EXPERIMENTAL RESEARCHES REGARDING THE ECOLOGICAL DYEING WITH NATURAL EXTRACTS

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Abstract:

*The concept of 'environmental awareness' has recently had a major impact on the textile industry and on the fashion world as well. In this context, the use of natural fibres and the development of natural dyeing processes gradually became important goals of the textile industry. Of all natural textile fibres, hemp is considered to be one of the strongest and most durable. A wide range of natural extracts have been used for natural textile coloration and dyeing. Dyes deriving from natural sources have emerged as an important alternative to synthetic dyes. Eco-friendly, nontoxic, sustainable and renewable natural dyes and pigments have been used for colouring the food substrate, leather, wood, natural fibres and fabrics from the dawn of human history. The purpose of the research is to obtain ecologically coloured fabrics for textiles by using a method of dyeing that relies on natural ingredients extracted from red beet, onion leaves and black tea. The experiments are conducted on three different types of hemp fabrics. This paper presents the results of the studies regarding the dyeing process of hemp fabrics with natural extracts, the colours of the dyed samples inspected with reflectance spectra and the CIE L*a*b* colour space measurements.*

Keywords:

Natural, extract, dyes, ecology, colours, analysis, hemp, fabrics

1. Introduction

The textile processing industry is well-known for being one of the biggest polluters in the world [5], mainly because it uses large amounts of processed water, chemicals and dyeing products that are harming the environment. Therefore, in order to suppress the negative impact of this particular industrial sector, there are two essential ways of protecting nature: building facilities that are efficient and big enough so as to treat the eliminated water and using eco-friendly dyeing products and chemical substances. [3]

Ecological considerations became a crucial factor in industry as early as the 1980s, when people grew more and more interested in using natural dyes when manufacturing textile products [30]. Even though everyone agrees that the use of artificial dyes harms the workers by facilitating the occurrence of allergies that are visible on the skin and the surrounding environment, as well by damaging the natural balance through contamination, not much has been done so far because such dyes are easily available, cheap and can produce a wide spectrum of colours. [26]

As the world becomes more and more aware that nature must be protected, the research community is putting a lot of work into identifying various ecological solutions for treating and finishing fabrics, as well as into developing technologies that would assure the creation of eco-friendly textile products, including the use of natural fabrics and dyes.

For this purpose, all natural fabrics such as hemp, one of the highest quality fibres with exceptional physical properties, high comfort, excellent durability and ecological manufacturing processes and, at the same time, one of the most environmentally friendly and versatile natural textile plants on Earth, has a promising potential. Also, fabrics made of hemp can be produced in a variety of weights and textures. Hemp not only possesses several excellent properties such as strength, warmth, comfort and durability, it is also considered to be an environmentally friendly plant because it does not require as many pesticides and herbicides to be successfully grown [15].

Dyeing is considered to be an art that goes back to the dawn of humankind. In Europe, dyeing techniques have been developed as early as the Bronze Age. From ancient times, natural dyes have been used for dyeing fabrics and apparel products [6, 10, 20].

Until the development of artificial dyes, the textile dyeing process was done with the help of colorants and pigments extracted from natural sources, such as plants, roots, stems, bark, leaves, berries and flowers. After the discovery of synthetic colorants, the natural ones were forgotten for quite a while. They were dismissed as being obsolete.

The raw materials used in the fabrication of natural dyes are mostly plant parts: leaves, roots, flowers, tree bark, and seeds [9, 13].

Nature has always been an extremely rich source of visual inspiration, even from early times when primitive man discovered vegetal pigments and the way to use it so as to give colour and life to textile products. At first, the dyeing techniques were rudimentary. The plants were attached to, rubbed against or crushed on the fabric. As man progressed, the dyeing methods and techniques became more and more sophisticated by boiling the fruit and plants when colouring the material [11, 16].

The natural pigments, considered to be renewable, biodegradable, eco-friendly and long-lasting, made a comeback as being a viable alternative to the excessive use of artificial colorants (about 10,000,000 tons a year) [5, 11, 16, 25], in the context of society being increasingly preoccupied with protecting the environment and staying healthy. As a consequence, the use of natural pigments when dyeing textile fabrics has become a global hot topic.

