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ENHANCEMENT OF MACRO-UNIFORMITY OF COPPER(I) OXIDE PRINTED LINEN FABRICS BY ADDITION OF *PINUS SYLVESTRIS* L. PLANT EXTRACT

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Abstract: *High surface texture of textile materials is rougher than other printing substrates which can cause excessive macro non-uniformity. Adding metal oxides into the ink to enhance material properties usually add to surface roughness and increase print mottle. In this paper copper(I)oxide particles and different amounts of Pinus sylvestris L. plant extract were added to modified alginate paste (CHT-NV) prior to printing. The aim of this paper is to inspect the influence of added metal oxide and plant extract on the print quality of linen based material via surface macro non-uniformity GLCM determination method. In the pattern recognition phase, the co-occurrence matrix is applied to calculate the texture characteristics, such as contrast, correlation, energy, entropy and homogeneity. The research results indicated that the metal oxide particles have had a negative influence on macro uniformity of printed linen. Increasing of the concentration of extract leads to a dilution of the printing paste, and thus to a greater penetration of copper ions between the threads of the fabric, as well as into the yarn itself.*

Key words: Macro non-uniformity; Printing fabrics; *Pinus sylvestris* L.; Copper(I) oxide; GLCM method

1. INTRODUCTION

Screen printing of textile materials using alginate paste modified with pigments from plants and different types of mordants, while respecting ecological principles, is gaining more and more importance today. Natural colors represent an emerging trend in the textile industry and eco-fashion due to the growing awareness of the concept of sustainability that must be applied to the environment. Natural materials are the basis of sustainable clothing production today. Some of the natural materials used in the production of clothing are cotton, silk, wool and linen. Linen is a versatile and highly durable fabric that is twice as strong as cotton and offers similar comfort to clothing. Medicinal elements found in the fibrous shell of flaxseed are plant lignans. Lignans are precursors of phytohormones that exhibit immunostimulating and antibacterial, antifungal and antiviral effects. *Pinus sylvestris* L. (white pine) is a tree up to about 40 m tall, with a trunk up to 1 m wide. The needles are in tufts, 4 to 7 cm long and 2 mm wide. Hoai et al. (2015) found that *Pinus sylvestris* L. needle extract inhibited the growth of several cancer cell lines. Essential oils, isolated from white pine needles, have much better antimicrobial effects, as well as effects on inhibiting the growth of cancerous cells (Czerwinska & Szparaga, 2015; Hoai et al., 2015). The most important components of the essential oil extracted from white pine needles have antiseptic, anti-allergic, anti-inflammatory and deodorizing properties, as well as an effect on faster wound healing (Kumar et al., 2010).

Copper has strong anti-fungal and anti-bacterial properties. Copper is also an essential trace element, vital for the normal function of many tissues and necessary for the creation of new capillaries and skin. Human skin is not sensitive to copper and the risk of side effects due to dermal exposure to copper is extremely low (Borkow, Zatcoff & Gabbay, 2009). Copper-impregnated products possess a wide range of antimicrobial and anti-fungal properties, without causing hypersensitivity or skin irritation (Borkow & Gabbay, 2004; Gabbay et al., 2006). Cupric oxide-impregnated nonwoven fabric has been safely used in adult diapers and antimicrobial wound dressings for years (Borkow et al., 2010a; Weinberg et al., 2013). Their safety in respiratory face masks has also been proven (Borkow et al., 2010b). Copper(I) oxide as a mordant shows great promise for biomedical applications due to its unique potential to combine antibacterial effects with multiple other functionalities. Wang, Yonghong & Liu (2017) analyzed the antibacterial activities of different forms of Cu_2O and found that Cu_2O, even after being coated with various surfactants, still showed activity (Wang, Yonghong & Liu, 2017).

In textile screen printing, many parameters affect the evenness of the print application and the macro-uniformity of the print surface. Previous research has shown that textile material printed by screen printing has high macro non-uniformity, caused by the texture of the material (Stančić, 2016; Vujčić & Ružičić, 2017). The quality of printing, mostly, is tested by testing the quality of color reproduction, but this is often not enough. In a series of experiments (Fedorovskaya, Blommaert & de Ridder, 1993), (de

