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# COLOR STABILITY OF NATURALLY DYED DENIM FABRICS

**SUBTIRICA Adriana-Ioana[1], TASKOPARAN Fazilet[2], GHITULEASA Carmen[1], VAMESU Mariana[1]**

[1]*The National R&D Institute for Textile and Leather, 030508, Bucharest, Romania, E-Mail: adriana.subtirica@certex.ro*

[2] *Modazen INC, Istanbul, Turkey, E-Mail: ftaskoparan@modazen.com*

Corresponding author: Subtirica Adriana, E-mail: adriana.subtirica@certex.ro

***Abstract:*** *The desire to colour textiles is as old as spinning and weaving. Natural dyes have been used since thousands of years for their long endurance, soft and elegant colours. But the invention of synthetic dyes has limited the application of natural dyes. The health hazards associated with the use of synthetic dyes and also the increased environmental awareness have revived the use of natural dyes during the recent years. The major performance characteristic of a dye is its ability to maintain the colour in normal use and is known as colorfastness. The study provides information regarding colourfastness properties of naturally dyed denim fabrics. Three vegetable materials were used for dyeing denim fabrics: Punica granatum (bark powder), Indigofera tinctoria (leave powder) and Juglans regia (walnut dried shells). The results of the study indicated that using Walnut shells and Punica granatum deeper and more stable shades of colors are obtained in comparison with Indigofera Tinctoria dyed denim samples. All samples highlight a change in color in the sense of fading which has occurred to the highest extent when exposed to artificial light and washing. When tested against water, alkaline and acid perspiration, it is noticed that better results are obtained, and color change appear in a smaller extent.*

***Key words:*** *vegetable dyes, denim, color fastness, efficiency, fading*

## 1. 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. [1]

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. The economy should have only to realize that abundant dye sources are just around us and finding another valuable use for these plants coupled with appropriate technology can encourage more people to conserve these resources. 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 pigments are synthesized by various parts of plants, of which only about 150 have been commercially exploited [2].

In developing countries with a textile tradition, natural dyeing is still practised, 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.

Technology for production of natural dyes could vary from simple aqueous extraction to complicated solvent systems or to sophisticated supercritical fluid extraction techniques, depending on the product and purity required. Purification may consist in filtration or reverse osmosis or preparatory HPLC, and drying of the product may be obtained by spray or under vacuum or using a freeze-drying technique.

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 [3].

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 [4]. In 2010, Greenpeace published a report denouncing the pollution caused by the denim industry [5]. 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 [6]. 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 [7]. In general, textile fibres can allow the adherence of the dyes in their structures as a result of van der Waals forces, hydrogen bonds and hydrophobic interactions (physical adsorption). The uptake of the dye into the fibres depends on the nature of the dye and its chemical constituents. The strongest dye-fibre attachment is a result of a covalent bond with an additional electrostatic interaction where the dye ion and fibre have opposite charges [8].

## 2. EXPERIMENTAL PART

The textile production companies consider two options to overcome the ecological impact of finishing procesess: the high-tech wastewater treatment solution, which involves high implementation costs and the alternative of making the dyeing process more eco-friendly by using dyes obtained from renewable resources. Considering the latest option, MODAZEN Company started to gain interest on using natural dyes within the industrial denim garment production. For this reason MODAZEN INC initiated VEGDENIM project, financed through ERANET CROSSTEXNET Programme.

In the last ten years, the demand for natural dyes and the interests generated by them has been going hand in hand with fashion trends. 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. Denim garments are dyed in aqueous solutions of dyestuffs, together with dyebath additives such as salt, alkali, acids and other auxiliary chemicals. The dyestuff must first be absorbed onto the fibre surface and then diffuse into its interior.

In the present work, vegetable materials of *Indigofera tinctoria* (leaves powder), *Punica granatum* (pomegranate bark powder) and *Juglans* (walnut shells) were used to dye denim fabrics at optimized dyeing conditions and the resulted colour fastness of the dyed samples was evaluated (colour fastness to washing, acid & alkaline perspiration and light).

Known natural destructive agents for vegetable dyes are light, moisture, oxygen and other atmospheric gases which can lead to fading. Most dyes are organic compounds, therefore are sensitive to the action of destructive agents.

