe because of their non-toxic, non-allergic and biodegradable nature. Many of the plants used for dye extraction are classified as medicinal, and some of them have recently been shown to possess remarkable antibacterial activity [18-21]. Henna is a flowering plant and the sole species of the *Lawsonia* genus. Henna has been used since antiquity to dye skin, hair, and fingernails, as well as fabrics including silk, wool, and leather. The pigment in the colorant extracts obtained from Henna is collectively known as *Lawsonone* (Figure 1) [22-24].

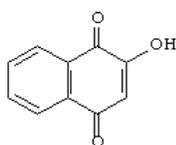


Figure 1: Structures of *Lawsonone* (2-hydroxy-1,4-naphthaquinone).

Nylon, the first commercial fiber product of polyamide, it has been one of the most widely used polymers in various industries such as fiber, film, and plastics. Polyamide has major advantages of high modulus and strength, stiffness, stretch, wrinkle and abrasion resistances [25]. However, nylon can be easily attacked by bacteria *in vivo*. In this study, antibacterial nylon fabric was prepared by Henna natural dyeing in the presence of various mordants, and we also focused on the antibacterial activity of treated fabrics against two common pathogenic bacteria: *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*).

Results and discussion

Toxicity Assay:

The results demonstrate that Henna at different concentrations caused no inhibition to germination and root growth to the green grams (moong beans) and a growth rate of more than 90% was observed. The untreated and treated green grams were almost equal in their germination and growth rate. Thus, the Henna was found to be non-toxic.

Colour strength of nylon fabrics:

Figure 2 shows the graph of treated samples K/S dyed by Henna (20%). The result of dyeing samples shows that using mordants considerably increased dye absorption leading to higher K/S values in case of mordanted samples than un-mordanted ones. Ferric

sulfate mordant was found to have the most prominent effect on colour strength.

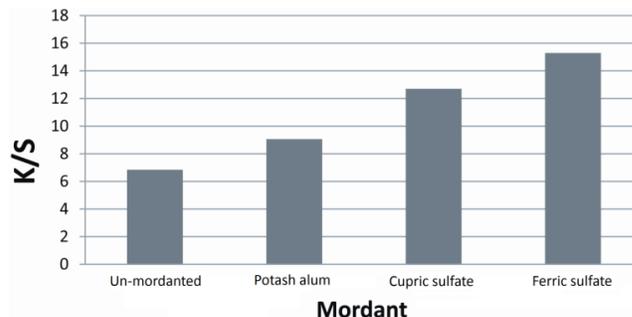


Figure 2: K/S graph of the dyed nylon fabric samples with 20% Henna (O.W.F.).

Antibacterial activity:

Tables 1 and 2 show the photos of bacterial growths upon treated fabrics and Table 3, shows the antibacterial activity (R%) of nylon fabrics dyed with Henna in different conditions against *E.coli* and *S.aureus*. Figure 3 and 4 exhibit comparative diagrams of antibacterial activity results for the treated sample in the presence of *E. coli* and *S. aureus* bacteria. From the data in Table 3 it is clear that dyed fabric with henna was proved to be effective in inhibiting microbial growth. This is due to the inherent antimicrobial characteristics of the *lawsonone* dye. As mentioned before, henna has an orange-coloured pigment *lawsonone* which is responsible for both its dyeing as well as antimicrobial characteristics. The antibacterial activity of treated fabrics were ranked as ferric sulfate > cupric sulfate > potash alum > without mordant against *S.aureus* and cupric sulfate > ferric sulfate > potash alum > without mordant against *E. coli*.

The results demonstrated that Henna is more effective against *S. aureus* than *E. coli*. They also showed that using mordant had better antibacterial activity. Hence, it is suggest that the Henna dye can be used for dyeing nylon as an alternative to the very expensive, synthetic and toxic antibacterial agents.

Washing fastness properties:

Textiles are subjected to frequent washing, rubbing and sweating during their use and the requirement of durability is a very important parameter. Figure 5 and 6 depict the durability of antibacterial activity after repeated home launderings. As shown, the antibacterial activity reduced with increased number of washing cycles. The inhibition rate of treated sample without mordant was more reduced than the treated sample with mordant after laundering.

Table 1: Photos of growth *E.coli* bacterium upon treated samples.

