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COLOUR ANALYSIS IN THE CIE LAB SPACE REGARDING THE DYEING WITH WELD AND MADDER DYES

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Abstract: *In recent years, there is a great tendency for ecological dyeing and finishing of natural fabrics with natural dyes. Natural dyes obtained from nature were used for dyeing of textiles from ancient times till the nineteenth century. Weld (Reseda Luteola L.) produces the most stable yellow colour and shades and Madder (Rubia tinctorum L.) produces the most beautiful red colour and shades. These natural dyes were usually combined toghether to produce different shades of orange. Colour represents the bridge between science-art-industry, and can be described by various methods, with the following features: hue, saturation or purity (chroma) and brightness. Any colour can be defined by these three values which describe a unique color. The paper presents the colour analysis, resulting 16 variants of the ecological dyeing on hemp fabric with natural dyes Weld and Madder. In the colour analysis, the following was observed: the influence of the prior application of treatments for improving the absorption capacity of the dye (pre-treatments with enzyme and scouring and bleaching in one step), the influence of using different combinations and concentrations of dye (Weld-Madder combination and Madder-Weld combination), but also the colour resistance after washing on the tested samples. In order to have a general view over the colours obtained after dyeing with natural dyes on hemp samples, colouring measurements in the CIE LAB system with spectrophotometer 968 (X– Rite, USA), with light source D_{65} and observer of 10^0 (Enhanched polarization filter according to ISO/ DIS 13655) have been carried out.*

Key words: *combination of natural dyes, Weld, Madder, hemp, colour measurements*

1. INTRODUCTION

Worldwide, growing consciousness about organic value of ecological products has generated a renewed interest of the use of natural fibre, like hemp, dyed with natural dyes. In this context, an important attention has been focused on research to replace synthetic dyes, in a competitive manner, with natural dyes. Dyeing with natural dyes is a topical issue in the field of textile finishing.

Colour represents the bridge between science, art and industry. Nowadays, the science that studies the colours demonstrates a interdisciplinarity and occupies an important place in theoretical and applied fields, being one of the few disciplines that are linked to branches of knowledge, like art, chemistry, psychology, biology, physics and more [1]. As well is known, colour is one of the most fascinating phenomena which were enticed to chemistry, full comprehension compound needs knowledge of chemistry and spectroscopy. In the scientific field of chromatology, researchers place a special emphasis on the use of colours and chromatic combinations. In textile industry, colour is also particularly importants, the emphasis is mainly on the appearance of the products, because it is supposed to be one of the most important feature.

Natural dyes were used for dyeing of textiles from ancient times till the nineteenth century and as the name suggests, natural dyes are derived from natural sources from nature [2, 3, 4]. At present, application of natural dyes in the dyeing process is gaining popularity all over the world. Weld (Reseda luteola L.) is the flavonoid yellow dye source mentioned in traditional European recipes. The predominant chromophores found in this plant are the flavones luteolin, apigenin and glycosides like luteolin 7-O-glucoside [5]. Weld was usually combined with red dyes to produce different shades of orange [6, 7, 8, 9]. Madder (Rubia tinctorum L.) is a plant anthraquinone red dye, alizarin and purpurin are the main chromophores of this plant. Madder produces pigments in its roots, such as alizarin, pseudopurpurin, purpurin, munjistin, rubiadin, xanthopurpurin and also [2, 5, 6, 10]. The roots of Rubia tinctorum L. are the source of a natural dye and have been used to dye textiles in many parts of the world since ancient times [5, 7, 8, 11]. Madder gives a unique red colour to textiles, and also, combined with different mordants can produce shades that vary from pink to black, purple and red.

The science of colour measurement is an objective method of measuring colour, which takes into account three factors that determine the measured colour: light source, material characteristics and colour response of the observer, which fully characterizes the colour, being extremely precise.

From the research in this field, it is found that the need to approach the research related to colorimetry occurred as a result of implementing practical applications of colour spectrophotometric measurement in the textile industry, especially in the objective control of bleaching and dyeing processes.

2. EXPERIMENTAL

2.1. Materials and methods

In this experimental study the hemp fabric (fineness of warp yarn: Nm=10/2 and fineness of weft yarn: Nm=10/1 with specific weight: 276 g/m2) realised in Romania was used. Natural dyes Weld and Madder (supplied from Couleurs de Plantes, France) were used in the dyeing process. All experiments were performed with demineralized water in the Zeltex VISTA COLOR equipment and the 5 grams textile material was used as sample.

