INVESTIGATION OF COLOR STABILITY OF NATURALLY DYED DENIM GARMENTS

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Natural dyes represent an essential part of the world's ecological and cultural heritage; their selection and usage to create colors are common to all civilizations. In the new era of synthetic dyes, research is focusing on identifying environmental friendly dyeing solutions and on the need for a sustainable "green economy". Natural dyes provide important alternative to petrochemical-based dyes and offers environmental and social benefits in comparison with synthetic dyes. Natural dyes are organic compounds and are, therefore, vulnerable in some degree to the action of destructive agents such as light, moisture, detergents, which may conduct in color fading. The study provides useful information regarding color fastness properties of naturally dyed denim garments, obtained within ERANET CROSSTEXNET project VEGDENIM, coordinated by MODAZEN Turkey. Using conditions for the tests specified in different ISO and EN standards, a direct comparison of L*, a*, b* values, for change in color and staining were undertaken. The results of the study indicated that using Punica Granatum and Walnut Shells deeper and more stable shades of colors are obtained in comparison with Indigofera Tinctoria dyed denim samples. All treated samples highlights a change in color in the sense of fading which has occurred to the highest extent when exposed to artificial light and washing.

Keywords: vegetable dyes, denim, color fastness

INTRODUCTION

People never stopped adding colour to their life, starting from the clothes they wear, the cosmetics they apply on their face and the way they dye their hair. Colour is a reflection of our mood, feelings and personality. Today, dyeing is a complex, specialized science. Nearly all dyestuffs are now produced from synthetic compounds. This means that costs have been greatly reduced and certain application and wear characteristics have been greatly enhanced. Synthetic dyes are being used in all commercial applications. Large amounts of water are used to flush conventional synthetic dyes from garments and then this waste water must be treated to remove the heavy metals and other toxic chemicals before they can be returned to water systems (Sengupta and Singh, 2003).

European regulations are more stringent in terms of dye environmental impacts. Many countries are rich in natural and renewable resources and they often have expertise on how to produce and process these resources in a sustainable way. Although the Earth possesses large plant resources, only little has been exploited so far. More detailed studies and scientific investigations are needed to assess the real potential and availability of natural dye-yielding resources. Almost all parts of the plants produce dyes. It is interesting to note that over 2000 molecules used for dyeing are synthesized by various parts of plants, of which only about 150 have been commercially exploited (Siva, 2007).

In developing countries with a textile tradition, natural dyeing is still practiced, but only as a handcraft. Recently, a number of commercial dyers have started looking at the possibilities to overcome environmental pollution caused by the synthetic dyes, by replacing them with natural dyes. Natural dyes produce soft shades as compared to synthetic dyes. In spite of the better performance at multiple washing, recently the potential use of natural dyes on textile materials has been attracting more and more scientist to study the natural alternative for dyeing due to the following reasons: wide spread of natural dyes sources and huge potential; available experimental evidence for allergic and toxic effects of synthetic dyes; available information on different natural colorants, including methods for their extraction and purification.

For successful commercial use of natural dyes, appropriate scientific techniques need to be established by scientific studies on dyeing methods, dyeing kinetics and compatibility of selective natural dyes, in order to obtain shades with acceptable colour fastness behavior and reproducible colour yield (Samanta, 2009).

In the last few decades, denim garments has gained popularity unimaginable for those who initially wore it for protection, rather than for fashion. Denim has become a wardrobe staple. Fit, comfort and price are the most important factors affecting the purchase of denim jeans. Due to longer life span of jeans, the denim industry continues to hold an advantageous position over other types of apparel (Nayak, 2010). In 2010, Greenpeace published a report denouncing the pollution caused by the denim industry (Greenpeace, 2010). Apart from conventional cotton production, which can be one of the most water-consuming industries, the report was also critical of jeans laundry, printing and dyeing processes, which involve high water usage and heavy toxic metals such as cadmium, lead, copper and mercury. A renewed international interest has arisen in natural dyes due to increased awareness of the environmental and health hazards associated with the synthesis, processing and use of synthetic dyes (Ali *et al.*, 2007). Most of the natural dyes have no substantivity for the fiber and are required to be used in conjunction with mordants. A mordant, usually a metallic salt, is regarded as a chemical, which will be fixed on the fiber and which will attach the dyestuff. A link is formed in this way between the fiber and the dye (Singh and Purohit, 2012). The uptake of the dye into the fibres depends on the nature of the dye and its chemical constituents (Zaharia and Suteu, 2012).

The heavy metals detached from the traditional mordants, however, may contaminate the water and the environment, thereby jeopardising the original intention of using environmentally friendly dye for better protection of the environment (Chan *et al.*, 2002).

Coloring components are derived from roots, barks, leaves, fruits and flowers of plant. All plants show a certain reaction to the increasing of toxic elements concentration in soil, depending upon their sensitivity and exposure intensity. Some species of plants disappear, while others are stimulated by these elements. Different plant parts contain different heavy metals quantities, the highest ones being contained in roots and leaves, and the smallest in flower buds and fruit (Smical *et al.*, 2008).