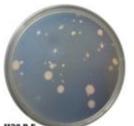
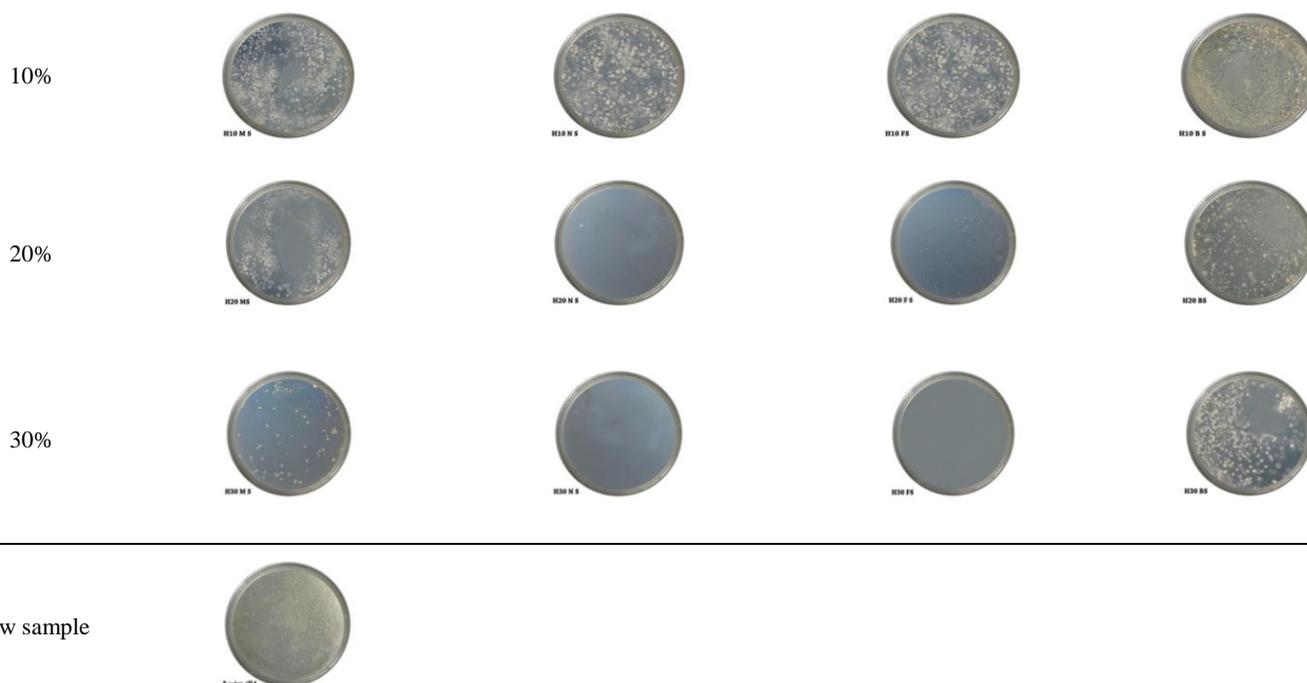
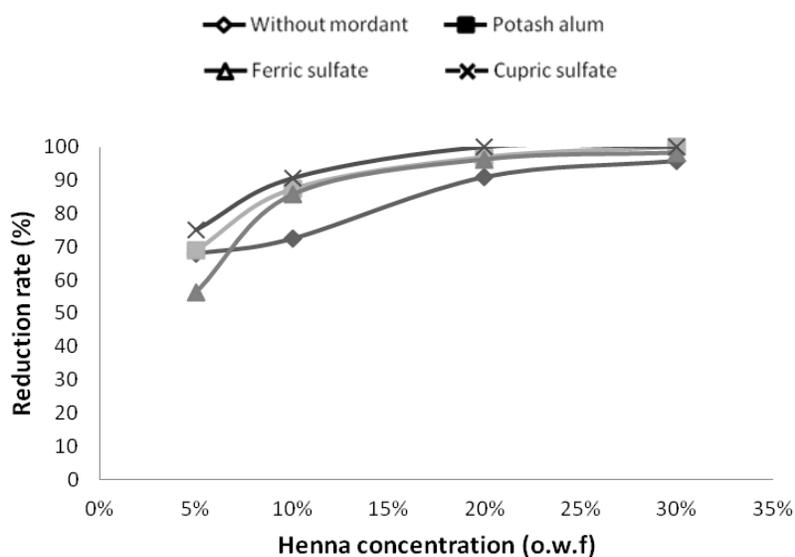
Henna concentration (O.W.F.%)	<i>E.coli</i>			
	Cupric sulfate	Ferric sulfate	Potash alum	Without mordant
5%				
10%				
20%				
30%				
Raw sample				

Table 2: Photos of growth *S.aureus* bacterium upon treated samples.