In textile dyeing, natural dyes extracted from various plants can be used for the coloration of both textile fibres and fabrics. Apart from the fact that all natural dyes have a better biodegradability and are more compatible with the environment, they also have a range of properties such as excellent softness, shininess and aesthetic appeal, aspects that are considered to be the most important attributes in the eyes of the consumers [2].

The technology of producing such pigments varies from the use of aqueous solutions to complicated solvent systems and sophisticated supercritical fluid extraction techniques, depending on the required product and purity. Generally, the fabrication of natural pigments consists of boiling the crushed powder with water and leaving it to steep in cold water [27]. Several researchers noticed that the extraction of natural pigments by inducing cosolvents leads to extracts that are not completely soluble in water [14, 23]. So far, literature and researchers focused on the application of natural dyes on various textile fabrics, mordants and mordanting methods and so on, recording their fastness properties and colorimetric data [17].

All natural dyes are eco-friendly and provide a wide range of beautiful shades with acceptable level of colour fastness [4, 7, 12, 28]. Various reports have been favourable to the behaviour and applications of natural dyes on textiles [1, 8, 22, 24, 29]. Natural pigments are considered safe because of their nontoxic, nonallergic and biodegradable nature [19, 25]. Many of the plants used for extracting natural dyes are classified as medicinal plants. Some of them were recently proved to possess remarkable antibacterial properties [21].

Currently, natural dyes are used in textile manufacturing, as well as in other industrial branches: cosmetics, pharmaceuticals, paint industries and so on, in order, to prevent the ecological issues caused by synthetic colorants. The art of dying by using natural pigments keeps spreading because it brings beauty and innovation in industry, but it also protects the environment and our health.

2. Experimental

2.1. Materials

This exploratory study was conducted in order to develop an ecological process of dyeing with natural extracts of red beet, onion leaves and black tea on three different types of hemp fabrics. The material used is 100% hemp fabric (three different types from TEXFIR, Romania). The following ingredients were used to treat the fabric: sodium hydroxide 38°BE, 33%, Tannex CB, Hydrogen peroxide 35% and Tanaterge Advance.

- Fabric 1: hemp 100%, fineness of warp yarn: Nm =10/2, fineness of weft yarn: Nm =10/1 and specific weight: 276 g/m²
- Fabric 2: hemp 100%, fineness of warp yarn: Nm =10/1, fineness of weft yarn: Nm =10/1 and specific weight: 400 g/m²
- Fabric 3: hemp 100%, fineness of warp yarn: Nm =14/1, fineness of weft yarn: Nm = 14/1 and specific weight: 250 g/m²

2.2. Methods

2.2.1. Pretreatment of fabrics (Scouring)

In order to obtain a high degree of white, the fabric samples were previously treated by scouring and bleaching. The experiments were conducted in the laboratory on a Linitester device. The optimal conditions were: temperature of 98°C, 1h of incubation time, Sodium hydroxide 38°BE, 33% Tannex CB, 5 ml Hydrogen peroxyde 35%, Tanaterge Advance). After completing the process, the samples were rinsed with water at 90°C for 1 hour on Linitester and then rinsed thoroughly with cold water and dried in an oven for 30 minutes at 50°C.

The scoured material was thoroughly washed with tap water and dried at room temperature. The scoured material was soaked in clean water for 30 minutes prior to dyeing.

2.2.2. Dyeing Process with natural extracts

The samples were dyed with extracts (see Figure 1) from red beet, onion leaves and black tea, at 1:40 liquor ratio.

- **Red beet:** it was cut into small pieces (3 kg) and put to boil in a dyeing bath with 2 litres of water at a temperature of 150°C, resulting in 1 litre of dye.
- **Onion leaves:** 600 grams of dried onion leaves were left to boil for 1 hour in 4 litres of water at 100°C, thus obtaining 2 litres of dye solution.
- **Black tea:** 500 grams of black tea was left to boil in about 2.5 litres of water at a temperature of 130°C for 50 minutes, resulting 1 litre of dye.

Dyeing additions (pH adjustment) were: acetic acid. After dyeing, fabrics were washed at 30°C, rinsed and dried at room temperature. Figure 1 shows the raw material from which natural pigments are made: (a) red beet, (b) onion leaves and (c) black tea.

Figure 1. Dyestuff sources: (a) red beet, (b) onion leaves and (c) black tea.

