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ANTIMICROBIAL BEHAVIOR OF GREEN SILVER NANOPARTICLES DEPOSITED ON KNITTED TEXTILE SUPPORT

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Abstract: *Since the synthesis of nanoparticles by green methods is still an emerging trend in nanotechnology, many research projects aim to contribute with additional data to the existing knowledge related to nanotechnology applications for materials functionalization. Green synthesis of nanoparticles involves the use of metallic salts and different biological agents, such as enzymes, microorganisms, oligo- or polysaccharides, yeasts, fungi, or different parts of plants (root, leaf, petals, etc.). However, the most common green reduction agent remains the plant extracts, due to the ease of production, at low cost and lack of toxicity, without compromising the efficiency. The data presented in this work follow the application of green synthesised silver nanoparticles (AgNPs) on colored knitted textile fabric. The padding method was used for the fixation of the treatment. The antimicrobial evaluation was performed by the agar diffusion method. Thus, the treated knitted fabrics were incubated with Escherichia coli and Staphylococcus aureus bacteria strains and the size of the inhibation zone was measured. The physico-chemical characteristics of the resulted fabric were analysed, in terms of mass per unit area, knit density, permeability to air, and hydrophilicity. Nevertheless, the structure, morphology and integrity of the textile fibres were studied using the scanning electron microsope technique (SEM).*

Key words: *silver nanoparticles, antimicrobial activity, knitted textile*

1. INTRODUCTION

The synthesis of nanoparticles by *green* methods is an emerging trend in nanotechnology. These methods aim to overcome the limitations of conventional ones, such as high cost, toxicity of reagents, and environmental impact [1]. Green alternatives involve the synthesis of nanoparticles using different biological agents, such as enzymes, microorganisms, oligosaccharides, polysaccharides, yeasts, fungi, or different parts of plants (root, leaf, petals, etc.) [2].

The green synthesis of silver nanoparticles (AgNPs) involves the use of silver nitrate ($AgNO_3$) solution and various biological agents containing biochemical or phytochemical compounds with reducing character. These biomolecules can be alkaloids, terpenoids, phenolic compounds, flavonoids, proteins, vitamins, enzymes, co-enzymes, sugars, etc [3]. By varying the reaction medium, particles of different shapes and sizes can be obtained [4]. In figure 1, the synthesis procedure of AgNPs using various biological species is schematically represented.

The most common reducing agents used are plant extracts. The generation of AgNPs is indicated by the color change of the reaction mixture, from light brown to dark brown [5,6]. The synthesis of silver nanoparticles using bacteria can be carried out either intracellularly or

extracellularly. In intracellular synthesis, silver accumulation occurs inside the cell, along with the nucleation process with formation of silver nanoparticles and continues with bacterial growth. The living microorganisms are harvested after the optimal moment of bacterial growth. The harvested cells require special treatment to release the synthesized nanoparticles. In the extracellular synthesis process, the extracellular secretion product of the bacterial populations is separated and used for synthesis [7,8]. The potential of fungi for the synthesis of metal nanoparticles is due to their metal bioaccumulation capacity and tolerance, as well as their high binding capacity and intracellular uptake [9]. They also secrete enzymes with reducing potential [10]. Vigneshwaran and his team reported that monodisperse AgNPs with particle sizes of 8.92 ± 1.61 nm can be synthesized using the fungus *Aspergillus flavus* [11]. In another method, Kathiresan and co-workers reported the in vitro synthesis of AgNPs using *Penicillium fellutanum* isolated from coastal mangrove sediment [12]. Ahmad studied the reduction of Ag ions when exposed to *Fusarium oxysporum*, leading to the formation of silver particles with sizes in the range of 5–15 that are stabilized by proteins secreted by the fungus [13].

For this study, AgNPs dispertion *green* syntheised was applied on a colored knitted textile support using the padding method and the characteristics of the resulted fabric were evaluated in terms of antibacterian activity, morphology, mass per unit area, knit density, permeability to air, and hydrophilicity.

