ANTIBACTERIAL AND UV PROTECTIVE EFFECTS OF COTTON FABRICS DYED WITH BRASI-COLOR EXTRACT

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The wood of the *Caesalpinia sappan* species is the main source of red dyes used for dyeing textiles and paper, stain biological samples, metals identification, as anti-convulsant, immunosuppressant, anti-inflammatory, anti-bacterial and cancer drug. The main component, brazilin is colorless and to obtain a functional dye, it is oxidized to brazilein. The experimental work consisted in dyeing pre-mordanted cotton knit with Brasi-Color, a dyestuff extract of brazilwood. The aim of this research was to evaluate the effectiveness of mimosa tannin and aluminum potassium sulfate on dye exhaustion, the dyeing fastness, the antibacterial efficiency and UV protective effects of pre-mordanted and dyed cotton fabrics. The dyeing fastness is modest and need to be further optimized. The UV-Vis spectra demonstrated the presence of brazilein (λmax: 445nm and 542nm) as the main compound of the dye solution. The highest degree of dye exhaustion was obtained at the lowest concentration of mimosa tannin and alum. All the fabrics show an excellent ultraviolet protection factor (UPF>50+). The fabric pre-mordanted with 2% mimosa/4% alum and dyed with Brasi-Color transmits the lowest amount of UV rays on both UVA and UVB domains. All the dyed fabrics show a good antibacterial effect against *S. Aureus*.

Keywords: Brasi-Color, UV protection, *S. Aureus*

INTRODUCTION

Both acute and low-dose UV radiation exposure has immunosuppressive effect increasing the risk of infection with viral, bacterial, parasitic or fungal infections, cataracts, photokeratitis and photoconjunctivitis, skin cancer (http://www.who.int/uv/health/uv_health2/en/). In 2012, 100339 persons were diagnosed in EU with skin cancer, the mortality rate being of 2.3 (Ferlay *et al*., 2013). The clothes could avoid at least a part of these harmful effects if they have a specific structure, design and are dyed in certain colors. In the last decade, natural dyes are preferred instead synthetic dyes due to their multiple valences: pharmacological effects, UV blocking, renewability. Numerous natural dyes were tested for their biological and UV protection such as eucalyptus (Hussein and Elhassaneen, 2014), red onion peel, madder, chamomile (Gawiash *et al*., 2016). Most of the natural dyes such as indigo, annatto, gardenia, and cochineal absorb about 80% of the ultraviolet rays (Gogoi and Gogoi, 2016). The extract from *Caesalpinia sappan* L. was used in food, as dye, and medicines (antioxidant, antibacterial, anti-inflammatory, anti-photoaging, hepatoprotective) (Nilesh *et al*., 2015) and protects the human epidermal keratinocytes exposed to UVA irradiation (Hyung and Joong, 2018). The aim of this research was the evaluation of mimosa tannin and aluminum potassium sulfate effectiveness on Brasi-Color exhaustion, the dyeing fastness, the antibacterial efficiency and UV protective effects of pre-mordanted and dyed cotton fabrics.

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EXPERIMENTAL

Materials

Brasi-Color: dyestuff extracts of brazilwood, kindly provided by NIG Nahrungs - Ingenieurtechnik GmbH, Austria;

Cotton knit, 165 g/m^2, chemically bleached.

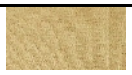
Methods

Pre-mordanting: the fabrics were pre-mordanted with 2% and 8% mimosa tannin, 2% mimosa and 4% alum, 8% mimosa and 15% alum at 30-40^{0}C for 60 minutes at a liquor ratio of 1:60. After that, the fabrics were maintained at room temperature for 3 hours, washed 3 times with hot, warm and cold water, squeezed and freely dried.

Dyeing: the pre-mordanted fabrics were dyed with Brasi-Color solution (4% o.w.f) in a liquor ratio of 1:60, at 80^{0}C for 1 hour. The squeezed fabric was immersed in 20g/L NaCl and maintained at 40^{0}C for 30 minutes. Then, the fabric was rinsed 3 times with hot, warm and cold tap water, squeezed and dried at room temperature.

The appearance of dyed fabrics is displayed in the table 1.

