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CHROMATIC BEHAVIOR OF WOOL TEXTILES TREATED WITH GREEN SILVER NANOPARTICLE DISPERSIONS SUBJECTED TO ACCELERATED AGING

LITE Mihaela-Cristina[1], CHIRILĂ Laura[1], POPESCU Alina[1], TĂNĂSESCU Elena-Cornelia[1,2], IORDACHE George-Ovidiu[1], BADEA Nicoleta[2]

[1] National Research and Development Institute for Textiles and Leather, Bucharest (INCDTP), Department of Materials' Research and Investigation, 16 Lucretiu Patrascanu, 030508, Bucharest, Romania, E-Mail: office@incdtp.ro

[2] Politehnica University of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Gheorghe Polizu Street, 011061, Bucharest, Romania, E-Mail: secretariat@chimie.upb.ro

Corresponding author: Lite Mihaela-Cristina, E-mail: cristina.lite@incdtp.ro

Abstract: *The present work aimed to study the chromatic impact of the green synthesized silver nanoparticles (AgNPs) applied on wool-based fabrics. The need to evaluate the behavior of the AgNPs-based treatment applied on textiles arises from the research of this type of treatment in the conservation of heritage objects, due to its remarkable antimicrobial properties. Therefore, it is essential to ensure that the conservation treatment does not alter the aesthetic aspect of the materials. Thus, in this research, wool textile materials treated with green AgNPs dispersions were exposed to an accelerated aging process (UV radiation, temperature, and humidity). The dispersions used were obtained by phytosynthetesis, using two type of plant extracts. For fifteen days, the samples were collected after every three days and colors measured. The total color change was calculated and compared to the unexposed samples. It was found that the value of the brightness was not affected by the presence of the treatment. While the variation of the a* parameter was also not affected by the treatment, b* appeared to change more gradually in the case of the untreated fabric. Comparing the total color shift, the modification of the visual aspect of the samples was minimum. These results support the beneficial effect of AgNPs treatment for cultural heritage conservation.*

Key words: *silver nanoparticles, wool, heritage, chromatics*

1. INTRODUCTION

It is important to have knowledge about the chromatic effect of the treatment used in the conservation-restoration of heritage objects, as it is necessary that it does not change the color of the artifacts or, in the case of restoration, slightly intensifies the color tones, for objects that have faded over time [1]. Combating textile degradation using silver nanoparticles (AgNPs) is a topic of great interest for researchers [2-4]. The green synthesis and the effect against the contamination with microorganisms represented the object of many studies around AgNPs fabrication [5, 6]. For this work, two types of AgNPs dispersions were phythosynthesized, by using plant extracts of *Primula officinalis* and *Stellaria media*, respectively. Afterwards, they were applied on textile fabrics and the samples were exposed to artificial degradation, in order to determine the behavior of such treatments to accelerated weathering conditions. Accelerated aging tests are commonly conducted to evaluate the weatherability and service life of polymeric materials and involve the simulation of the environment conditions [7]. A special chamber equipped with UV lamps with controlled temperature and humidity is used for this purpose. The support textile selected for the experiments consisted of wool fabrics, since it is a common material used in traditional garment manufacturing and it was reported to suffer significant modification when exposed to UV light [8, 9].

2. EXPERIMENTAL

2.1 Materials and methods

Five wool samples measuring 11×9 cm were exposed to accelerated aging conditions, in a UV chamber (QUV accelerated weathering tester device), following a working cycle reported in our previous study [9]. The equipment was provided with fluorescent UV-B lamps (UVB-313), having nearly all the energy concentrated in the range 280-360 nm, with a wavelength peak at 313 nm. The working cycle involved UV light for 8 hours at, 70°C, followed by 4 hours of humidity (60%), at 50°C. Samples of the exposed fabrics were collected every three days, and they constituted the control samples. In parallel, wool fabrics treated with AgNPs dispersions were subjected to the same process. The AgNPs dispersions were synthesized and applied according to the following reports [10, 11].

2.2 Characterization technique

The chromatic effect of the textile samples was evaluated using a Datacolor (D65/10 lamp) instrument (Datacolor, Inc., Lucerne, Switzerland). The chromatic parameters were expressed in the CIE L*a*b* color system (figure 1).