Pre-treatments of fabric: The fabric samples were previously treated by applying two treatments, scouring with enzyme (50°C, 1 h, BioPrep 3000L -Novoyzmes and non-ionic surfactant Triton X-100 -Sigma Aldrich) and scouring and bleaching in one step (98°C, 1 h, 5 g/L NaOH 38°BE, 33%; 1 ml/L Tannex CB; 5 ml/L H_2O_2; 2 ml/L Tanaterge Advance -Tanatex Chemicals B.V.).

Mordanting: The mordanting procedure was achieved using 0.8 gr of $Al_2(SO_4)_3$ at 98°C, 1 h.

Dyeing: The dyeing procedure involved the combination of natural dyes in different combinations (Weld-Madder combination and Madder-Weld combination) and concentrations of dye (5% and 10%), fabric: liquor ratio 1:30 at a temperature of 98°C, 1 h.

Colour fastness tests: Wash fastness was achieved in the Linitester equipment, at the temperature of 40°C, for 30 min. and evaluated according to ISO 105-C06 standard procedure.

2.2. Objective colour evaluation using Cie lab space

CIELAB system (1976) was introduced to describe the colour that results from three factors. The colour of the fibre is the result of three combined factors: the spectrum of the light source, the spectral reflectivity of the fibre colour, and the spectral sensitivity of the eye [12]. The system is a three-dimensional space, with coordinate axes L*, a*, b* where the L* axis denotes the lightness of the colour (L* of 0 corresponds to black, L* of 100 corresponds to white), a* represents the green-red axis (a* negative: green, a* positive: red), and b* represents the blue-yellow axis (b* negative: blue, b* positive: yellow). Each sample colour can be represented as a set of values for L*, a*, b*, and consequently as a point in this colour space. The colour representation method in the CIE Lab system uses the trichromatic X, Y, Z coordinates to define three other coordinates, as follows:

Coordinate for luminosity: $L^*=116\cdot f(Y/Y_0)$; **(1)**

Coordinate red-green: $a^*=500\cdot[\,f(X/X_0)-f(Y/Y_0)]$; **(2)**

Coordonata yellow-blue: $b^*=200\cdot[\,f(Y/Y_0)-f(Z/Z_0)]$. **(3)**

In these equations, X_0, Y_0 and Z_0 are the trichromatic coordinates for an object with perfectly white reflection, and are obtained from the following relations:

$$\begin{cases} X_0 = \sum_{\lambda=380}^{770} E(\lambda)\cdot\bar{x}(\lambda) \\ Y_0 = \sum_{\lambda=380}^{770} E(\lambda)\cdot\bar{y}(\lambda) \\ Z_0 = \sum_{\lambda=380}^{770} E(\lambda)\cdot\bar{z}(\lambda) \end{cases} \quad \textbf{(4)}$$

a *, b *=each represents a change in position in the chromatic chart, thus obtaining information regarding the displacement of the chromatic components of the colour of the samples, knowing that the axes correspond:

(+) a*- red colour;

(+) b*- yellow colour;

(-) a*- green colour;

(-) b*- blue colour.

Saturation increases as the distance from the origin increases.

L*=represents the luminosity component and has a positive value (+), if the sample is lighter, respectively (-) negative, if the sample is darker. If all values are positive, the higher it is, the lower the dye intensity.

It is also possible to calculate the colour difference (ΔE*) between two objects represented by the geometric distance between the points corresponding to the colours of the objects located in the colour space:

$$\Delta\boldsymbol{E}^* = \left(\boldsymbol{DL}^{*2} + \boldsymbol{Da}^{*2} + \boldsymbol{Db}^{*2}\right)^{1/2} \quad \textbf{(5)}$$

$$\Delta\boldsymbol{L}^* = \boldsymbol{L_1} - \boldsymbol{L_2} \quad \textbf{(6)}$$

$$\Delta\mathbf{a}^* = \boldsymbol{a_1} - \boldsymbol{a_2} \quad \textbf{(7)}$$

$$\Delta\mathbf{b}^* = \boldsymbol{b_1} - \boldsymbol{b_2} \quad \textbf{(8)}$$

$$\boldsymbol{C}^* = \sqrt{\boldsymbol{a^2} + \boldsymbol{b^2}} \quad \textbf{(9)}$$

ΔL* is the difference in luminosity between the colours of the two objects, Δa* is the difference between the red-green coordinates, Δb* is the difference between the yellow-blue coordinates, Δc* =saturation difference, Δh*=shade difference.