Table 1. The appearance of the fabrics mordanted with mimosa/alum and dyed with Brasi-Color

 2% Mimosa	 8% Mimosa	 2% Mimosa 4% alum	 8% Mimosa 15% alum
 Brasi-Color 2% Mimosa	 Brasi-Color 8% Mimosa	 Brasi-Color 2% Mimosa 4% alum	 Brasi-Color 8% Mimosa 15% alum

Characterisation

The maximum absorption and the degree of exhaustion of Brasi-Color dyestuff were measured by UV-Vis spectroscopy (Lambda 950, Perkin Elmer, USA). Ultraviolet Protection Factor (UPF) was evaluated on UV-Vis spectrophotometer (Cary 50, Varian, Australia) according to standard AS/NZ 4399:1996. Fabrics are rated as providing an "Excellent UV Protection" if UPF value is 40 or greater, "Good UV Protection" if UPF values are between 25 and 39 and as having "Good UV Protection" if UPF value is in the range 15 – 24 (Hatch, 2003). The samples were tested for microbial activity against *Staphylococcus aureus* according to SR EN ISO 20645/2005. The dyeing fastness was evaluated according the ISO standards with grey scale values (rating 1 to 5: 1-poor and 5 = excellent) for washing, perspiration and rubbing fastness and the blue scale values for light fastness evaluation (rating 1-8: 1=poor, 8=excellent).

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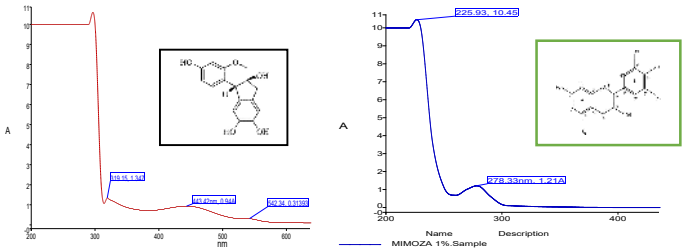
RESULTS

UV-Visible Spectra

The recorded UV-VIS spectra of Brasi-Color dyestuff and mimosa tannin are presented in the Fig.1.



a. b.

Figure 1. UV-VIS spectrum: a. Brasi-Color; b. mimosa tannin

Except the very broad and intensive band in 200-280nm region, the Brasi-Color solution shows 3 peaks, situated at 319nm, 443nm and 542nm. The result is in accordance the data reported (Lee *et al*., 2008) for sappan wood extract having the maximum absorption wavelength at 447 and 538 nm, specific for yellow and red components. The absorption at 254 and 280 nm are characteristic for phenolic compounds (brazilin) while the absorption at 445 nm and 540nm are attributed to the protonated form of brazilein (Kim *et al*., 1997). Mimosa having the maxima absorption at 226nm and 279nm doesn't interfere with Brasi-Color spectra.

Degree of Dye Exhaustion

To quantify the dye concentration, a calibration curve (Fig. 2) was plotted at 443 nm in five points using 0.1g/L, 0.3 g/L, 0.4g/L, 0.5 g/L, 0.7g/L dye solutions.

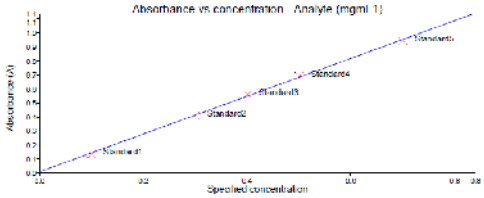


Figure 2. Calibration curve of Dyestuff extract of Brasi Color at 443nm (r2 =0.9996)

The initial and final concentrations of dye baths were determinate based on calibration curve by recording the absorption of diluted solutions (dilution factor: 6:1).

The degree of exhaustion was calculated according to equation (1):

$$\% E = 100(C_i - C_f)/C_f \quad (1)$$

where C_i: the initial concentration; C_f = the final concentration of the dye.

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The exhaustion degree of premordanted and dyed cotton fabrics are shown in table 2.

Table 2. The exhaustion degree of the Brasi-Color (BC) initial and final dye baths, λ = 443 nm

Sample	C_i	C_f	E, %
BC, 2 % mimosa	0.2120	0.1974	6.88
BC, 8 % mimosa	0.2425	0.2789	-15.01
BC, 2% mimosa 4% alum	0.3060	0.2459	19.64
BC, 8% mimosa 15% alum	0.2888	0.2657	7.99

As the results show, a high content of mimosa tannin negatively influenced the dye bath exhaustion, probably due to the saturation of the cotton knit with tannin and low bonding between the fibers and dye. The hypothesis is confirmed by the lower degree of dyebath exhaustion when a higher amount of mimosa tannin (8%) and alum (15%) is used. The optimum condition for the highest diffusion of dye into cotton fabric was obtained at 2% mimosa/4% alum. The red color could indicate an absorption shift to longer wavelengths due to complex formed with Al ions. Some authors suggested that the ionized hydroxyl group and carbonyl oxygen of brazilein are coordinated to Al^{3+} which with two water molecules form an octahedral configuration (Wongsooksin, 2008).