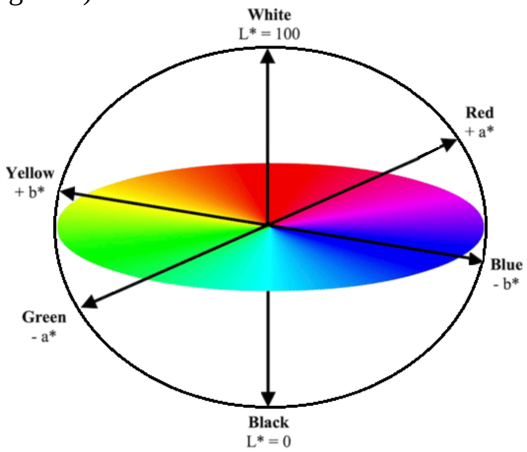

Fig. 1. *The CIE L*a*b* chromatic space.*

The CIE L*a*b* parameters are L* which quantifies the brightness of the sample, and a* and b*, which refer to the color of the sample. The values of a* and b* are situated in the range −100 and +100. When a* and b* are both positive, the color of the sample is in the range of red-orange-yellow. When a* is negative and b* is positive, the color of the sample is in the yellow-greenish-green range. When a* and b* are negative, the color of the sample is in the range green-turquoise-blue. When a* positive and b* negative, the color of the sample is in the range of blue-purple-red. The total color changed (ΔE*) can be calculated according to the formula:

$$\Delta E^* = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2 \ [12]. \quad (1)$$

3. RESULTS AND DISCUSSIONS

The chromatic parameters of the untreated sample revealed a total color shift of 26.92 (table 1). The most affected parameter was the b* parameter, which increased gradually from 9.77 (before exposure) to 33.06 (after 15 days of exposure). The luminosity was also affected (from 84.21 to 71.07). The visual effect consisted of acquiring a yellow tint. This behavior correlates with previous reports related to wool exposure to accelerated weathering conditions [9, 13] and it is attributed to the wool content of photoactive protein residues, such as cystine, tryptophan, phenylalanine, and tyrosine. These components absorb UV radiation, producing chromophores, which are responsible for the visual effect of a color [14]. The values of the chromatic parameters obtained by measuring the samples treated with AgNPs dispersions are listed in table 2 and 3, corresponding to the treatments produced with *Primula officinalis* extract and *Stellaria media*, respectively. The exposed samples were compared to the treated samples. The total color shift was 26.46 for samples treated with *Primula officinalis*-based treatment and 27.98 for *Stellaria media*-based treatment. While in both cases the b* parameter varied almost identically, the brightness difference was slightly higher in the case of *Stellaria media*-based treatment. However, the total color shift was very close to the value obtained for the untreated sample, for both treatments, suggesting that the visual impact is minimal. The increase of ΔE* of only 0.5 and 1, respectively, is not generally discernible.

Table 1. *Chromatic measurements of the **untreated** wool sample exposed to accelerated degradation conditions.*

Exposure time	L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*
Before exposure	84.21	0.03	9.77	-	-	-	-
After 3 days	77.69	-0.75	18.92	-6.52	-0.78	9.15	11.26
After 6 days	75.62	-0.3	25.11	-8.59	-0.33	15.34	17.58
After 9 days	73.43	1.27	30.67	-10.78	1.24	20.9	23.55
After 12 days	71.89	2.62	32.38	-12.32	2.59	22.61	25.88
After 15 days	71.07	3.16	33.06	-13.14	3.13	23.29	**26.92**

Table 2. *Chromatic measurements of the wool sample **treated** with AgNPs dispersions based on Primula officinalis extract, exposed to accelerated degradation conditions.*

Exposure time	L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*
Before exposure	77.54	1.16	9.12	-	-	-	-
After 3 days	75.24	-0.09	22.37	-2.3	-1.25	13.25	13.51
After 6 days	72.93	0.91	28.12	-4.61	-0.25	19	19.55
After 9 days	70.87	2.18	31.43	-6.67	1.02	22.31	23.31
After 12 days	70.75	2.69	30.69	-6.79	1.53	21.57	22.67
After 15 days	68.51	4.29	33.79	-9.03	3.13	24.67	**26.46**