3. Measurements and analysis

Figures 2, 3 and 4 illustrate the colour spectrum obtained after dyeing the fabric with natural pigments extracted from red beet, onion leaves and black tea:

The colours corresponding to **the first fabric** were obtained by applying the following recipes : **sample 1**: 10 ml red beet extract/l at a liquor ratio of 1:100, for 2 hours; **sample 2**: 10 ml onion extract/l at a liquor ratio of 1:100, for two hours; **sample 3**: 7 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 4**: 10 ml onion extract/l at a liquor ratio of 1:100, for 2 hours; **sample 5**: 10 ml black tea extract/l at a liquor ratio of 1:100, for 2 hours; **sample 6**: 10 ml black tea extract/l at a liquor ratio of 1:100, for 2 hours; **sample 7**: 5 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 8**: 10 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 9**: 10 ml red beet extract/l at a liquor ratio of 1:100, for 2 hours; **sample 10**: 5 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 11**: 5 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour.

The colours corresponding to **the second fabric** were obtained by applying the following recipes : **sample 1**: 7 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 2**: 10 ml red beet extract/l at a liquor ratio of 1:100, for 2 hours; **sample 3**: 5 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 4**: 10 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 5**: 10 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 6**: 5 ml red beet extract/l at a liquor ratio of

1:100, for 1 hour; **sample 7**: 10 ml black tea/l at a liquor ratio of 1:100, for 2 hours; **sample 8**: 10 ml black tea extract/l at a liquor ratio of 1:100, for 1 hour; **sample 9**: 10 ml onion extract/l at a liquor ratio of 1:100, for 2 hours; **sample 10**: 7 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour;

The colours corresponding to **the third fabric** were obtained by applying the following recipes: **sample 1**: 5 ml black tea/l at a liquor ratio of 1:100, for 1 hour; **sample 2**: 7 ml black tea/l at a liquor ratio of 1:100, for 1 hour; **sample 3**: 10 ml red beet extract/l at a liquor ratio of 1:100, for 2 hours; **sample 4**: 7 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 5**: 10 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 6**: 7 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour; **sample 7**: 5 ml onion extract/l at a liquor ratio of 1:100, for 1 hour; **sample 8**: 10 ml onion extract/l at a liquor ratio of 1:100, for 2 hours; **sample 9**: 5 ml onion extract/l at a ratio of 1:100, for 1 hour; **sample 10**: 5 ml red beet extract/l at a liquor ratio of 1:100, for 1 hour;

3.1. Measurement of Colours

The Colour strength (K/S) values for each sample were obtained by measuring the reflectance of the dyed samples using the instrument DATACOLOR Spectroflash 300, spectrophotometer under illuminant D65, using 10° Standard observer for each dyed samples (figures 5, 6 and 7). The colour strength of the dyed fabric samples, in terms of the K/S values, was obtained by using the Kubelka Munk equation [10, 18]

Figure 2. Samples hemp fabric 1 after dyeing.

Figure 3. Samples hemp fabric 2 after dyeing.

Figure 4. Samples hemp fabric 3 after dyeing.

Figure 5. Spectral curves for Fabric 1.

Figure 6. Spectral curves for Fabric 2.

Figure 7. Spectral curves for Fabric 3.

$$F(R) = (1-R)^2/2R = K/S \quad (1)$$

Where: K is the absorption coefficient and S is the scattering coefficient for a colorant at a specific wavelength; R is the fractional reflectance value of the dye on the substrate at the λ_{max} . The K/S value at λ_{max} is directly proportional to the concentration of dye on the substrate using the instrument DATACOLOR Spectroflash 300.

The colours are given according to the CIE $L^*a^*b^*$ coordinates, as specified by the International Commission on Illumination with L^* corresponding to brightness (100 = white, 0 = black), a^* to the red-green coordinate (positive sign = red, negative sign = green) and b^* to the yellow-blue coordinate (positive sign = yellow, negative sign bright red to soft lilac and pink based on carmine, it was = blue).

Tables 1, 2 and 3 illustrate the CIE lab colour range of the analysed fabrics.

4. Results and discussion

After assessing all the samples belonging to **the first fabric** and considering the variety of colours displayed in **Figure 5**, it can be observed that **samples 1 and 10** have the most intense colours, followed by **samples 9 and 8**. The colour intensity of the other samples was ranked according to the lightness factor after the process of absorption from the visible spectrum done through the chromophores belonging to the used natural pigments.