The Colour Fastness Evaluation of the Fabrics Dyed with Brasi-Color

The colour fastness of the fabrics dyed with Brasi-Color are shown in table 3.

Tabel 3. Colour fastness of the fabrics mordanted and dyed with Brasi-Color (BC)

Colour fastness to/Sample		BC + 2% Mimosa	BC + 8% Mimosa	BC +2% Mimosa + 4% alum	BC + 8% Mimosa + 15% alum
Washing		1-2	2	1	1
Acid perspiration		1-2*	1-2*	1-2*	2*
Alkaline perspiration		2	2-3	2	2-3
Rubbing	dry	4-5	4-5	4	4
	wet	2-3	3	2	2-3
Light fastness		2-3	2-3	3	3

Exposure time: * 7 hours, the colour is modified

Except the fastness to the dry rubbing which could be considered good, all the other tests demonstrate a poor fastness to washing, perspiration, artificial light.

Assessment of the Ultra-violet Protection Factor (UPF)

The UPF values of the fabrics pre-mordanted with mimosa tannin and dyed with Brasi-Color are shown in the table 4.

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Table 4. UPF values of the fabrics pre-mordanted and dyed with Brasi-Color (BC)

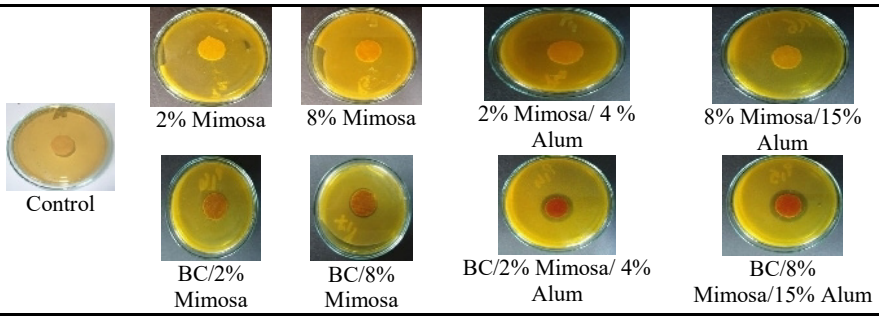
Sample	Mean UPF	Mean UVA Transmission	Mean UVB Transmission	UPF calculate	UPF rating
untreated	15.698	11.807	5.289	13.498	**10**
2% mimosa	136.207	1.345	0.669	114.127	**50+**
8% mimosa	232.204	0.752	0.377	207.556	**50+**
2% mimosa/ 4% alum	187.415	0.849	0.445	157.032	**50+**
8% mimosa/15% alum	189.435	1.084	0.443	154.351	**50+**
2% mimosa /BC	209.370	0.308	0.437	195.458	**50+**
8% mimosa /BC	175.413	0.461	0.536	145.199	**50+**
2% mimosa/ 4% alum /BC	572.350	0.073	0.202	293.592	**50+**
8% mimosa/15% alum /BC	472.271	0.406	0.210	325.778	**50+**

While the white, untreated fabric shows a high transmission of UV rays, a very small amount of UV rays penetrates through the mordanted and dyed samples on both UVA and UVB domains. The lowest transmission, so the highest UV protective effect is recorded for the knit pre-mordanted with 2% mimosa/ 4% alum and further dyed with Brasi-Color.

Antibacterial Activity of Knitted Fabrics Mordanted and Dyed with Reseda Luteola

The cotton fabrics mordanted and dyed were tested against *S. aureus* and the results were compared with control (table 5).

Table 5. Antibacterial effect of mordanted and dyed fabrics



The control fabric presents a moderate growth of *S. aureus*. The materials mordanted with mimosa and mimosa/alum are classified as having a satisfactory effect, the inhibition zone being zero and some restricted bacterial colonies are seen on their surface. Instead, the dyed fabrics do not allow the growth of *S. aureus* colonies, the antibacterial efficiency being higher as the amount of mordant is larger. The most effective activity is shown by the material treated with 8% Mimosa / 15% Alum.

The improved efficiency could be attributed to the dye if we consider the limited efficacy of the fabrics mordanted with the same mordants.

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CONCLUSIONS

The highest dye exhaustion is attained for the cotton pre-mordanted with 2% mimosa 4% alum. All the mordanted and dyed materials have a high UV protection on both UVA and UVB regions. The material dyed with Brasi-Color presents a good antibacterial efficiency against *S. aureus*.

Acknowledgments

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