Henna concentration (O.W.F.%)	<i>S.aureus</i>			
	Cupric sulfate	Ferric sulfate	Potash alum	Without mordant
5%				

**Table 3:** Percentage reduction of *E. coli* and *S. aureus* in different condition.

Henna concentration (O.W.F.%)	Reduction percent (R%)							
	<i>S. aureus</i>				<i>E. coli</i>			
	Cupric sulfate	Ferric sulfate	Potash alum	Without mordant	Cupric sulfate	Ferric sulfate	Potash alum	Without mordant
5%	75.6	56.2	75	68	70.1	43.8	82.2	79.8
10%	87.3	85.6	90.52	72	82.8	92	88.4	86.6
20%	96.9	96.2	99.96	90.9	98.8	99.9	99.9	98.9
30%	100	98.2	100	95.7	99.8	100	100	100

**Figure 3:** Antibacterial activity of dyed nylon samples with Henna in the presence and absence of mordant against *S. aureus*.

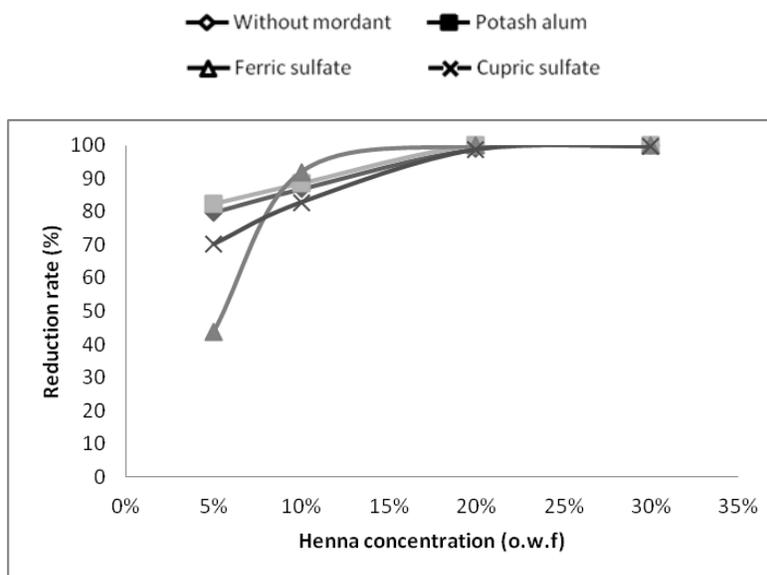


Figure 4: Antibacterial activity of dyed nylon samples with Henna in the presence and absence of mordant against *E. coli*.

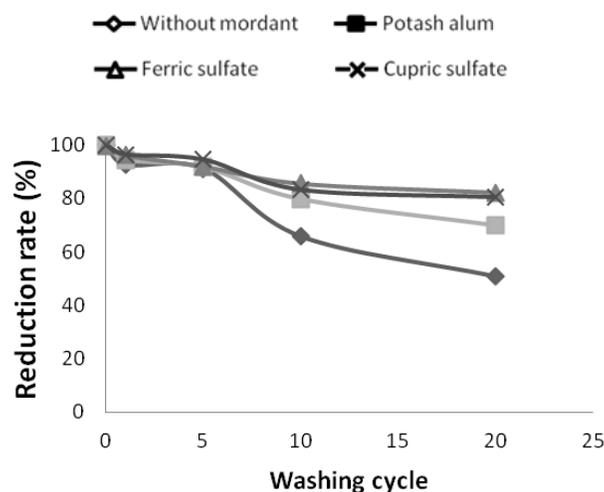


Figure 5: Antibacterial activity of dyed nylon samples with Henna in the presence and absence of mordant against *S. aureus* after laundering.

Conclusion

This is the first report where Henna, used in nylon dyeing, has been shown as a source of a natural, non-toxic dye. This research was conducted to introduce an effective natural dye to produce an ideal antibacterial nylon fabric. A common dyeing process provides nylon with colour and antibacterial properties. Since the dyeing process and antibacterial finishing have been conducted in one step and do not require an additional

step, thus this method is cost effective. Natural dyed nylon presented a strong antibacterial activity against two well-known pathogenic bacteria *S. aureus* and *E. coli*. Henna against *S. aureus* is more effective than *E. coli*. Moreover, using mordant had better antibacterial activity. The antibacterial activity of Henna mordant finished nylon is more durable to home laundering than without mordant.