EXPERIMENTAL

In recent years there has been a revival of the use of dyes and color of natural origin for coloring food, pharmaceutical, cosmetic and textile products. Colours obtained with vegetable dyes are warm and have particular nuances. Nevertheless they have two problems that are the same of the industry: color fastness and reproducibility. Colour fastness means the resistance of the colour when exposed to different procedures textiles may suffer during manufacture and use.

Considering the latest trends, MODAZEN Company started to gain interest in using natural dyes within their industrial denim garment production. For this reason MODAZEN INC initiated VEGDENIM project, financed through ERANET CROSSTEXNET Programme.

Vegetable materials of indigo (Indigofera tinctoria leaves powder), Punica granatum (pomegranate bark powder) and walnut shells (Juglans Species) were used to dye denim fabrics at optimized dyeing conditions and the resulted colour fastness of the dyed samples was evaluated through the following tests:

- color fastness to washing, according to SR EN ISO 105 C06: 2010
- color fastness to acid perspiration, according to SR EN ISO 105 E04: 2013
- color fastness to alkaline perspiration, according to SR EN ISO 105 E04: 2013
- color fastness to water, according to SR EN ISO 105 E01: 2013
- color fastness to artificial light, according to SR EN ISO 105 B02: 2003

Materials Used

- Denim naturally dyed samples, dyed with extracts of pomegranate, madder, walnut shells and indigo – supplied by MODAZEN INC (dyeing process is protected by a patent owned by the project coordinator);
- Adjacent multi-fiber, purchased from James Heal, England;
- ECE Detergent with phosphate, without optical brighteners, purchased from James Heal, England.

Testing Equipments Used during Evaluation

- Scourotester – for washing fastness;
- Memmert oven – for water and perspiration fastness;
- Hunterlab – used for measuring color change.

RESULTS

A number of 9 denim samples dyed with vegetable natural dyes prepared by MODAZEN INC. were tested by INCDTP in order to evaluate their colour fastness properties. Preliminary chemical and physical–mechanical tests were performed in order to characterize the denim garments.

The change in color has been made by visual assessment, using the 9 grades grey scale from James Heal, and confirmed by instrumental analysis performed by using Hunterlab equipment. Grades according to ISO 105 A02 have been atributed to each tested sample. An interpretation of the attributed grades: 1 = Poor durability of the colour; 2 = Moderate durability of the colour; 3 = Good durability of the colour; 4 = Very good durability of the colour; 5 = Excellent durability of the colour. Intermediate grades were also attributed.

Determination of Colour Fastness Properties

Table 1. Colour fastness test results

Colour fastness Test	Walnut shells		
	Sample code B 1	Sample code B 2	Sample code B 8
Washing	1-2	1-2	1-2
Acid perspiration	4-5	4	4-5
Alkaline perspiration	4-5	4	4-5
Water	4-5	4	5
Light	1	1	1
Colour fastness Test	Natural Indigo		
	Sample code B 5	Sample code B 6	Sample code B 7
Washing	2	3-4	3
Acid perspiration	3	4-5	4-5
Alkaline perspiration	2-3	4-5	4-5
Water	2-3	4-5	4-5
Light	1	1	1
Colour fastness Test	Punica granatum		
	Sample code B 3	Sample code B 4	Sample code B 9
Washing	1-2	1	1
Acid perspiration	3	2-3	3
Alkaline perspiration	4	4	4
Water	3-4	4-5	4-5
Light	1	1	1

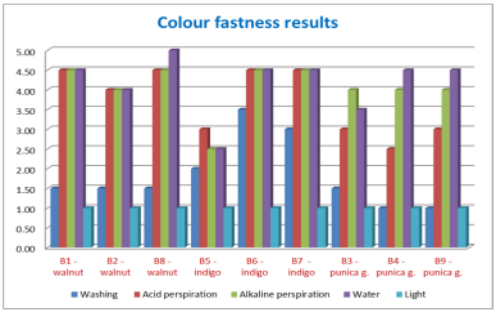

Figure 1. Graphic representation of colour fastness results

As it can be seen, the greatest modification of the colour has occured in the case of the following tests: colour fastness to light and colour fastness to washing. Acceptable results have been obtained for color fastness to water and perspiration in the case of using walnut shells and indigo dye.