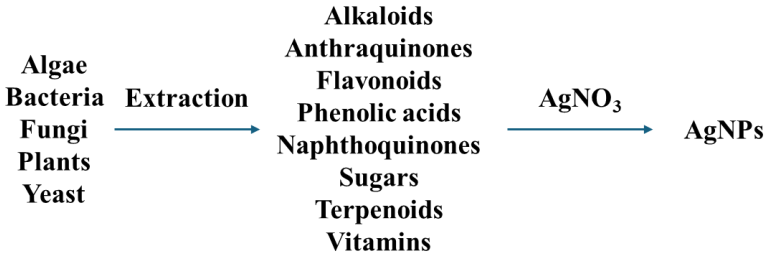

Fig. 1. *Schematic representation of AgNPs green synthesis using various biological species.*

2. EXPERIMENTAL

2.1 Materials and methods

The knitted textile support consisted of 95% cotton / 5% elastane (navy blue color) samples, made of Nm 50/1 yarn, with horizontal density: 13 rows / cm and vertical density: 19 rows / cm. The AgNPs dispersion was synthesized according to our previous report [14].

For depositing the AgNPs dispersion, a binder was used in the finishing process, which consisted of a self-crosslinking acrylic resin, in the form of a water-based emulsion (PERMUTEX® RA-9260) and was purchased from Stahl Europe B.V.. The knitted textile materials (20 cm × 30 cm) were treated with the dispersions obtained 24 hours after their preparation, using the pad method. The binder concentration used was 20 g/L.

The deposition was carried out according to the following technological flow: pad treatment with the dispersion of silver nanoparticles and binder → drying → condensation. Each sample was passed through the apparatus twice, then subjected to a drying operation for 4 min at 100°C, followed by a condensation step for 2 min at 150°C.

Standard laboratory glassware was used in the process of nanoparticle synthesis. The application of nanoparticles on textile supports was carried out using a padding instrument for impregnating textile materials with functionalizing substances (ROACHES, England) and a drying-

heat-fixing-condensation device for superior finishing operations, for fixing functionalizing substances (ROACHES, England).

2.2 Characterization technique

To perform a qualitative antimicrobial evaluation, the agar diffusion method was applied, using the bacterial strains *Staphylococcus aureus* ATCC 6538 (gram-positive bacterium) and *Escherichia coli* ATCC10536 (gram-negative bacterium), according to SR EN ISO 20645/2005.

The treated knitwear samples were characterized in terms of mass per unit area (SR EN 12127-2003), density (SR EN 1049-2:2000), air permeability (SR EN ISO 9237:1999) and hydrophilicity, according to SR 12751/1989.

To evaluate the appearance and morphology of textile fibers following treatment, scanning electron microscopy (SEM) measurements were performed.

3. RESULTS AND DISCUSSIONS

3.1 Antimicrobial effect

Images of Petri dishes inoculated with the tested strains and incubated with the textile samples are illustrated in figure 2. According to the SR EN ISO 20645:2005 standard, the criteria for inhibition zones are as follows: if the size of the inhibition zone is zero and the sample shows visible bacterial contamination, the effect is assessed as unsatisfactory. When the contamination is minimal, the effect is at the limit of effectiveness. The effect is assessed as satisfactory when no bacterial growth is observed on the sample (even if the size of the inhibition zone is zero). When the size of the inhibition zone is greater than zero, the antimicrobial effect can be quantified.

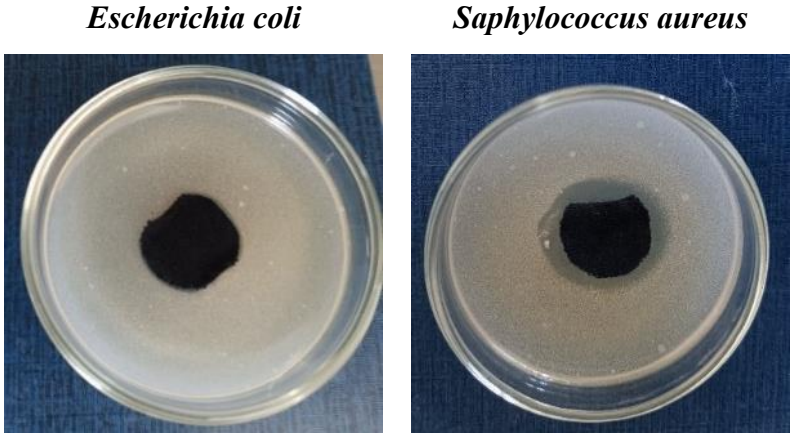

Fig. 2. *Images of Petri dishes inoculated with the tested bacterial strain and incubated with the colored knit textile samples treated with AgNPs*

