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Application of nanogold in woolen textiles dyeing

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ABSTRACT

Nanotechnology has a widespread application in textile fields, especially in technical textiles, finishing, and dyeing processes. Accordingly, in this research, we investigated the effect of nanogold as a mordant for woolen textile dyeing. The purpose of this research was to produce a multifunctional woolen textile by applying nanogold particles as a novel mordant. Therefore, after the yarn purification and neutralization, the yarns were pre-treated with nanogold (60ppm) in boiling water for 1 hour and then were dyed using the onchrome method. Nanoparticles and dyed yarns were subsequently assessed through DLS, EDS, FESEM, SEM, washing fastness, light fastness, and antibacterial properties. The obtained results indicated that nanogold was absorbed by the wool and the washing fastness was enhanced without affecting softness and causing stains whereas light fastness remains constant. Furthermore, the yarns showed excellent antibacterial properties against Gram-positive and Gram-negative bacteria, namely Escherichia Coli and Staphylococcus Aureus.

KEYWORDS: *Woolen textile, Nanogold, Dyeing, Mordant dye, Multifunctional finishing.*

1. Introduction

Wool is one of the most important fibers in the textile business, with a long history. Wool fibers are used to make many types of clothing, socks, gloves, hats, and carpets. From ancient times to the present, man has attempted to improve the quality of textiles by felting, weaving, knitting, dyeing, and finishing procedures, and wool fibers, among others, play a unique role in human life [1-3].

Wool has been dyed for textiles and garments as fiber, yarn, felt, and fabric. As a result, a variety of natural and synthetic dyes are applied in the wool dyeing process, as well as mordants, to increase light and wash fastness. Metallic salts, oil, and tannin-based mordants are popular materials used in different dyeing processes such as onchrome, metachrome, and afterchrome, which have long been implemented [4, 5].

Furthermore, rather than acidic mordants, metallic mordants are becoming more popular, and several kinds of metallic compounds are made from these components, which include chromium, aluminum, iron, copper, and tin [6, 7].

Other metal compounds, such as silver and gold salts, have a long history as colorants, and colloidal forms of these elements have been employed as colorants in a variety of industries, including glass and textiles [8-10].

Gold nanoparticles (AuNPs) have recently attracted increasing attention due to unique qualities such as hue and shade variation, UV protection, antimicrobial properties, and higher biocompatibility, and several researchers are focusing on using them in textile and garment production [11].

Nanogold colloids of various particle sizes (10-100 nm) have been used to color natural fibers such as silk, wool, and cotton directly, and other studies have focused on the in situ synthesis of AuNPs on fibers and textiles [8, 12].

Most of the previous research was applied mordant dyes (dyes fixative) for a long time as a traditional method in the wool dyeing process in handicrafts but we used nanogold as mordant instead of traditional ones. To the best of our knowledge, it is the first attempt to investigate the effect of AuNps usage as a novel mordant in the dyeing process for improving wash and light fastness, as well as providing multifunctional properties in woolen yarns.

2. Experimental details

2.1 AuNPs properties

Nanogold was purchased from Nanopadsharif Co. (Tehran, Iran). Chemical and particle size analysis of AuNPs were investigated through EDS, DLS, and FESEM.

2.2 Yarn properties and preparation

3 ply woolen yarns (hank) with 175 S t.p.m and 12 metric counts were purchased from Nasaji Nasle Emrouz Co. To eliminate contaminants from the yarns, an alkaline scouring technique was used according to Table 1. After 5 minutes, the samples were rinsed with distilled water and neutralized via acid acetic.

2.3 Dyeing process

Following the onchrome dyeing method, the coloring procedure consists of two steps: at first, the wool fibers were treated with nanogold (60ppm), potassium dichromate (9% w/w), and acid formic (6% w/w), and then the specimens were dyed (2g/l) in a fresh bath with selected chromic dyes (Figures 1 and 2). The chromic dye, Crom Fast Blue BGL, was also used in the dyeing process. Other chemicals were purchased from Merck Chemicals [4].

