

Using Eggplant Skin as a Source of Fruit Waste Colorant for Dyeing Wool Fibers

M. Parvinzadeh*¹, A. Kiumarsi²

¹ Ph.D. Student, Department of Textile, Islamic Azad University, Shahre Rey Branch, P.O.Box: 18735-334, Tehran, Iran.

² Assistant Professor, Department of Organic Colorants, Institute for Colorants, Paint and Coatings, P.O.Box:16765-654, Tehran, Iran.

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ABSTRACT

Today, natural colorants are emerging globally due to their safety and environmental friendly characteristics. Natural dyes have been employed in dyeing Persian carpet piles for many years. Food and fruit industry wastes are one of the main sources of colorants which can be employed for textile coloration. Eggplant (*Solanum melongena*), a member of the family Solanaceae, is used in food recipes. Anthocyanin pigments are responsible for the dark purple color of its skin. In this research, dyeing wool fibers was carried out using powdered skin of eggplant. For this purpose, the Iranian wool was first treated with some metal salts including Fe(II), Sn(II), Cu(II), Cr(VI) and Al(III). These salts are commonly used as mordant to improve the wash and light fastness of natural dyed textiles. The wool fiber was then dyed with 50% powdered skin of eggplant. The colorimetric properties of the dyed yarns were evaluated using a reflectance spectrophotometer. The wash and light fastness of the samples were also measured according to ISO 105-CO5 and Daylight ISO 105-BO1. Results showed that skin of eggplant is a potential source for dyeing wool fibers. Prog. Color Colorants Coat. 1(2008) 37-43. © Institute for Colorants, Paint and Coatings.

1. Introduction

For several centuries human have admired the beauties of natural colors of plants and minerals. Natural dyes have been known and used for painting of body and making foods for ancient humans for thousands of years [1]. The greatest use of natural dyes occurred when the art of weaving being developed [2-4]. Today dyeing processes based on natural sources have gained importance in view of stringent environmental and industrial safety conditions.

Innovative ideas in natural dyeing of textiles are being tried to cater to such needs [5, 6]. Natural sources of dyes processed for dyeing do not undergo any chemical operations. Those operations involved are purely physical, such as grinding, drying and water extractions. None of these operations create any great environmental problems. Special color effects are also achieved in fibers dyed with natural dyes with good washing properties. The combination of natural sources with new processes

*Corresponding author: mparvinzadeh@gmail.com

could improve to expand into the value added consumer goods [7].

Many studies have continued on natural sources of dyes covering such areas as: variation in the quantity of dyes in plants or other sources, combination of dyes, properties of natural dyes, effects of mordant and auxiliaries on different properties of dyed samples, enzymes for improvement natural dyes absorption, improvement in production of natural dyes, and the discovery of other natural sources [8-13]. The fastness properties of some natural yellow dyes with different mordants have been studied by Indian researchers [8-10]. They concluded that the presence of the mordant does not affect the fastness characteristics of henna, kamala and turmeric, while onion and dolu are capable of forming stable complexes with metal ions, in which the application of mordants improves the fastness properties of dyed fibers. Syed Ishrat Ali also suggested that during dyeing procedure with natural dyes, mordants react with some functional groups from dye molecules and the fiber, and make metal complexes which increase the fastness properties [11].

Many research papers have been published on dyeing of rug piles with natural dyes but few research papers deal with dyeing, in which they are using food wastes [14-17]. Waste materials from fruits processing units can be used directly in dyeing rug piles with no necessary processing, in advance. Commercial and institutional food waste producers including restaurants, supermarkets, school cafeterias, hospitals, food processors, farmers, hotels, prisons, employee lunch rooms and parks, and community events, can introduce fruit wastes to dyeing sectors for producing added value products [18,19]. In our previous studies on some fruit wastes such as: onion, pomegranate and walnut husks, several bright shades of dyed wool yarns were produced using ammonia treatment [15-17].

The eggplant, a member of the family *Solanaceae* (also known as the nightshades) and Genus *Solanum*, is a vegetable of dubious origin. It is mostly believed to be originated in China some 4000 years ago, which was then introduced into the Mideast by Arab traders in the 8th century. Others believe that it was first originated and domesticated in India, and then brought home by members of Arab armies in the 7th century. Others yet say, it has been grown and eaten as a vegetable in Iran since 1500 BC [20-22]. Fruit and plant color is affected during eggplant domestication. Anthocyanins are the largest group of water-soluble pigments in the plant

kingdom which are present in the skin of eggplant. They are also responsible for most of the red, purple and blue colours exhibited by flowers, fruits and other plant tissues, and have found applications in the food industry as natural colorants. This group of pigments is proved to be antioxidants with anti-cancer properties [23].