Table 3. *Chromatic measurements of the wool sample **treated** with AgNPs dispersions based on Stellaria media extract, exposed to accelerated degradation conditions.*

Exposure time	L*	a*	b*	ΔL*	Δa*	Δb*	ΔE*
Before exposure	77.91	0.84	8.01	-	-	-	-
After 3 days	73.54	0.47	23.49	-4.37	-0.37	15.48	16.09
After 6 days	70.72	1.65	29.49	-7.19	0.81	21.48	22.67
After 9 days	68.15	2.7	30.03	-9.76	1.86	22.02	24.16
After 12 days	67.93	3.94	33.18	-9.98	3.1	25.17	27.25
After 15 days	65.15	4.58	32.63	-12.76	3.74	24.62	**27.98**

The chromatic diagrams (figures 2-5) illustrate the color variation during the exposure.

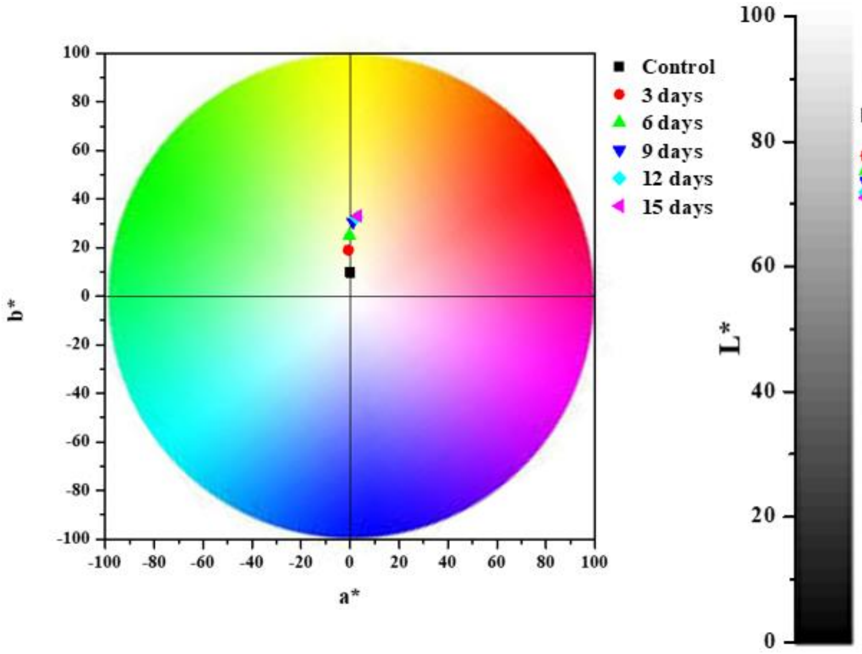

Fig. 2. *Chromatic diagrams of the untreated wool samples exposed to accelerated degradation conditions.*