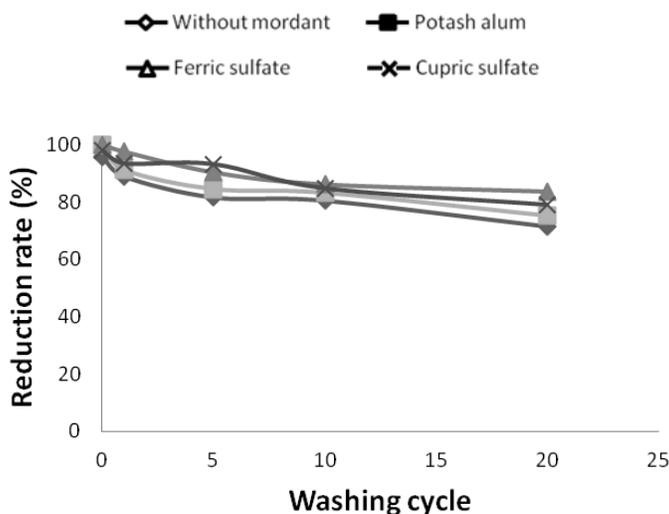


Figure 6: Antibacterial activity of dyed nylon samples with Henna in the presence and absence of mordant against *E. coli* after laundering.

Experimental

Materials:

The nylon fabric was supplied by Yazdbaf Company, Iran. The Henna was purchased from Iranian traditional natural dyers. potassium aluminum sulfate, cupric sulfate and ferric sulfate as a mordant were purchased from Merck. *Escherichia coli* (*E. coli*), a Gram negative bacterium, were selected due to its popularity as a test organism and its resistance to common antimicrobial agents. *Staphylococcus aureus* (*S. aureus*), a pathogenic Gram positive bacterium, was used because it was the major cause of cross-infection in hospitals and it is the most frequently evaluated species. Cultures of following microorganisms were used in the study: *S. aureus* ATCC 25922, *E. coli* ATCC 25923.

Toxicity Assay:

A Henna (1 g/100 ml) was prepared and, from this stock, different concentrations (50, 75 and 100 ppm) were prepared for testing and were finally applied to sterile 9 cm diameter Whatman No. 1 filter paper disks in Petri dishes. Then 10 surface-disinfected green grams (moong beans) were placed on the wetted paper. After 14 days of incubation at $27 \pm 1^\circ\text{C}$, total root growth (germination) was measured and compared with the control (untreated sample) and was expressed as root growth inhibition percentage [26].

Dyeing procedure:

To study the relationship between dye concentration and antimicrobial activity, 100% nylon fabrics were dyed with 5, 10, 20 and 30% Henna on weight of fabric (O.W.F.) at neutral pH with potassium aluminum sulfate, cupric sulfate and ferric sulfate as a mordant and without mordant. The nylon fabric was dyed in an AHIBA dyeing system with Henna dye. The dye bath was comprised of dye, 1% acetic acid and 3% mordant. The liquor ratio was kept at 40:1. The temperature was raised to 100°C by a thermal gradient of 2°C min^{-1} , and dyeing operation continued for 60 min.

Colour measurements:

The dyed nylon fabrics were individually tested for their colour strength. The colour strength (K/S) values of the dyed fabrics were instrumentally determined by reflectance spectrophotometer (BYK- Gardner, India, with CIELAB 1976 color space and D65-light source) with Kubelka-Munk equation.

$$\left(\frac{K}{S} = \frac{(1-R)^2}{2R} \right) \quad (1)$$

where R is the reflectance of the dyed fabric at the maximum absorption wavelength. S is the scattering coefficient and K is the absorption coefficient of the dyed fabrics.

Antibacterial test:

AATCC Test Method 100-1999 was used to determine the antibacterial activity of the treated nylon. In the next set of experiments the antibacterial activity of dyed nylon specimens was tested. The reduction of bacterial growth by dye was expressed as follows:

$$((R = (B - A) / B \times 100)) \quad (2)$$

where R denotes the percentage of reduction of microbial population; B is the absorbance of the media inoculated with microbes and un-dyed fabric; and A shows the absorbance of the media inoculated with microbes and dyed fabric.

Durability to laundering:

Durability of antimicrobial activity to washing is one of the major concerns of textile researchers and users because textiles are subjected to frequent laundering. The treated samples with 30% concentration of Henna were washed under condition of the ISO 105-CO2 Test Method condition to determine the antimicrobial effect of fabrics after laundering of 1, 5, 10 and 20 times.

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