In this article, the skin of eggplant was used in dyeing wool yarns as rug piles, and the effect of metal salts as mordants on the dyeing properties was investigated.

2. Experimental

2.1. Materials and chemicals

The wool was Iranian yarn of 430/2 tex and 144 twists/m. The nonionic detergent was used for the scouring of wool yarns. It was obtained from Shirley Development Limited. Mordants. Other chemicals, including: aluminium potassium sulfate, copper sulfate, potassium bichromate, ferric sulfate and stannous chloride from Merck, were used for pre-mordanting of wool yarns. Acetic acid 85% (Merck) was applied for pH adjustment in mordanting and dyeing processes. Skin of Iranian eggplant was dried, powdered and used for dyeing.

2.2 Sample preparation

Scouring

The yarns were scoured in 5% nonionic detergent. The L:G (liquor to good ratio) of the scouring bath was kept at 50:1 for 25 mins at 75°C.

Mordanting

The scoured yarns were divided into sixteen parts. One part was retained untreated for references and the others were each mordanted with aluminium potassium sulfate, copper sulfate, potassium bichromate, stannous chloride and ferric sulfate (5, 10 and 15% w/w). The L:G of mordanting was 50:1. Acetic acid was used in the mordanting bath for adjusting the pH 5. The process was started at 40°C and then was gradually raised to the boiling point during 20 mins. Finally the mordanting bath was boiled for 1hour.

Dyeing

The eggplant skin powder was poured into water (0.1 w/w) and left for 24 hrs. The pH of the dyebath was kept at 5 by adding acetic acid (1.5 M). The concentration of skin powder was 50% of sample and the L: G was kept at 50:1. The dyeing started at 40°C and the

temperature was raised to 85°C over 20 mins. Finally, the dyeing was carried out at this temperature for 1 h.

Washing

The dyed yarns were washed in 5% nonionic detergent. The L:G (liquor to good ratio) of the washing bath was kept at 50:1 for 15 mins at 50°C.

Tests

Reflectance measurement

CIELAB color coordinates of dyed samples (L^* , a^* and b^*) were measured using a spectrophotometer COLOREYE 7000A from Gretagmacbeth integrated with an IBM computer. Color co-ordinates were calculated from the reflectance data for 10° observer and illuminant D_{65} .

Determination of color fastness

The wash-fastness properties of the dyed yarns were measured according to ISO 105-C01. ROTOWASH COLOR FASTNESS TESTER from SDL Company was used for wash fastness test. The color hue changes of the yarn and the degree of staining on the adjacent yarns were measured after drying.

For light-fastness measurements, the yarns were exposed to the daylight for 4 days according to the daylight ISO 105-B01, and the changes in the color (fading) were assessed by the blue scale.

3. Results and discussion

3.1. Color measurement

The results of color measurement of mordanted and dyed samples are shown in Table 1. Skin of eggplant gave a reddish yellow on wool. The color obtained on application of aluminium potassium sulfate, potassium bichromate and stannous chloride were dark dull reddish yellow. Copper sulfate made a dark dull greenish yellow on wool and it was dark orangish-yellow for wool treated with ferric sulfate. For the sample dyed with skin of eggplant without using metal salts, the L^* was 70.06 which clearly shows the relatively poor absorption of anthocyanin on the fiber. On the other hand, the amounts of L^* (lightness) were decreased for all of the samples treated with any mordants, and the more the concentration of mordants was, the less the L^* values of dyed samples were. More decrease in the L^* value was observed, with increase of copper sulfate percentage in the mordanting bath. Pre-treatment of fibers with different mordants caused an increase in the absorption

of pigments into the wool fibers. The color shades of the dyed wool fibers also was depended on the type of mordant. The redness values (a^*) of the mordanted samples were different from the non-mordanted one. The a^* values of the samples mordanted with copper sulfate were less comparable to other mordanted samples, and the hue changed from yellow-red region to yellow-red region among others.

3.2. Fastness properties

The wash fastness and staining on adjacent materials were measured for mordanted and dyed wool yarns. All of the mordants improved the wash fastness and bleeding behavior of dyed wools from 4 up to 5, where being compared to grey scale standards.

The results of light fastness tests are shown in Table 2. According to the results, the light fastness was improved by all mordants. Stannous chloride shows the best light fastness properties on wool yarns when comparing to other mordants. Light fastness results follow the results obtained from the wash fastness measurement. The mordanting process caused to increase the dye absorption into the fiber, due to complex formation, resulting darker shades and less vulnerable to the action of light.