2.4 Wash fastness test

The wash fastness of the treated and untreated samples were evaluated according to standard ISIRI 10076. Treatment was applied for 30 minutes at 40 rpm and after the drying process at room temperature, a gray scale was used to compare the specimens.

Table 1- Scouring bath materials and condition

Materials	
Na_2Co_3	1 (g/l)
Detergent	1-3 (g/l)
Temperature	60 (°C)
Time	5 (min)
L:R	1:30

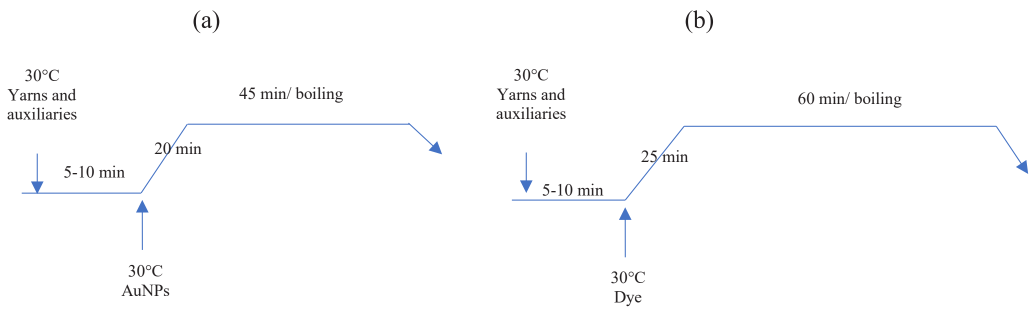


Fig. 1- The graph of (a) mordanting and (b) dyeing process.

Fig. 2- (a) AuNPs colloid and (b) dyed yarns.

2.5 Light fastness test

To compare the light fastness of the samples, treated and untreated wool yarns were exposed to artificial light generated by a xenon lamp for 72 hours in Xenostest Alpha instrument, and then according to standard ISIRI 205, through a blue scale, the light fastness of the samples was determined. On the blue and gray scale, samples are rated from 1, not enduring the light, to 5, showing no color change when exposed to the light.

2.6 FESEM/SEM

The particle size, shape, and morphology of nanogold were investigated through FESEM (Model: MIRA3TESCAN-XMU) and the surface morphologies of normal and mordanted wools were observed by SEM (Model: XL30, Philips, Netherland).

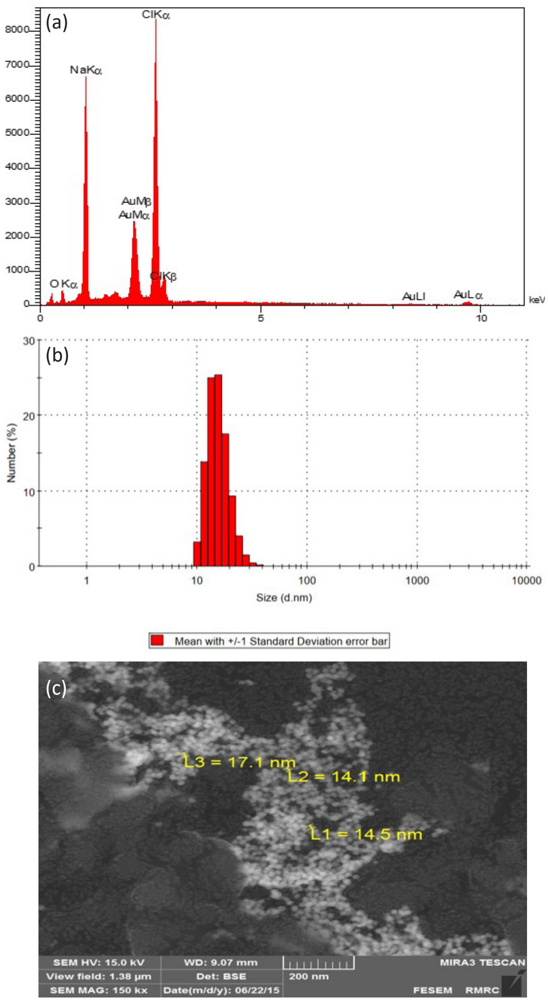


Fig. 3- (a) DLS, (b,) EDS, and (c) FESEM image of gold nanoparticles.