The CIE Lab system allows, in addition to the representation of its rectangular coordinates (L*, a*, b*) the representation of the cylindrical ones L*- luminosity, C*- saturation or purity (chroma), h- shade or hue.

3. RESULTS AND DISCUSSION

Colour measurement in the CIE lab space was performed with the 968 spectrophotometer (X-Rite, USA), with the D_{65} light source and the 10^0 observer (Enhanced polarization filter according to ISO / DIS 13655). Each sample was folded to provide opacity, as three measurements were made for each sample.

The colorimetric values are the coordinates of the green-red axes (a), the yellow-blue axes (b) and the Luminosity (L). The colorimetric values studied were the colour parameters L*, a*, b*, c*, which means L*=luminosity in percent, a*=red-green variation for positive and negative values in Adams Nickerson (AN) units, b*=yellow-blue variation for positive and negative values in units (AN), ΔL=difference in luminosity, Δa=difference between red-green coordinates, Δb=difference between yellow-blue coordinates, ΔE=difference in colour. C*=saturation or purity (chroma).

All these use in order to compare the colour on the samples dyed with 5% and 10% concentration of dye, and also, the samples after washing with detergent for colour testing ECE - Colour Detergent, with Phosphate for Fastness Test acc. ISO 105-C06 (Test Gewebe GmbH, Germany). The final values and and the results were presented in Table 1 and Table 2.

Table 1. *Cie Lab values for the combination of WELD and MADDER dyes*

	WELD-MADDER	5% concentration of dye				10% concentration of dye			
	Pre-treatments	L*	a*	b*	c*	L*	a*	b*	c*
1	scouring with enzyme	52,98	10,95	20,30	23,06	52,11	7,64	29,42	30,40
2	washed	52,56	9,98	25,10	27,01	55,02	4,18	35,98	36,22
3	scouring and bleaching	64,13	9,63	29,40	30,94	64,67	7,58	36,59	37,37
4	washed	65,88	6,54	34,80	35,41	64,41	5,41	44,35	44,68

	WELD-MADDER	ΔL*	ΔL*	ΔL*	ΔE*
	Pre-treatments				
1	scouring with enzyme	0,87	3,31	-9,12	9,74
2	washed	-2,46	5,80	-10,88	12,57
3	scouring and bleaching	-0,54	2,05	-7,19	7,50
4	washed	1,47	1,13	-9,55	9,73

Table 2. *Cie Lab values for the combination of MADDER and WELD dyes*

	MADDER-WELD	5% concentration of dye				10% concentration of dye			
	Pre-treatments	L*	a*	b*	c*	L*	a*	b*	c*
1	scouring with enzyme	55,02	7,51	26,20	27,26	47,63	15,20	22,10	26,82
2	washed	54,12	7,68	30,40	31,36	50,82	12,20	24,89	27,72
3	scouring and bleaching	61,52	14,78	25,10	29,13	58,23	18,20	27,91	33,32
4	washed	68,39	9,99	28,70	30,39	60,26	11,30	33,25	35,12

	MADDER-WELD	ΔL*	ΔL*	ΔL*	ΔE*
	Pre-treatments				
1	scouring with enzyme	7,39	-7,69	4,10	11,43
2	washed	3,30	-4,52	5,51	7,85
3	scouring and bleaching	3,29	-3,42	-2,81	5,52
4	washed	8,13	-1,31	-4,55	9,41

Figure 1 presents the graphical representation of values in the Cie Lab space for the combination of WELD and MADDER dyes.