Table 2. L*a*b* values obtained for naturally dyed denim samples

Colour fastness Test	B1 - Walnut shells		
Values	L*	a*	b*
Reference value:	55.07	1.11	7.34
Washing	62.90	-0.77	3.31
Acid perspiration	56.38	0.80	7.55
Alkaline perspiration	56.27	0.90	7.04
Water	55.52	0.94	6.58
Light	78.34	-0.43	4.57
Colour fastness Test	B 2 - Walnut shells		
Values	L*	a*	b*
Reference value:	54.84	0.87	6.89
Washing	63.63	-0.61	3.66
Acid perspiration	56.83	1.19	8.07
Alkaline perspiration	56.14	0.99	7.11
Water	55.98	1.00	6.68
Light	78.55	-0.32	4.54
Colour fastness Test	B 8 - Walnut shells		
Values	L*	a*	b*
Reference value:	58.52	3.22	17.29
Washing	65.18	2.22	16.74
Acid perspiration	59.15	3.66	17.88
Alkaline perspiration	58.08	3.87	18.58
Water	58.70	3.49	17.16
Light	70.52	1.03	13.64
Colour fastness Test	B 5 – Natural indigo		
Values	L*	a*	b*
Reference value:	69.99	-2.96	-11.16
Washing	76.94	-2.46	-7.02
Acid perspiration	74.25	-2.84	-8.44
Alkaline perspiration	74.62	-2.60	-8.12
Water	75.02	-2.85	-7.12
Light	88.71	-2.11	7.19
Colour fastness Test	B 6 – Natural indigo		
Values	L*	a*	b*
Reference value:	70.00	-3.02	-11.38
Washing	72.67	-2.56	-11.39

Acid perspiration	70.88	-2.70	-11.64
Alkaline perspiration	71.14	-2.72	-11.51
Water	69.56	-2.82	-11.95
Light	88.12	-2.21	6.07
Colour fastness Test		B 7 – Natural indigo	
Values	L*	a*	b*
Reference value:	71.38	-3.13	-11.04
Washing	73.59	-2.33	-11.03
Acid perspiration	71.03	-2.58	-11.44
Alkaline perspiration	71.01	-2.68	-11.67
Water	71.47	-2.56	-11.10
Light	88.22	-2.09	6.55
Colour fastness Test		B 3 – Punica granatum	
Values	L*	a*	b*
Reference value:	65.34	17.98	4.35
Washing	74.55	13.15	2.62
Acid perspiration	68.30	16.72	7.70
Alkaline perspiration	66.64	17.37	5.07
Water	67.18	17.10	4.25
Light	85.05	5.77	5.96
Colour fastness Test		B 4 – Punica granatum	
Values	L*	a*	b*
Reference value:	64.19	18.48	4.96
Washing	75.25	10.64	7.22
Acid perspiration	68.88	16.74	8.22
Alkaline perspiration	65.81	17.75	5.85
Water	64.24	18.03	5.32
Light	82.14	6.12	6.43
Colour fastness Test		B 9 – Punica granatum	
Values	L*	a*	b*
Reference value:	55.09	21.84	8.89
Washing	66.10	19.37	8.59
Acid perspiration	58.55	19.37	8.59
Alkaline perspiration	57.80	20.14	6.98
Water	56.24	20.36	6.77
Light	80.45	7.79	8.33

Analysing the data obtained it can be seen that all the samples have been losing saturation, samples luminosity has increased and the shade was altered. The data obtained through visual assessment was confirmed: the most significant fading was observed in the case of samples submitted to washing and to artificial light for denim garments dyed with natural indigo, followed by pomegranate. The best results obtained were noticed in the case of using walnut shells.

The colour degradation has reached the lower limit (grade 1) according to the 9 grade scale after 5 consecutive washings for the denim samples dyed with extracts of walnut shells and pomegranate and after 7 consecutive washings for the denim samples dyed with natural indigo.

CONCLUSION

Over the past few years natural textiles have been developed out of a growing awareness of the environmental, health-related and social problems caused by the conventional production of textiles. Many producers are also realising that low consumption and more careful and efficient use of water, energy and raw materials bring benefits to their performance. There is clear evidence that opportunities exist for optimizing the use of natural resources, while simultaneously creating opportunities for cost savings and increased competitiveness. Textile

industry is continuously searching for new technologies in order to accomplish the consumer's demands. In recent years, there has been a revival of the use of dyes and colors of natural origin for coloring textile products. This increasing demand for the material with natural origin is because of the health hazards attributed to some of the synthetic dyes.

Natural dyes are subjected to more destructive agents who can fade significantly the color of a naturally dyed product. Considering the low affinity for natural dyes specific for cotton fibers used within traditional denim garments, the purpose of this study was to assess the fastness properties of the preliminary samples obtained by MODAZEN INC within Crosstexnet EraNet Project acronym VEGDENIM.

Laboratory tests were performed, according to specific standardized methods. The visual assessment of the samples subjected to different treatments was confirmed instrumental results. All samples highlight a change in colour in the sense of fading, which has occurred to the highest extent at exposure to artificial light and washing. Slightly fading has been observed also for the other performed tests, but to a much smaller extent. As a conclusion generated from the information gathered so far: colour fastnesses of denim naturally dyed samples are generally poor. Lower limit of color change (grade 1) is reached after 5 to 7 consecutive washings.

From the sustainability point of view it is desirable to use natural dyes to a greater extent. An intensified use of renewable raw materials represents a substantial contribution to sustainable development and reduced environmental impact.

There is clear evidence that opportunities exist for optimizing the use of natural resources, while simultaneously creating opportunities for cost savings and increased competitiveness.

As a conclusion generated from the information gathered so far: colour fastnesses of denim naturally dyed samples are generally moderate. Optimization of the dyeing procedure is necessary.

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