2.7 Antibacterial properties

AATCC100-2004 was used to investigate the antibacterial characteristics of mordanted and regular dyed wools (colony count test method). This approach is the industry standard procedure to assess the antimicrobial property of textiles by exposing the samples to Gram-negative (Escherichia coli) and Gram-positive (Staphylococcus Aureus) infectious bacteria [10]. So, the number of bacterial colonies that grew in the agar plate was counted, and the reduction of infectious bacteria colonies (R) was computed using Eq. 1. [13-15]:

$$R\ (\%) = (D_1 - D_2 / D_1) * 100 \qquad (1)$$

Where D_1 is the number of bacterial colonies at the initial point (0 h) of the test for the treated and untreated yarns, and D_2 is the number of bacterial colonies grown on the sample after one day (24 h) of exposure.

3. Results and discussion

3.1 AuNPs characteristics

To study the chemical properties and particle size of AuNPs, the Energy-Dispersive X-Ray Microanalysis (EDS), Dynamic Light Scattering (DLS), and Field Emission Scanning Electron Microscope (FESEM) were used. Figure 3 depicts the chemical analysis (a), nanoparticle size distribution (b), and FESEM image of the nanoparticles (c). Additionally, the chemical composition of the colloid was shown in Table 2. The EDS spectrum of AuNPs was observed in order to obtain the elemental composition of nanoparticles. According to the EDS profile, a prominent peak (around 2.3 keV) of nanogold was identified, confirming nanosized metallic gold particles in collied, which is made by the surface plasmon resonance property of AuNPs [16, 17]. Furthermore, gold elements constituted 7.99 and 39 of atomic and weight percent of the collied respectively.

3.2 Color fastness

Color fastness is one of the most important features of woolen textiles. Woolen textiles should

Table 2- Element composition of gold nanoparticles

Element	Weight (%)	Atomic (%)
O	7.34	18.50
Na	20.24	35.51
Cl	33.41	38.00
Au	39	7.99
Total	100	100

not lose their color due to washing or exposure to the sun during use. In addition, dyed woolen fibers should not stain other fibers during the washing process. Therefore, the wash and light fastness of the mordanted and regular dyed woolen yarns were studied and the results are shown in Table 3. According to the findings, wash fastness improved after mordanting, and the affinity of the dye to stain white wools reduced. This suggests that gold nanoparticles provide an ideal environment for dye and fiber to link and, therefore, boost dye absorption affinity of the fiber through the modification of the wool fibers. Furthermore, the light fastness of the dye was high, and determining the effect of mordant is not possible.

3.3 SEM

Figure 4 shows SEM images of a yarn (a), a fiber (b), and a scale of the wool fiber (c) which were treated with nanogold particles. The dispersion of AuNPs on the fibers is visible, and the presence of various sizes of gold nanoparticles indicated their strong affinity for wool. In addition, figure 4c confirms the fact that the nanogolds can thoroughly penetrate the fibers during the dyeing process. Due to the existence of boiling water, the fibers swell and some of the nanoparticles can move inside the wool fibers through the scales. This phenomenon increases the wash fastness of the dyed wool fibers as well as their dye affinity.

Additionally, figure 4c signifies the presence of various contaminants and chemical compounds, which were used during the pretreatment and dyeing, caused the agglomeration of gold nanoparticles.