Wool yarns as rug piles were first treated with different metal salts and then dyed with powdered skin of eggplant. Some properties of the dyed samples including; colorimetric, wash and light fastness were evaluated. All metal salts used contributed to the resulting shade of the dyed samples and are measurable according to the color intensity. The color values were evaluated in CIELAB color space, i.e., the three axes namely as; L^* , a^* and b^* . The L^* is the color coordinate which represents the lightness of samples and can be measured independently of the color hue. Any decrease in the lightness of samples could be concluded as the more color absorption by the fiber. The a^* stands the horizontal red-green color axis. The b^* represents the vertical yellow-blue axis.

Metal ions form a coordination complex with the electron donor functional groups (OH, CO) of the anthocyanin molecule extracted from the skin of eggplant. They, Along with the functional groups of the wool proteins (NH_2 , COOH), provide a bridge between the dye and the wool. Figure 1 shows the metal complex between aluminium and the functional groups of the wool. The Improvement of the wash fastness properties of samples could also be attributed to this anthocyanin-metal-wool complexes. Figure 2 illustrates this complex formation.

Formation of this complex with dye molecule is also responsible for dramatic changes in color. This is likely

to be due to the incorporation of the metal atom into the delocalized electron system of the anthocyanin molecule.

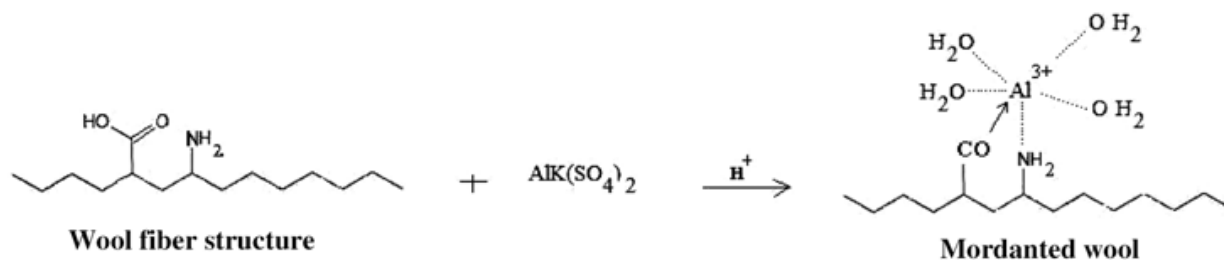


Figure 1: Complex formation between the functional groups of the wool protein and the aluminium cation at pre-mordanting process [5, 14, 15].

Table 1. The L*, a*, b*, C* and h values of the mordanted-dyed wool yarns.

Sample	Mordant %	L*	a*	b*	C*	h
Non-mordanted	-	70.06	5.27	37.94	47.31	40.07
Aluminium potassium sulfate	5	63.34	5.77	36.34	55.21	64.31
	10	61.96	6.31	33.98	59.33	63.81
	15	59.63	6.10	31.66	66.71	66.27
Copper sulfate	5	44.34	-0.73	28.32	79.25	71.91
	10	42.65	-0.90	26.02	83.40	80.72
	15	40.64	-0.91	25.55	85.08	85.03
Potassium bichromate	5	56.96	3.47	37.53	61.49	62.99
	10	53.14	3.85	37.18	63.00	67.24
	15	52.02	4.02	37.74	63.75	59.88
Ferric sulfate	5	52.74	8.73	20.11	60.28	54.44
	10	52.08	8.33	20.53	68.82	50.31
	15	51.76	8.76	19.45	69.31	59.90
Stannous chloride	5	65.77	6.09	41.11	58.56	93.56
	10	65.36	7.45	41.74	65.87	87.42
	15	64.98	7.83	41.96	70.85	85.01