By analysing the spectral curves of **the second fabric** in **Figure 6** and observing the K/S values in concordance with the Kubelka Munk equation, the highest values were obtained for **samples 2 and 10**. The other values were ranked according to their degree of adhesion to the cellulose material and the luminance factor.

When it comes to **the third fabric** illustrated in **Figure 7**, it is obvious that the colours corresponding to **samples 6 and 3** are the most intense. Sample 6 has the highest colour intensity.

Table 1. CIE lab colour range for fabric 1.

Fabric	Dye	Batch	DE*	DL*	Da*	Db*	Dc*	DH*	Colour	Batch is
1.	Red beet	D65/10	10.456	-7.420	7.126	-1.863	7.127	-1.862		Darker redder less yellow
		A/10	9.306	-6.594	6.564	-0.163	6.371	-1.589		Darker redder less yellow
		F11/10	9.849	-7.268	6.402	-1.786	6.333	-2.018		Darker redder less yellow
2.	Onion leaves	D65/10	11.321	10.562	-1393	3.829	2.992	2.766		Lighter less red yellow
		A/10	11.194	10.619	-0.549	3.499	2.821	2.142		Lighter less red yellow
		F11/10	11.569	10.698	-1.287	4.212	3.521	2.645		Lighter less red yellow
3.	Red beet	D65/10	9.817	8.091	-4.520	-3.236	-4.378	-3.427		Lighter less red less yellow
		A/10	9.694	7.317	-4.284	-4.699	-4.999	-3.930		Lighter less red less yellow
		F11/10	9.669	7.556	-4.427	-4.099	-4.332	-4.200		Lighter less red less yellow
4.	Onion leaves	D65/10	6.769	-3.920	0.504	5.495	5.222	1.782		Darker redder yellow
		A/10	6.733	-3.641	0.801	5.607	5.309	1.973		Darker redder yellow
		F11/10	7.139	-3.674	0.358	6.110	5.836	1.845		Darker redder yellow
5.	Black tea	D65/10	3.555	3.075	-1.734	0.417	-0.114	1.780		Lighter less red yellow
		A/10	3.168	2.908	-1.255	-0.071	-0.615	1.096		Lighter less red
		F11/10	3.350	2.990	-1.446	0.439	0.015	1.511		Lighter less red yellow
6.	Black tea	D65/10	7.567	7.376	-1.405	-0.941	-1.338	1.034		Lighter less red less yellow
		A/10	7.398	7.182	-1.145	-1.357	-1.730	0.401		Lighter less red less yellow
		F11/10	7.460	7.278	-1.244	-1.067	-1.389	0.869		Lighter less red less yellow
7.	Red beet	D65/10	15.323	13.740	-1.572	-6.597	-1.902	-6.510		Lighter less red less yellow
		A/10	15.270	13.099	-2.759	-7.346	-3.686	-6.928		Lighter less red less yellow
		F11/10	15.444	13.312	-1.702	-7.643	-2.148	-7.530		Lighter less red less yellow
8.	Onion leaves	D65/10	8.941	7.515	-0.569	4.811	4.196	2.421		Lighter less red yellow
		A/10	9.038	7.700	0.221	4.727	4.263	2.054		Lighter redder yellow
		F11/10	9.402	7.723	-0.628	5.325	4.781	2.429		Lighter less red yellow
9.	Red beet	D65/10	4.963	-3.057	2.038	-3.336	2.148	-3.266		Darker redder less yellow
		A/10	4.766	-2.992	2.067	-3.081	1.476	-3.404		Darker redder less yellow
		F11/10	5.283	-3.265	1.647	-3.813	1.671	-3.803		Darker redder less yellow
10.	Red beet	D65/10	17.941	15.143	-9.293	-2.489	-9.207	-2.791		Lighter less red less yellow
		A/10	17.279	13.823	-9.028	-5.099	-9.759	-3.502		Lighter less red less yellow
		F11/10	17.289	14.511	-8.762	-3.402	-8.721	-3.505		Lighter less red less yellow
11.	Red beet	D65/10	8.627	7.390	-1.572	-4.165	-1.324	-4.250		Lighter less red less yellow
		A/10	8.661	6.915	-1.594	-4.965	-2.329	-4.665		Lighter less red less yellow
		F11/10	8.657	6.905	-1.595	-4.972	-1.401	-5.030		Lighter less red less yellow

Table 2. CIE lab colour range for fabric 2.