Ridder, 1996) and (Fedorovskaya, de Ridder & Blommaert, 1997) it was proved that print quality is not only a function of color and color-related features. Parameters such as contrast, sharpness, uniformity of image elements, etc., are not directly related to tone and color, but affect the overall quality. Surface pattern is a term that refers to optical heterogeneity, non-uniformity of optical density and brightness. It appears on fields of full tonal value and is a non-uniform reflection of light from the print. It usually appears in the form of systematically structured patterns that are easily perceived by the human eye due to its perfect response to pattern detection (Petersson, 2005). The larger the surface pattern, the greater the non-uniformity, and based on this, it can be concluded how much influence the non-uniformity has on the sharpness of the print and on the overall quality of the print. In their research, Gebeješ et al. (2012) concluded that a higher entropy value suggests a stronger textural pattern that is easier to perceive with the naked eye. Textures are present on textile materials due to the very structure of the substrate. The assessment of full-tone print uniformity in this research was conducted with the help of GLCM (Grey Level Co-occurrence matrix) image processing methods. GLCM, also known as a gray level spatial dependency matrix, is a table that tracks how often they are different combinations, pairs of pixel intensities (gray level values), occur in a certain spatial relationship and distance in the analyzed image (Hladnik & Lazar, 2011).

2. METHODS

Alginate paste (CHT-NV) was prepared by adding 92 ml of distilled water at room temperature in 8 g of modified alginate. A homogeneous mixture is obtained by continuous mixing. This paste is used as a base for screen printing. After creating a homogeneous paste 20 ml, 40 ml and then 60 ml of *Pinus sylvestris* L. alcoholic extract was gradually added with mixing. Then, an additional 0.2 g of copper(I) oxide was added individually to each mixture. All samples are listed in Table 1.

Table 1: Sample overview

Sample name	Sample modification
E1	Printed with alginate paste + 20 ml *Pinus sylvestris* L. extract
E2	Printed with alginate paste + 40 ml *Pinus sylvestris* L. extract
E3	Printed with alginate paste + 60 ml *Pinus sylvestris* L. extract
Cu	Printed with alginate paste + 0,2 g Cu_2O
E1-Cu	Printed with alginate paste + 0,2 g Cu_2O + 20 ml *Pinus sylvestris* L. extract
E2-Cu	Printed with alginate paste + 0,2 g Cu_2O + 40 ml *Pinus sylvestris* L. extract
E3-Cu	Printed with alginate paste + 0,2 g Cu_2O + 60 ml *Pinus sylvestris* L. extract

A semi-automatic Screenprinter S300 screen printing system was used to print the material. Each sample of linen fabrics previously bleached with hydrogen peroxide (H_2O_2) was printed in two passes at a speed of 0.08 m/s on a 15 threads/cm screen. Fabrics characteristics are listed in Table 2.

Table 2: Fabrics characteristics

Sample	Fiber fineness [tex]	Surface mass [g/m^2]	Density [m^{-1}]	
			Warp	Weft
LINEN	42,386	199,37	22,7	20,5
	METHODS:	ISO 3801	ISO 7211-2	

The fabrics are cut to a size of 50 x 50 cm, and a 40 x 30 cm patch was printed on each sample. After drying, the samples were scanned with a Mustek 1200 ub plus flatbed scanner. The resolution used is 1200 spi, and image was generated using the Adobe Photoshop software. When scanning, all options for automatic image adjustment are turned off. The scan setup is the same for all samples. The samples were photographed with a Velleman digital microscope and the Xploview software application. The GLCM image processing method was applied to scanned printed samples using MATLAB software and a plugin proposed by Uppuluri (2008). This plugin provides information on 22 parameters, the most relevant of which are used in the literature, as well as in this research, are contrast, correlation, entropy, energy and homogeneity (Hladnik & Lazar, 2011; Chen, 1998). It was found that the parameters of these five parameters can be used to assess the uniformity of print (Hladnik & Lazar, 2011; Fahlcrantz, 2005). Low contrast, low correlation, low entropy, high energy and high homogeneity correspond even distribution of gray levels, that is, they indicate a uniform, smooth surface (Hladnik & Lazar, 2011; Chen, 1998).

3. RESULTS

The results are shown in Figure 1.