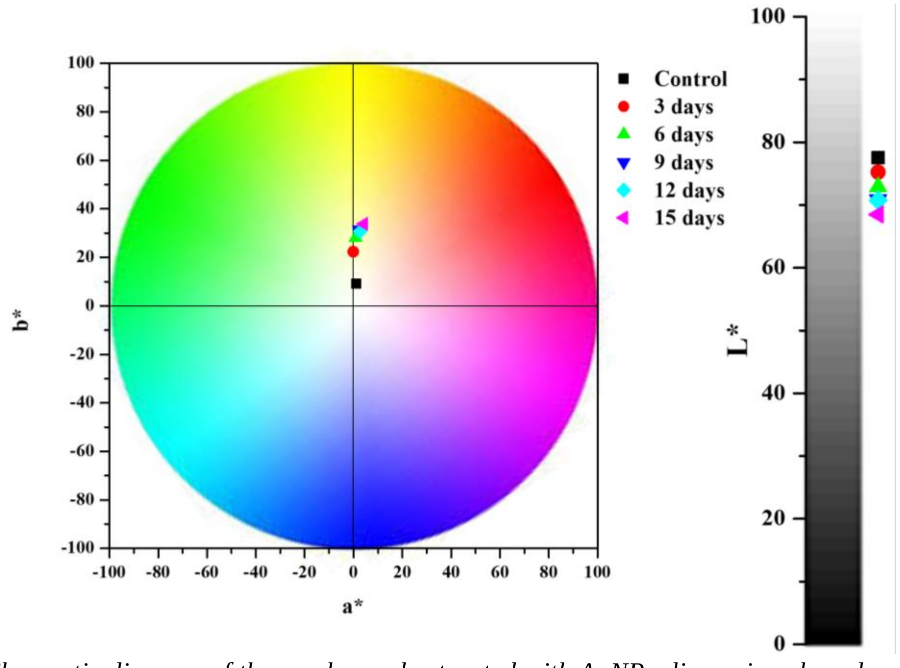

Fig. 3. *Chromatic diagram of the wool samples treated with AgNPs dispersions based on Primula officinalis extract, exposed to accelerated degradation conditions.*

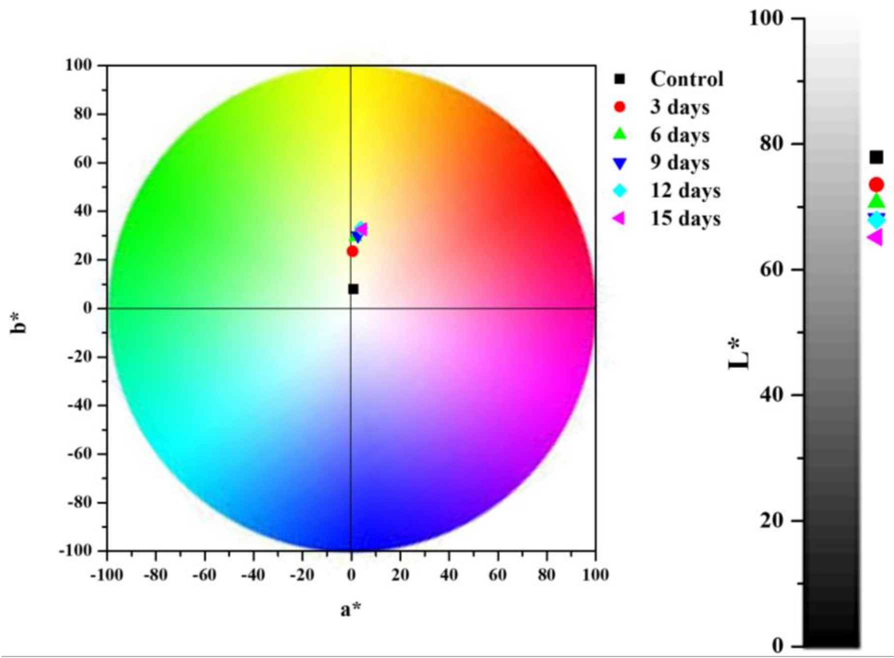

Fig. 4. *Chromatic diagram of the wool samples treated with AgNPs dispersions based on Stellaria media extract, exposed to accelerated degradation conditions*.

The observations regarding the brightness decrease revealed that minimum value was not influenced by the presence of the AgNPs treatment, even though this parameter was lower before the exposure, compared to the untreated sample. In the case of the a* parameter, the slight shift at the end of the process is more visible in the case of the treated exposed samples. Also, the b* parameter variation occurs more gradually in the case of the untreated sample.

4. CONCLUSIONS

The chromatic behavior of wool fabrics treated with phytosynthesized AgNPs dispersion subjected to accelerated weathering conditions was analyzed. The minimum value of the brightness was not affected by the presence of the treatment. While the variation of the a* parameter was not affected by the treatment, b* appeared to change more gradually in the case of the untreated fabric. Following the total color shift, the alteration of the visual aspect was minimum in both cases. The slightly higher value obtained in the case of the *Stellaria media*-based treatment was attributed to the phytocomponents of the extract. These results support the promoting effect of AgNPs treatment for cultural heritage conservation.

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