Fabric	Dye	Batch	DE*	DL*	Da*	Db*	Dc*	DH*	Colour	Batch is
1.	Red beet	D65/10	4.786	1.631	-4.499	0.044	-4.492	0.246		Lighter less red
		A/10	4.130	1.081	-3.781	-1.260	-3.974	-0.311		Lighter less red less yellow
		F11/10	4.280	1.294	-4.071	-0.271	-4.079	0.063		Lighter less red less yellow
2.	Red beet	D65/10	13.912	-12.072	6.897	-0.476	6.883	-0.650		Darker redder less yellow
		A/10	12.895	-11.157	6.312	1.405	6.464	-0.180		Darker redder yellow
		F11/10	13.161	-11.871	5.675	-0.274	5.645	-0.649		Darker redder less yellow
3.	Red beet	D65/10	7.659	7.243	2.315	0.910	2.459	-0.378		Lighter redder yellow
		A/10	8.183	7.575	2.733	1.454	3.094	-0.098		Lighter redder yellow
		F11/10	7.822	7.358	2.409	1.117	2.635	-0.329		Lighter redder yellow
4.	Onion leaves	D65/10	7.184	3.327	0.786	6.319	6.092	1.853		Lighter redder yellow
		A/10	7.673	3.717	1.564	6.528	6.476	1.768		Lighter redder yellow
		F11/10	7.957	3.625	0.586	7.059	6.807	1.958		Lighter redder yellow
5.	Onion leaves	D65/10	33.420	35.521	-7.625	-1.084	-3.220	6.996		Lighter less red less yellow
		A/10	32.574	31.648	-7.119	-2.967	-5.642	5.258		Lighter less red less yellow
		F11/10	32.961	32.265	-6.630	-1.209	-2.930	6.069		Lighter less red less yellow
6.	Red beet	D65/10	6.038	5.292	2.901	-0.206	2.511	-1.468		Lighter redder less yellow
		A/10	6.581	5.625	3.395	0.368	3.194	-1.207		Lighter redder yellow
		F11/10	6.106	5.327	2.981	-0.160	2.556	-1.543		Lighter redder less yellow
7.	Black tea	D65/10	5.651	5.495	-1.058	0.788	0.419	1.251		Lighter less red yellow
		A/10	5.507	5.428	-0.773	0.524	0.127	0.925		Lighter less red yellow
		F11/10	5.647	5.499	-0.957	0.856	0.541	1.164		Lighter less red yellow
8.	Black tea	D65/10	4.914	4.378	-0.324	2.208	1.989	1.012		Lighter less red yellow
		A/10	4.950	4.469	0.285	2.109	2.012	0.694		Lighter redder yellow
		F11/10	5.086	4.441	-0.251	2.465	2.280	0.970		Lighter less red yellow
9.	Onion leaves	D65/10	5.575	3.397	-0.080	4.419	4.007	1.867		Lighter yellow
		A/10	5.722	3.601	0.452	4.424	4.096	1.732		Lighter redder yellow
		F11/10	6.105	3.603	-0.111	4.927	4.565	1.858		Lighter less red yellow
10.	Red beet	D65/10	8.643	5.086	-6.659	-2.117	-6.625	-2.222		Lighter less red less yellow
		A/10	8.156	4.143	-5.767	-4.013	-6.412	-2.870		Lighter less red less yellow
		F11/10	8.518	4.490	-6.602	-2.968	-6.620	-2.928		Lighter less red less yellow

Table 3. CIE lab colour range for fabric 1.