The value of te inhibition zone was 2 mm in the case of *Escherichia coli* and 4 mm for *Staphylococcus aureus*. This difference is attributed to the general ability of gram-negative bacteria to be more rezistent to antibiotic agents [15], corroborated to the synergistic capacity of the AgNPs to exhibit both antimicrobian and antioxidant activity, wich disrupt predominantly the peptidoglycan thick layer within the cell wall of gram-positive bacteria [16,17].

3.2 Physico-mechanical characteristics

The color of the textile material was not altered by the presence of the treatment, while the physico-mechanical characteristics (table 1) suffered little change in mass per unit area, and density while air permeability decreased by 27,7% and the hydrophilicity decreased by almost 300%.

***Table 1**. Physical and mechanical characteristics of colored knitted textile support treated with AgNPs-based dispersions.*

Sample	Mass per unit area (g/m^2)	Knit density		Permeability to air (l/m2/s)	Hydrophilicity (s)
		Orizontal (no. of yarns/10 cm)	Vertical (no. of yarns/10 cm)		
Reference knit sample	175	148	191	305.3	105
Knit sample treated with AgNPs	173	140	190	220.6	390

3.3 Morpological characteristics

The appearance of the textile fibers, evaluated by scanning electron microscopy (figure 3), remained unaltered after the application of the dispersions. Moreover, no agglomerate formation was observed on this knitted support.

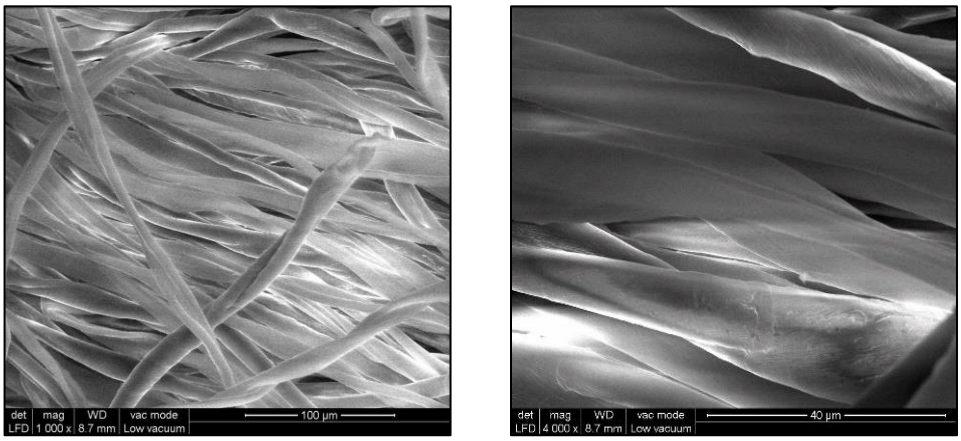

***Fig. 3.** Images obtained by scanning electron microscopy for colored knitwear textile samples treated with AgNPs*

4. CONCLUSIONS

A colored knitted textile fabric was functionalized in order to provide antimicrobian properties. For this purpose, AgNPs dispertion *green* syntheised in a previous reported manner was used. The finishing process involved the padding method and consisted of pad treatment with the dispersion of silver nanoparticles together with a comercialy available binder, followed by a drying and a condensation procedure.

The knitted textile fabric was characterised in terms of antibacterian activity, morphology, mass per unit area, knit density, permeability to air, and hydrophilicity. The value of te inhibition zone was 2 mm in the case of *Escherichia coli* and 4 mm for *Staphylococcus aureus*. While the color of the

textile material, the mass per unit area and density were not altered by the presence of the treatment, the air permeability decreased by 27,7% and the hydrophilicity decreased by almost 300%.

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