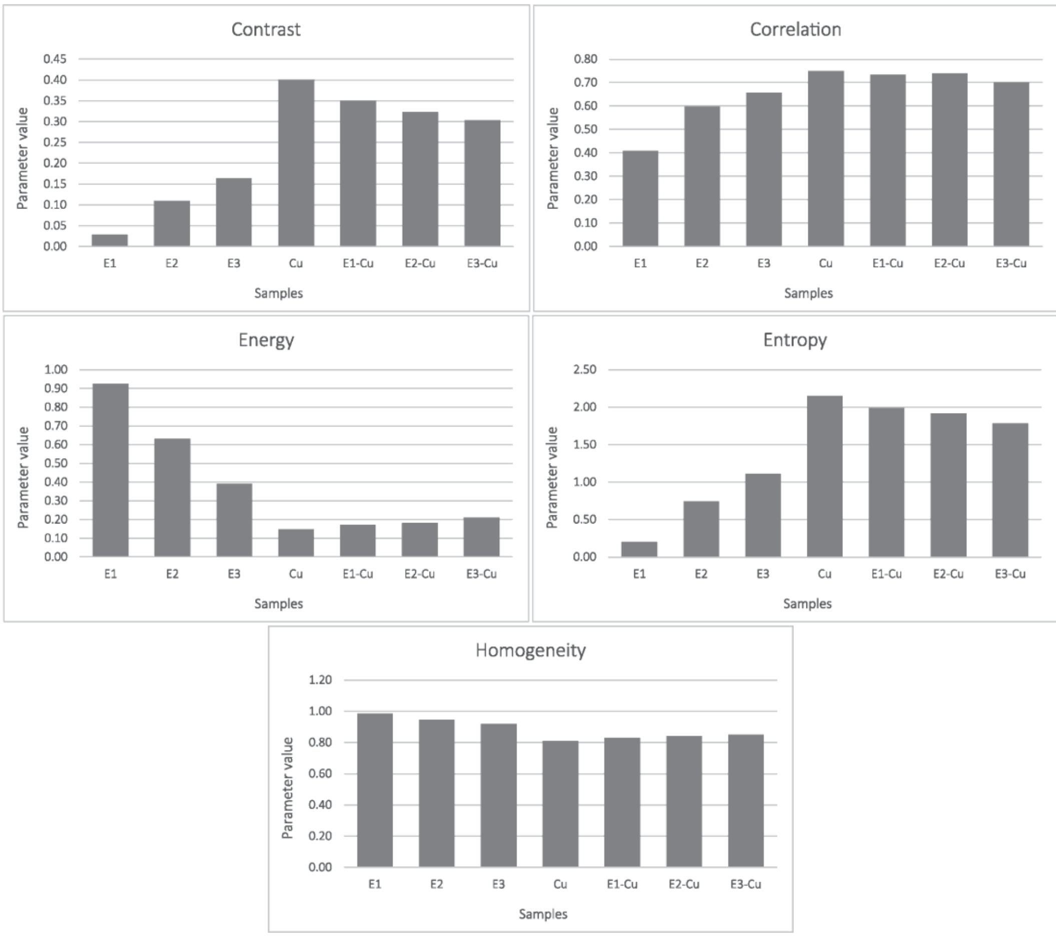

Figure 1: Macro non-uniformity parameters

By visual analysis of the samples, as on Figure 2., small copper particles were observed in the yarn of the printed linen fabrics on the 600x enlarged sample.

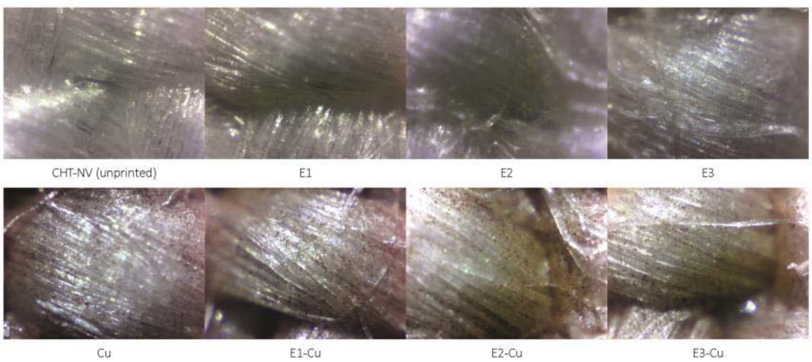

Figure 2: Enlarged images of samples

4. DISCUSSION

Observing all parameters of surface non-uniformity, it can be concluded that the sample E1 has the most favorable parameters and the highest uniformity during printing, and this uniformity is decreased by increasing the concentration of the extract. This could be caused by the accumulation of extract in the weaves of the fabric, which becomes more pronounced as the concentration of the extract increases. This can also be attributed to the structure of the linen fabric by looking at the entropy parameter that best correlates with the human perception of texture. We see that, where the entropy value is high, a certain texture becomes more visible and noticeable. On samples with added copper(I) oxide (sample Cu) it can be concluded that Cu_2O significantly disrupt the uniformity of the printed surface, however, by adding the extract, particles of copper ions penetrate deeper into the yarn and the macro non-uniformity decreases.

5. CONCLUSIONS

The addition of Cu_2O to the printing ink has an effect on the macrouniformity of the printed fabric, which is confirmed by all parameters of surface non-uniformity. It has been shown that the samples with added copper(I) oxide significantly impair the uniformity of the printed surface, however, by adding the extract, the copper ion particles penetrate deeper into the yarn and macro non-uniformity is reduced.

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