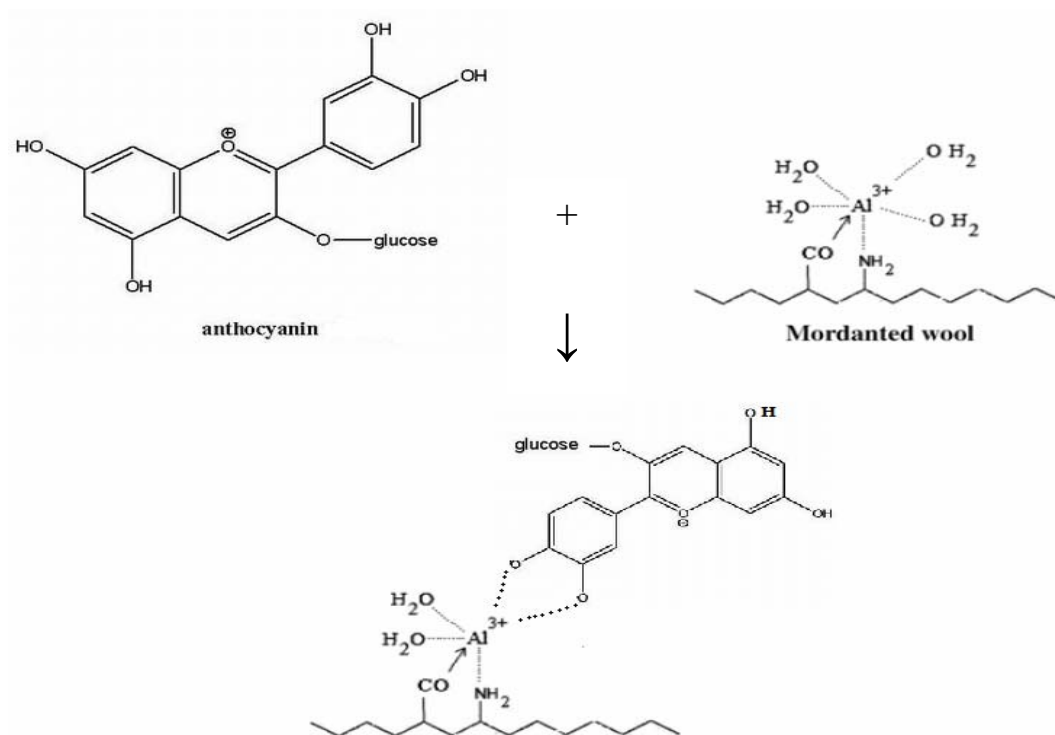


Figure 2: The complex formation between anthocyanin-aluminium-wool [5, 14, 15].

Table 2. The results of light-Fastness tests of mordanted-dyed wool yarns.

Sample	Mordant %	After 4 days
Non-mordanted	-	4-5
Aluminium potassium sulfate	5	5
	10	5
	15	5
Copper sulfate	5	5-6
	10	6
	15	6
Potassium bichromate	5	6
	10	6
	15	6-7
Ferric sulfate	5	5
	10	5-6
	15	6
Stannous chloride	5	7
	10	7
	15	7

All of the mordants improved the wash fastness and bleeding behavior of dyed wool on adjacent fibers. For the wash fastness tests of colored textiles, a piece of dyed textile was sewn together with a white piece of cloth and washed according to the standard procedure. The discoloration of the white piece of textile or, in other terms, the bleeding properties of the dye was recorded. As for the most general properties of dyes, five classes could be used for characterizing wash fastness, namely as grey scale which referred to: class 1; very poor, class 2; poor, class 3; fair, class 4; good, and class 5; excellent.

In the case of light fastness, 8 pieces of different dyed fabrics which formed the blue scale were exposed to the light at the same time as the test was proceeded for the specimen in order to determine and take into account any differences between various light fastness testers. After the exposure, the degree of fading of the test specimen was compared the blue scale. In this test any light fastness above 5 out of 8 was considered as the good light fastness.

Light fastness was also improved on mordanted-dyed samples. The strong complex formation between fiber, dye and metals contributes to the improved fastness properties.

4. Conclusions

The wool yarns as rug piles were first treated with different metal salts and then dyed with the extracted

solution of eggplant skin. Some properties of dyed samples including colorimetric, wash and light fastness were evaluated. Significant color changes were observed for mordanted yarns compared to non-mordanted ones. It was believed that the incorporation of the metal atoms into the delocalized electron system of the anthocyanin through the formation of metal complexes was likely to be responsible for these color changes. All of the mordants improved the wash fastness and bleeding behavior of wool and cotton adjacent fibers. Light fastness was also improved on samples. The strong complex formation between fiber, dye and metals also contributes to the fastness properties. According to the results, aluminium potassium sulfate and stannous chloride were desirable mordants before dyeing of wool with skin of eggplant.

In this research, eggplant was suggested as a potential fruit waste for dyeing rug piles which is a valuable product, although the use of some metal salts for obtaining the desired color fastness was a disadvantage. As a result, some synthetic dyes used in dyeing sectors could be replaced by different fruit wastes, due to their ability to match the desired color, added value, economical and environmental aspects and availabilities.

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