3.4 Antimicrobial properties

Some studies have shown that gold nanoparticles have antimicrobial properties. The pathogens, E. coli and S.aureus, were employed to test the antibacterial impact of the mordanted and conventionally dyed woolen yarns (Figure 5). The Gram-negative bacteria (E. coli) had an antibacterial property of 90.69 percent, while Gram-positive bacteria (S.aureus) had an antibacterial value of 94.20 percent, indicating that the Gram-positive infectious bacteria are more sensitive to nanogold particles. According to many studies, the internal structure of both bacteria has a significant influence on antimicrobial properties. Although both types of the infectious bacteria are negatively charged on the surface, Gram-negative bacteria have a higher negative surface charge. Due to their phospholipid outer membrane, they are more attracted to the positive charge of AuNPs on the surface, forming a coordination link between nanogolds and Gram-negative bacteria [12].

4. Conclusions

Gold nanoparticles have become one of the most important areas of nanometal study in recent years. AuNPs show unique properties such as antibacterial activity, biocompatibility, and UV absorption, which make them an excellent candidate for industrial and medicinal use. Among other things, the textile industry has benefitted

Table 3- Color fastness of mordanted and normal dyed woolen yarns

sample	Wash fastness	Light fastness	Staining on white wool fibers	Staining on other white fibers
Untreated woolen yarn	4	5	4-5	5
mordanted woolen yarn	5	5	5	5

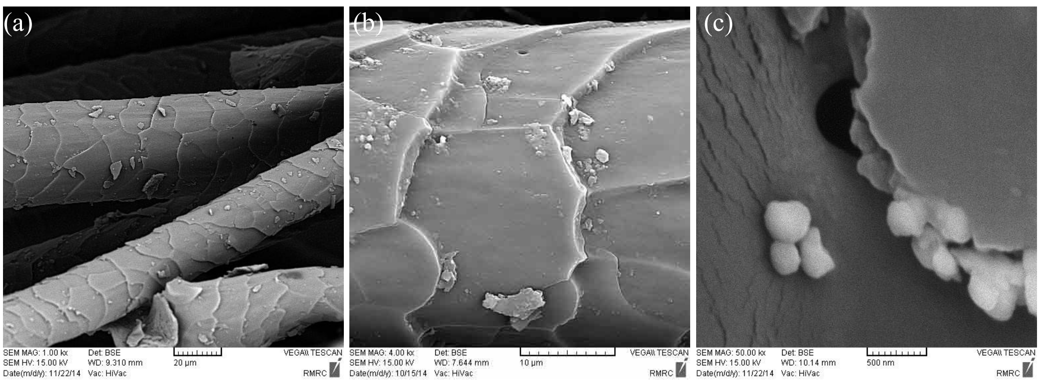


Fig. 4- SEM images of mordanted wool: a) yarn surface, b) fiber surface, and c) under the scale of wool fiber.

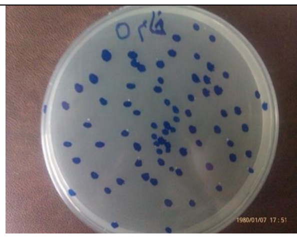
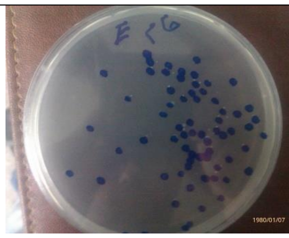
Sample	*S. aureus*	*E. coli*
conventionally dyed yarn		
AuNPS mordanted yarn		

Fig. 5- Antibacterial properties of conventionally dyed woolen yarns and AuNPs mordanted one against Staphylococcus aureus and Escherichia coli.

from AuNPs in dying and the production of luxury clothes. For the first time, nanogold as a mordant was used to improve wash fastness and created a multi-functional finishing for woolen textiles in this study. The results showed that mordanting wool with gold nanoparticles enhanced wash fastness while AuNPs had no negative impact on textile hand feel. Furthermore, the treated fabric has good potential against infectious bacteria.

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