For evaluation of naturally dyed denim fabrics, the following tests were performed:

- 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

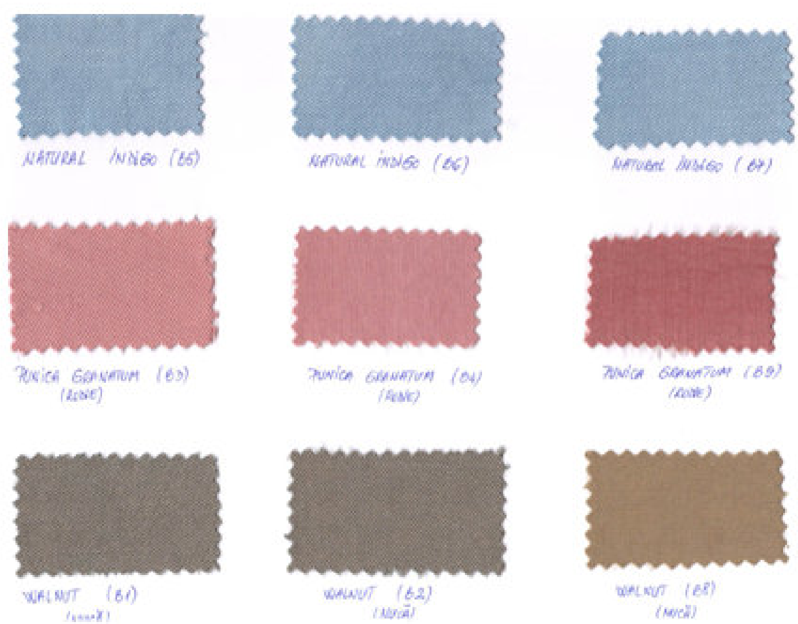
Materials used:

- Denim naturally dyed samples, dyed with extracts of pomegranate, walnut and indigo – supplied by MODAZEN INC (dyeing process is protected by a pattent 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
- Xenotest Appolo – for light fastness
- Hunterlab – used for measuring color change

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.




***Picture 1:*** *Naturally dyed denim samples*

## 3. RESULTS AND DISCUSSIONS

The results of physical-mechanical tests suggested that different base materials were used during preliminary dyeing procedures:

***Table 1:*** *Physical-mechanical test results*

| Test / Applicable standard | | Sample code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 |
| 1. | Weight per unit area (g/m$^2$) | 400 | 395 | 397 | 341 | 381 | 386 | 384 | 349 | 343 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2. | Thickness (mm) | 0.84 | 0.84 | 0.84 | 0.75 | 0.84 | 0.84 | 0.85 | 0.73 | 0.85 |
| 3. | Density – warp (no. yarns/10 cm) | 368 | 363 | 366 | 552 | 363 | 364 | 361 | 502 | 447 |
| | Density – weft (no. yarns/10 cm) | 224 | 221 | 219 | 273 | 219 | 218 | 220 | 276 | 283 |
| 4. | Breaking force (N) warp | 1647 | 1554 | 1607 | 1678 | 1685 | 1756 | 1792 | 1433 | 1184 |
| | Breaking force (N) weft | 1146 | 1133 | 1018 | 626 | 1200 | 1333 | 1240 | 765 | 778 |
| 5. | Alongation at breaking (%) warp | 32.7 | 31.8 | 38.5 | 27.9 | 29.1 | 29.0 | 28.8 | 26.2 | 31.3 |
| | Alongation at breaking (%) weft | 18.58 | 17.7 | 20.1 | 12.2 | 17.73 | 18.56 | 18.22 | 13.25 | 12.2 |
| 6. | Tear resistance (N) warp | 60.4 | 58.3 | 56.3 | 30.3 | 40.1 | 40.5 | 39.7 | 28.9 | 55.8 |
| | Tear resistance (N) weft | 57.8 | 55.5 | 44.5 | 18.49 | 29.5 | 32.1 | 28.5 | 20.9 | 31.7 |
| 7. | Air permeability (mm/sec) | 24.84 | 25.76 | 29.32 | 19.52 | 30.54 | 30.26 | 29.10 | 17.56 | 17.06 |

The change in color has been made by visual assessment, using the grey scale from James Heal, and confirmed by instrumental analysis. 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

***Table 2:*** *Colour fastness test results*

| No. crt. | Color fastness test | Walnut shells | | | Natural Indigo | | | Punica granatum | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B1 | B2 | B8 | B5 | B6 | B7 | B3 | B4 | B9 |
| 1. | Washing | 1-2 | 1-2 | 1-2 | 2 | 3-4 | 3 | 1-2 | 1 | 1 |
| 2. | Acid perspiration | 4-5 | 4 | 4-5 | 3 | 4-5 | 4-5 | 3 | 2-3 | 3 |
| 3. | Alkaline perspiration | 4-5 | 4 | 4-5 | 2-3 | 4-5 | 4-5 | 4 | 4 | 4 |
| 4. | Water | 4-5 | 4 | 5 | 2-3 | 4-5 | 4-5 | 3-4 | 4-5 | 4-5 |
| 5. | Light | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