Fabric	Dye	Batch	DE*	DL*	Da*	Db*	Dc*	DH*	Colour	Batch is
1.	Black tea	D65/10	12.999	9.238	-4.704	-7.843	-3.037	-8.627		Lighter less red less yellow
		A/10	13.736	8.157	-5.442	-9.620	-4.447	-10.119		Lighter less red less yellow
		F11/10	13.440	8.425	-4.689	-9.364	-2.869	-10.072		Lighter less red less yellow
2.	Black tea	D65/10	13.123	9.762	-5.540	-6.800	-4.282	-7.654		Lighter less red less yellow
		A/10	13.778	8.656	-6.301	-8.672	-5.716	-9.068		Lighter less red less yellow
		F11/10	13.316	9.013	-5.429	-8.161	-4.266	-8.825		Lighter less red less yellow
3.	Red beet	D65/10	7.165	-4.503	5.338	-1.602	5.332	-1.624		Darker redder less yellow
		A/10	6.099	-3.909	4.671	-0.311	4.485	-1.341		Darker redder less yellow
		F11/10	6.758	-4.445	4.822	-1.632	4.753	-1.824		Darker redder less yellow
4.	Onion leaves	D65/10	4.239	2.532	-0.775	3.310	2.720	2.039		Lighter less red yellow
		A/10	3.957	2.613	0.141	2.969	2.661	1.324		Lighter redder yellow
		F11/10	4.617	2.594	-0.727	3.749	3.251	2.003		Lighter less red yellow
5.	Black tea	D65/10	4.756	4.605	-1.159	0.264	-0.112	1.183		Lighter less red yellow
		A/10	4.562	4.500	-0.745	-0.089	-0.415	0.625		Lighter less red
		F11/10	4.656	4.548	-0.966	0.248	-0.048	0.997		Lighter less red yellow
6.	Red beet	D65/10	3.652	-2.006	2.281	-2.028	2.292	-2.015		Darker redder less yellow
		A/10	3.238	-1.840	2.095	-1.647	1.707	-2.046		Darker redder less yellow
		F11/10	3.806	-2.100	2.221	-2.269	2.157	-2.329		Darker redder less yellow
7.	Black tea	D65/10	17.149	16.456	-4.341	-2.113	-3.574	3.245		Lighter less red less yellow
		A/10	16.704	15.879	-4.040	-3.252	-4.776	2.021		Lighter less red less yellow
		F11/10	16.790	16.258	-3.511	-2.295	-3.351	2.523		Lighter less red less yellow
8.	Onion leaves	D65/10	4.185	1.840	-0.503	3.725	3.205	1.963		Lighter less red yellow
		A/10	3.998	1.968	0.388	3.459	3.209	1.346		Lighter redder yellow
		F11/10	4.656	1.926	-0.473	4.212	3.771	1.935		Lighter less red yellow
9.	Onion leaves	D65/10	13.372	13.140	-0.103	-2.478	-2.241	-1.063		Lighter less red less yellow
		A/10	13.299	13.021	0.408	-2.677	-2.035	-1.786		Lighter redder less yellow
		F11/10	13.367	13.066	1.175	-2.563	-1.802	-2.169		Lighter redder less yellow
10.	Red beet	D65/10	8.413	6.835	-4.246	-2.454	-4.192	-2.545		Lighter less red less yellow
		A/10	8.160	6.154	-3.781	-3.796	-4.415	-3.035		Lighter less red less yellow
		F11/10	8.226	6.320	-4.166	-3.221	-4.171	-3.214		Lighter less red less yellow

Both colours were obtained after dyeing the fabric with natural pigments extracted from red beet.

The colour intensity is directly proportional with the quantity of reflected light. When it comes to the group of tests conducted on **the first fabric** and displayed in **Figure 5**, the highest chromatic intensities are reached when dyeing the fabric with red beet extract, followed by the black tea and onion extracts. The same ranking is maintained for **the second fabric** presented in **Figure 6**. In the case of **the third fabric (Figure 7)**, the highest chromatic intensities were obtained by using the red beet extract, like in the previous cases, the only difference being that the gap between the chromatic intensities is more accentuated.

5. Conclusions

The natural pigments used in the experimental study that we conducted have a good colouring capacity, thus being able to obtain bright nuances and go from dull to averagely intense colours. The dyeing factors, especially the quantity of extract that was used, determine the intensity of the obtained colours.

By using these three natural sources (red beet, black tea and onion) we were able to carry out an efficient and eco-friendly dyeing process that covered the necessary colour spectrum for each fabric.

Natural pigments have a rich history and are able to provide beautiful colours; they are eco-friendly and have a positive impact on our health. Still, they have to compete against artificial colorants that are cheaper, easier to obtain and able to produce a wider range of colours and nuances.

According to the literature, many researchers are preoccupied with the aspects, the issues and the perspectives of applying natural dyes at an industrial scale.

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