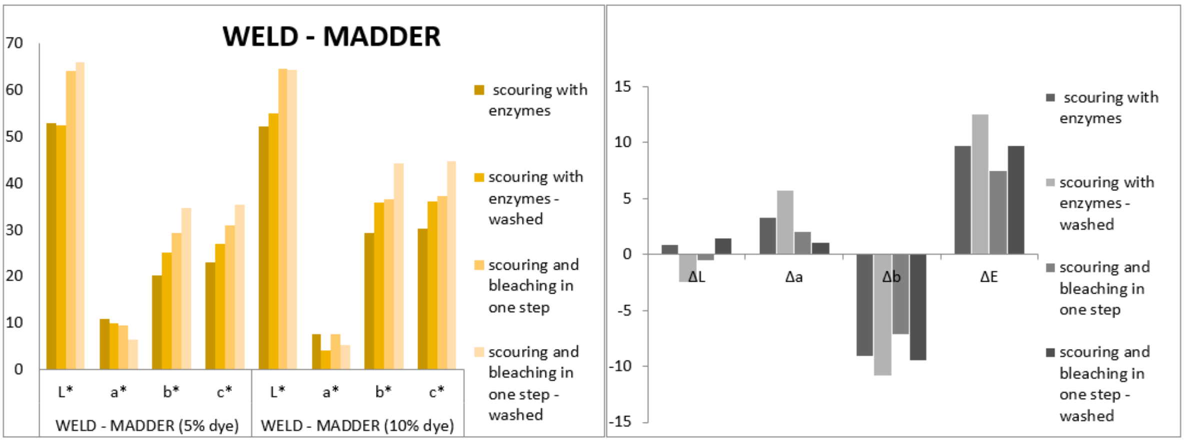

***Fig. 1**: Graphical representation of values in the Cie Lab space for the combination of WELD and MADDER dyes*

Figure 2 presents the graphical representation of values in the Cie Lab space for the combination of MADDER and WELD dyes.

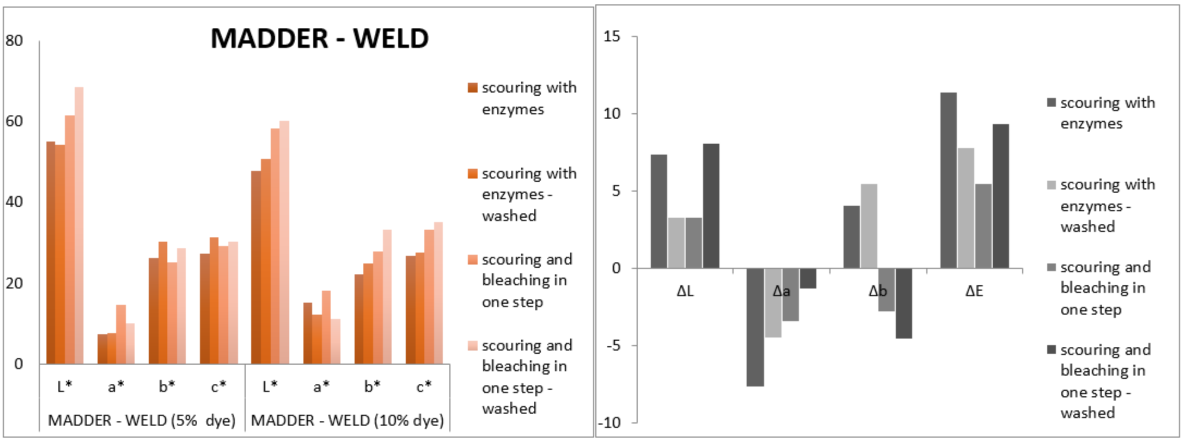

***Fig. 2**: Graphical representation of values in the Cie Lab space for the combination of MADDER and WELD dyes*

4. CONCLUSIONS

In this research, the colour parameters L*, a*, b*, c* were tested, which means L=brightness in percent, a=red-green variation for positive and negative values in Adams Nickerson (AN) units, b=yellow-blue variation for positive and negative values in (AN) units determined on spectrophotometer 968 (X - Rite, USA), with light source D_{65} and 10^0observer (Enhanced polarization filter according to ISO / DIS 13655).

From the data obtained we can observe that there is a marked differentiation between processes 1 and 2 (scouring with enzyme / washed) and processes 3 and 4 (scouring and bleaching in one step / washed) of the hemp support cleaning method. The influence is marked by the chromatic effect of the cleaning with enzymes which in processes 1 and 2 is brown, and in processes 3 and 4 it is white. From the analysis of data and values obtained, presented in Table 1 and Figure 1, the chromatic results show a majority yellow component, respectively with the data and values obtained from Table 2 and Figure 2, chromatic results show a majority red component. In all cases, by washing, a larger amount of dye is fixed on the textile support, as the oxygen dissolved in the washing water to the complexation process by mordanting probably interferes.

From the results of colour measurement in the Cie lab space it can be concluded that combination of natural dyes Weld and Madder are able to provide beautiful colours and shades. By using different pre-treatments and different combination or concentration of the dye we were able to carry out an efficient and eco-friendly process of hemp and developing a chromatic palette.

As a final conclusion, we can emphasize that the dyeing with natural dyes keeps spreading because it brings beauty and innovation in textile and fashion industry, but it also protects the humans health and environment.

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