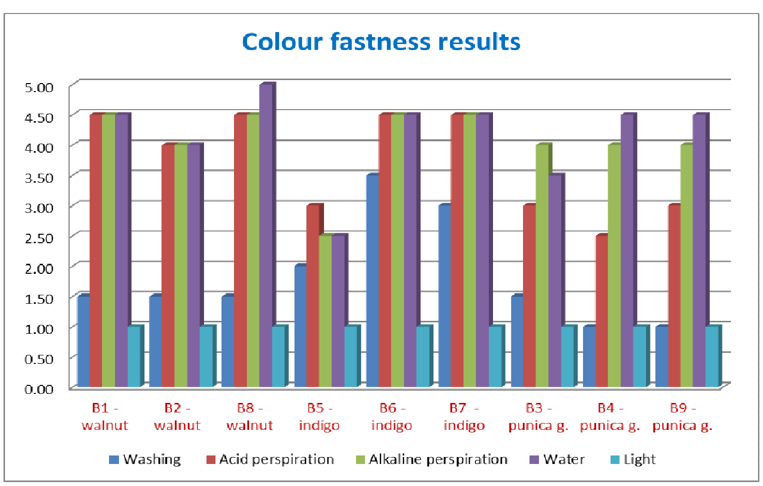


***Fig. 1:*** *Graphic representation of colour fastness results*

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 3:*** *L*a*b* values obtained for naturally dyed denim samples*

| **Sample:** | **B1 - Walnut shells** | | | **B5 - Natural Indigo** | | | **B3 - Punica granatum** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter: | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| Reference value: | 55.07 | 1.11 | 7.34 | 69.99 | -2.96 | -11.16 | 65.34 | 17.98 | 4.35 |
| Washing | 62.90 | -0.77 | 3.31 | 76.94 | -2.46 | -7.02 | 74.55 | 13.15 | 2.62 |
| Acid perspiration | 56.38 | 0.80 | 7.55 | 74.25 | -2.84 | -8.44 | 68.30 | 16.72 | 7.70 |
| Alkaline perspiration | 56.27 | 0.90 | 7.04 | 74.62 | -2.60 | -8.12 | 66.64 | 17.37 | 5.07 |
| Water | 55.52 | 0.94 | 6.58 | 75.02 | -2.85 | -7.12 | 67.18 | 17.10 | 4.25 |
| Light | 78.34 | -0.43 | 4.57 | 88.71 | -2.11 | 7.19 | 85.05 | 5.77 | 5.96 |
| **Sample:** | **B2 - Walnut shells** | | | **B6 - Natural Indigo** | | | **B4 - Punica granatum** | | |
| Parameter: | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| Reference value: | 54.84 | 0.87 | 6.89 | 70.00 | -3.02 | -11.38 | 64.19 | 18.48 | 4.96 |
| Washing | 63.63 | -0.61 | 3.66 | 72.67 | -2.56 | -11.39 | 75.25 | 10.64 | 7.22 |
| Acid perspiration | 56.83 | 1.19 | 8.07 | 70.88 | -2.70 | -11.64 | 68.88 | 16.74 | 8.22 |
| Alkaline perspiration | 56.14 | 0.99 | 7.11 | 71.14 | -2.72 | -11.51 | 65.81 | 17.75 | 5.85 |
| Water | 55.98 | 1.00 | 6.68 | 69.56 | -2.82 | -11.95 | 64.24 | 18.03 | 5.32 |
| Light | 78.55 | -0.32 | 4.54 | 88.12 | -2.21 | 6.07 | 82.14 | 6.12 | 6.43 |
| **Sample:** | **B8 - Walnut shells** | | | **B7 - Natural Indigo** | | | **B9 - Punica granatum** | | |
| Reference value: | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| Initial value: | 58.52 | 3.22 | 17.29 | 71.38 | -3.13 | -11.04 | 55.09 | 21.84 | 8.89 |
| Washing | 65.18 | 2.22 | 16.74 | 73.59 | -2.33 | -11.03 | 66.10 | 19.37 | 8.59 |
| Acid perspiration | 59.15 | 3.66 | 17.88 | 71.03 | -2.58 | -11.44 | 58.55 | 19.37 | 8.59 |
| Alkaline perspiration | 58.08 | 3.87 | 18.58 | 71.01 | -2.68 | -11.67 | 57.80 | 20.14 | 6.98 |
| Water | 58.70 | 3.49 | 17.16 | 71.47 | -2.56 | -11.10 | 56.24 | 20.36 | 6.77 |
| Light | 70.52 | 1.03 | 13.64 | 88.22 | -2.09 | 6.55 | 80.45 | 7.79 | 8.33 |

Analyzing the data obtained it can be seen that all the saples 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 Punica Granatum. The best results obtained were noticed in the case of using walnut shells.

## 4. CONCLUSIONS

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 - 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. Optimization of the dyeing procedure is necessary.

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